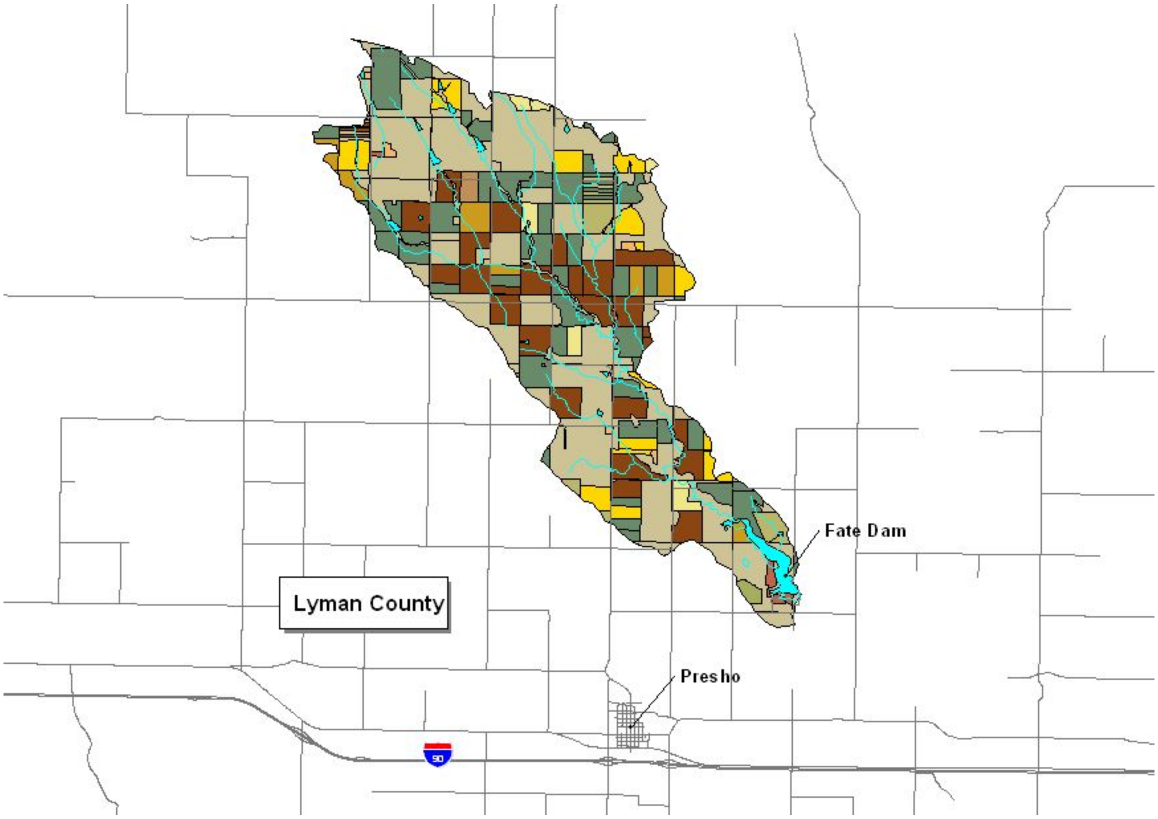
PHASE I
WATERSHED ASSESSMENT FINAL REPORT AND TMDL

FATE DAM/NAIL CREEK
LYMAN COUNTY, SOUTH DAKOTA



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

AUGUST, 2004

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South Dakota Water Resource Assistance Program
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Prepared By

Robert L. Smith, Environmental Program Scientist

1889

State of South Dakota
M. Michael Rounds, Governor

August 2004

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

FATE DAM/NAIL CREEK WATERSHED ASSESSMENT AND TMDL

(PART OF THE MEDICINE CREEK WATERSHED ASSESSMENT PROJECT)

by:
Robert L. Smith

Project Sponsor:
American Creek Conservation District

May 2004

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

EPA Grant # C9998185-00

Executive Summary

Project Title: Medicine Creek Watershed Assessment Project

Project Sponsor: American Creek Conservation District

Project Start Date: April 1, 2000 **Project Completion Date:** December 31, 2001

Original Funding: **Total Budget:** $ 169,660

Total EPA Budget: $ 101,796

Total Expenditures of EPA Funds: $ 101,796

Total Section 319 Match Accrued: $ 75,200.38

Budget Revisions: No Revisions

Total Project Expenditures: $ 176,996.38

Summary of Accomplishments

Fate Dam is listed on the 1998 and 2002 303(d) Impaired Waterbody List (SD DENR 1998 and SD DENR 2002) and in the 2004 Integrated Report (SD DENR 2004) for TSI (Trophic State Index). The Nail Creek tributary drains a watershed of approximately 6,961 ha (17,202 acres) and is impounded by Fate Dam in Lyman County, South Dakota. Fate Dam is a recreational lake of approximately 60.7 ha (150 acres) and has been impacted by periodic algal blooms and increasing TSI values. The American Creek Conservation District (ACCD) located in Kennebec, South Dakota sponsored this project.

A total of 12 tributary and 29 in-lake samples were collected by the sponsor from May 2000 through May 2001. No numerical tributary or in-lake surface water quality standards were exceeded during this project. Water quality and hydrologic data from Nail Creek was modeled using the FLUX model. FLUX data was used to calculate the annual sediment and nutrient loading to Fate Dam. In-lake water quality data was modeled using BATHTUB. BATHTUB was used to estimate current conditions and model TSI reductions based on measured tributary load reductions. Loading and reduction data were used to determine the TMDL for Fate Dam. The TMDL is based on measured loads that may not take into account long term annual load variability.

Landuse data from the watershed was also collected by the project sponsor for use with the AnnAGNPS model. The AnnAGNPS model was used to identify critical areas and to determine priority ranking in the watershed for sediment erosion and nutrient runoff for targeting during implementation. AnnAGNPS was also used to estimate/model best management practice (BMP) reductions in sediment and nutrient loads. Water quality modeling and AnnAGNPS data were sufficient to develop a TMDL for Fate Dam. Alternative site specific (watershed-specific) evaluation criteria (fully supporting, mean TSI $\leq$ 59.00) was proposed based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability.

Based on site-specific criteria, mean TSI $\leq$ 59.00, Fate Dam under current conditions only partially supports beneficial uses (mean TSI 59.91). The site specific (watershed) criteria/goals are more realistic and attainable based on AnnAGNPS modeling and BMP reductions within the Fate Dam watershed. BMP based reduction criteria for Fate Dam were estimated based on a 19.5 percent reduction in total phosphorus loads (671 kg/yr) to Fate Dam resulting in a phosphorus TMDL of 2,769 kg/yr and a mean TSI of 58.91.

The 19.5 percent modeled reduction is based on AnnAGNPS watershed modeling and consisted of: (1) all priority one phosphorus fertilized cells (fields) with moderate fertilizer rates reduced one level (moderate to low) or 8.8 percent phosphorus reduction; (2) converting all current pastures from fair condition to good condition or 3.1 percent phosphorus reduction; (3) applying conservation tillage to all priority-one phosphorus critical cells (10-critical cells) or 0.3 percent and (4) converting tilled/cropped priority-one phosphorus critical cells to all grass and results were again reduced 50 percent for a more conservative phosphorus reduction of 7.3 percent. The total acreage of priority one phosphorus critical cells modeled for watershed reductions was approximately 698 acres (4.1 percent of the entire watershed). Combining all reductions (summing each BMP reduction) the best estimated phosphorus reduction for the Fate Dam/Nail Creek watershed is 19.5 percent.

Acknowledgements

The cooperation of the following organizations and individuals is gratefully appreciated. The assessment of Fate Dam and its watershed could not have been completed without their assistance.

US EPA Non-Point Source Program
Lyman County
Jones County
South Dakota Conservation Commission
South Dakota Association of Conservation Districts
American Creek Conservation District
Jones County Conservation District
Natural Resource Conservation Service – Lyman County
Natural Resource Conservation Service – Jones County
SD Department of Game, Fish and Parks
SD Department of Environment and Natural Resources – Water Rights Program
SD Department of Environment and Natural Resources – Drinking Water Program
SD Department of Environment and Natural Resources – Water Resources Assistance Program
Lower Brule Sioux Tribe

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Waterbody Type:	Reservoir
Pollutant:	Trophic State Index (TSI) – Total phosphorus.
Designated Uses:	Warmwater permanent fish life propagation, Immersion recreation, Limited contact recreation and wildlife propagation and stock watering waters.
Size of Waterbody:	Fate Dam- 60.7 hectares (150 acres).
Size of Watershed:	6,961 ha (17,202 acres), HUC Code: 10140104.
Water Quality Standards:	Numeric: TSI.
Indicators:	Nutrient enrichment, water clarity and algal blooms.
Analytical Approach:	Effects of nutrients and sediment loads from the watershed on Fate Dam.

1.0 Introduction

Fate Dam is a reservoir located in the Northwestern Great Plains (43) ecoregion (Level III) in central South Dakota. Fate Dam (also known as Nail Creek Lake) was constructed in 1938. Fate Dam is located at 43.938726° Latitude and 100.007263° Longitude.

Fate Dam is listed on the 1998 and 2002 303(d) Impaired Waterbody List (SD DENR 1998 and SD DENR 2002) and the 2004 Integrated Report (SD DENR 2004) for TSI (Trophic State Index). The Nail Creek tributary drains a watershed of approximately 6,961 ha (17,202 acres) and is impounded by Fate Dam in Lyman County, South Dakota (Figure 1). Fate Dam is a recreational lake of approximately 60.7 ha (150 acres) and has been impacted by periodic algal blooms and increasing TSI values. The American Creek Conservation District (ACCD) located in Kennebec, South Dakota sponsored this project.

This project is intended to be the initial phase of a watershed-wide restoration project. Water quality monitoring, stream gauging, stream channel and land use analysis were used to document the sources of impairment to Nail Creek and Fate Dam. Feasible alternatives for both watershed and in-lake restoration are presented in this final report.

Land use in the watershed is primarily agricultural. Approximately 60.2 percent of the landuse is cropland (cultivated and non-cultivated) and 39.8 percent is range and pastureland. The Fate Dam/Nail Creek watershed was modeled using the AnnAGNPS model which estimates the overall loading in the Fate Dam/Nail Creek watershed. Watershed data indicated no animal feeding areas/operations were identified in the Fate Dam/Nail Creek watershed and are not considered a problem.

The major soil association found in the Fate Dam watershed is the Millboro association. The Millboro association consists of deep, well drained, nearly level to moderately sloping clayey soils formed in clayey material.

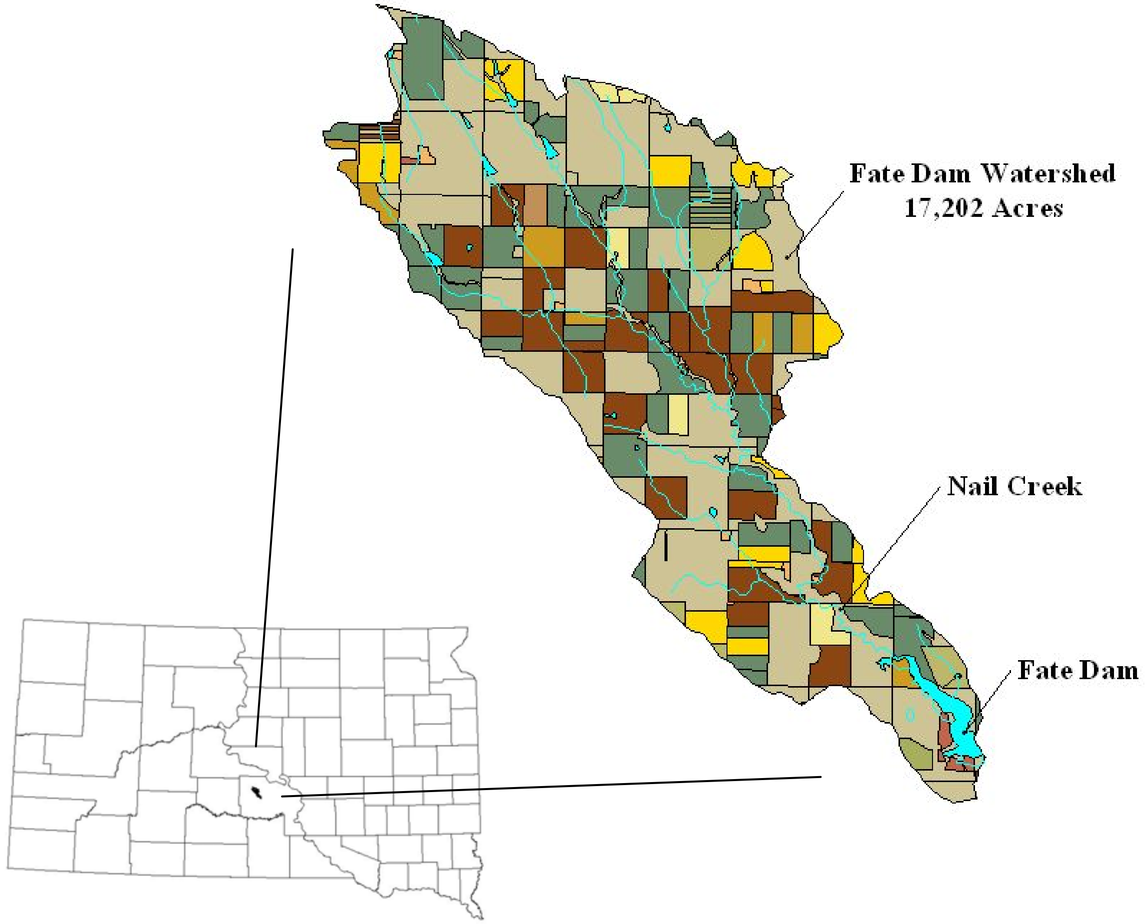


Figure 1. The Fate Dam/Nail Creek watershed and its location in the State of South Dakota.

The average annual precipitation in the watershed is 17 inches of which 13 inches or nearly 80% usually falls in April through September. During this study (April 2000 through May 2001) 22.1 inches of rainfall was recorded in Kennebec, South Dakota. Tornadoes and severe thunderstorms strike occasionally. These storms are local and of short duration and occasionally produce heavy rainfall events. The average seasonal snowfall is 30.9 inches per year (USDA, 1987).

Land elevation ranges from about 637 m (2,090 feet msl) in the northwestern sections of the watershed to about 531 m (1,742 feet msl) in the southeastern part.

The 2000 305(b) report to the U.S. Congress reported the 5-year water quality trend for lake assessment in Fate Dam as unknown, while the 2002 305(b) report (the most current) reported that Fate Dam based on lake assessment as eutrophic (SD DENR, 2000 and SD DENR, 2002). The 2002 305(b) also listed Fate Dam use support as warmwater permanent fish life propagation (partially supporting), immersion recreation (unknown), limited contact recreation (unknown) and fish and wildlife propagation, recreation, and stock watering waters (fully supporting) with use support as unknown due to lack of data (SD DENR, 2002). By 2004, the Integrated Report for Surface Water Quality (combined 305(b) and 303(d) reports) listed Fate Dam use support as warmwater permanent fish life propagation (non-supporting), immersion recreation (unknown), limited contact recreation (unknown) and fish and wildlife propagation, recreation, and stock watering waters as (fully supporting). The 2004 Integrated Report also lists Fate Dam as having an EPA category of 5; water impaired/requires a TMDL and a 303(d) priority rating of 1, high priority (SD DENR 2004, page 128). The overall use support for Fate Dam based upon current lake assessment data is partially supporting. The source listed for deviations from full support are listed as nonpoint source pollution (SD DENR, 2004).

The entire Fate Dam watershed is in the Northwestern Great Plains (43) ecoregion (Level III). Level III ecoregions can be refined to Level IV to elicit more resolution and landscape conditions. The Fate Dam watershed is located in one Level IV ecoregion, the Subhumid Pierre Shale Plains (43f), is located within the Northwestern Great Plains (43) (Bryce et al., 1998).

In the 1998 South Dakota Unified Watershed Assessment, the Medicine Creek Hydrologic Unit Code (HUC # 10140104) was scored, categorized and ranked as being a watershed in need of restoration. Some factors involved in the ranking were landuse, treatment needs and point source density; but the ranking was more weighted on the density of river miles and acres of TMDL waters within the HU. The final priority ranking for Medicine Creek was 4 out of a total 39 HU (watersheds) assessed in this manner (SD DENR, 1998b).

The 1999 South Dakota Nonpoint Source Management Plan schedule is based on the 1998 Section 305(b) report and the related 1998 Section 303(d) list of impaired waters needing Total Maximum Daily Loads (TMDL).

South Dakota Department of Environment and Natural Resources (SD DENR) has monitored Fate Dam as part of the statewide lakes assessment. Assessment data will be used as an indication of use support for Fate Dam.

2.0 Project Goals, Objectives and Activities

Goals

The long-term goal of the Medicine Creek Watershed Assessment Project is to locate and document sources of nonpoint source pollution in the watershed and produce feasible restoration alternatives in order to provide adequate background information needed to drive a watershed implementation project to improve sedimentation and nutrient problems within the creeks and lakes of the watershed. This project will result in four TMDL reports for four Integrated Report listed waters.

Project Description

Medicine Creek is a natural stream that drains portions of Lyman and Jones Counties in South Dakota and is the outlet tributary for Brakke Dam, Fate Dam and Byre Lake in Lyman County. The creek and the lakes receive runoff from agricultural operations and the lakes have experienced declining water quality based on Trophic State Index. The Medicine Creek watershed is approximately 390,072 acres with 11,288 acres above Brakke Dam, 17,202 acres above Fate Dam and 22,946 acres above Byre Lake. The watershed is predominately agricultural land use with cropland and grazing.

This project is intended to be the initial phase of a watershed-wide restoration project. Through water quality monitoring, stream gauging, stream channel analysis and land use analysis, the sources of impairment to the stream and the watershed will be documented and feasible alternatives for restoration will be presented in the final project report.

Objectives and Activities

OBJECTIVE 1: The objective of this task is to determine current conditions in the lakes and calculate the trophic state of each lake. This information will be used to determine the total amount of nutrient and sediment trapping that is occurring in each of the lakes and the amount of nutrient and sediment reduction required to improve the trophic condition of Fate Dam, Brakke Dam and Byre Lake.

Task 1 Nutrient and solids parameters will be sampled at two in-lake sites on Fate Dam, Brakke Dam and Byre Lake. All samples will be analyzed by the South Dakota State Health Laboratory in Pierre. Samples will be collected from the surface and bottom of Fate Dam, Brakke Dam and Byre Lake on a monthly schedule, except during periods of unsafe ice cover, for a period of 1 year. The total number of samples to be collected will be 120 for all three lakes in the project area.

Task 2 The purpose of the in-lake samples is to assess ambient nutrient concentrations in the lake and identify trophic states. Water column dissolved oxygen and temperature profiles will be collected on a monthly basis. Water samples will be collected with a Van Dorn sampler and the sample bottles will be iced and shipped to the lab by the most rapid means available. Fecal coliform samples will be analyzed by the SD State Health Lab in Pierre. All other biological samples will be analyzed by staff from Watershed Protection in the Matthew Training Center Laboratory, Pierre, SD.

Task 3 All samples will be collected using the methods described in the "*Standard Operating Procedures for Field Samplers*" by the State of South Dakota Water Resources Assistance Program.

SITE	LOCATION	STORET NUMBER

Lake Sampling Locations – Fate Dam

FD-1	Lat.	43.938726
	Long.	-100.007263

This site is located in the south central portion of the lake.

FD-2	Lat.	43.944529
	Long.	-100.009913

Approximate north central portion of the lake

Lake Sampling Locations – Brakke Dam

BD-1	Lat.	43.884496
	Long.	–99.944617

This site is located in the south central portion of the lake.

BD-2	Lat.	43.893604
	Long.	-99.954908

Approximate north central portion of the lake.

Lake Sampling Locations – Byre Lake

BL-1	Lat.	43.92978
	Long.	–99.83468

This site is located in the southeast portion of the lake.

BL-2	Lat.	43.92798
	Long.	-99.84155

Approximate northwest portion of the lake.

OBJECTIVE 2: Estimate the sediment and nutrient loadings from Medicine Creek and the individual tributaries in the Fate Dam, Brakke Dam and Byre Lake watersheds through hydrologic and chemical monitoring. The information will be used to locate critical areas in the watershed to be targeted for implementation.

TASK 4 Install water level recorders on tributary monitoring sites and maintain a continuous stage record for the project period, with the exception of winter months after freeze up (Figure 2).

Site	Location	
MC-1	Lat.	43.955531
	Long.	-100.328842
MC-2	Lat.	43.926020
	Long.	-100.186033

MC-3	Lat.	43.944717
	Long.	-100.130243
MC-4	Lat.	43.947701
	Long.	-100.089670
MC-5	Lat.	44.009901
	Long.	-100.086023
MC-6	Lat.	43.973990
	Long.	-100.048308
MC-7	Lat.	43.923644
	Long.	–100.077286
MCFDO-8	Lat.	43.938141
	Long.	-100.002275
MC-9	Lat.	43.896513
	Long.	-100.023068
MCLBO-10	Lat.	43.897975
	Long.	-99.953841
MC-11	Lat.	43.861707
	Long.	-99.954456
MC-12	Lat.	43.859372
	Long.	-99.923395
MC-13	Lat.	43.911083
	Long.	-99.822682
MC-14	Lat.	43.948913
	Long.	–99.885828
MC-15	Lat.	43.926849
	Long.	–99.832414

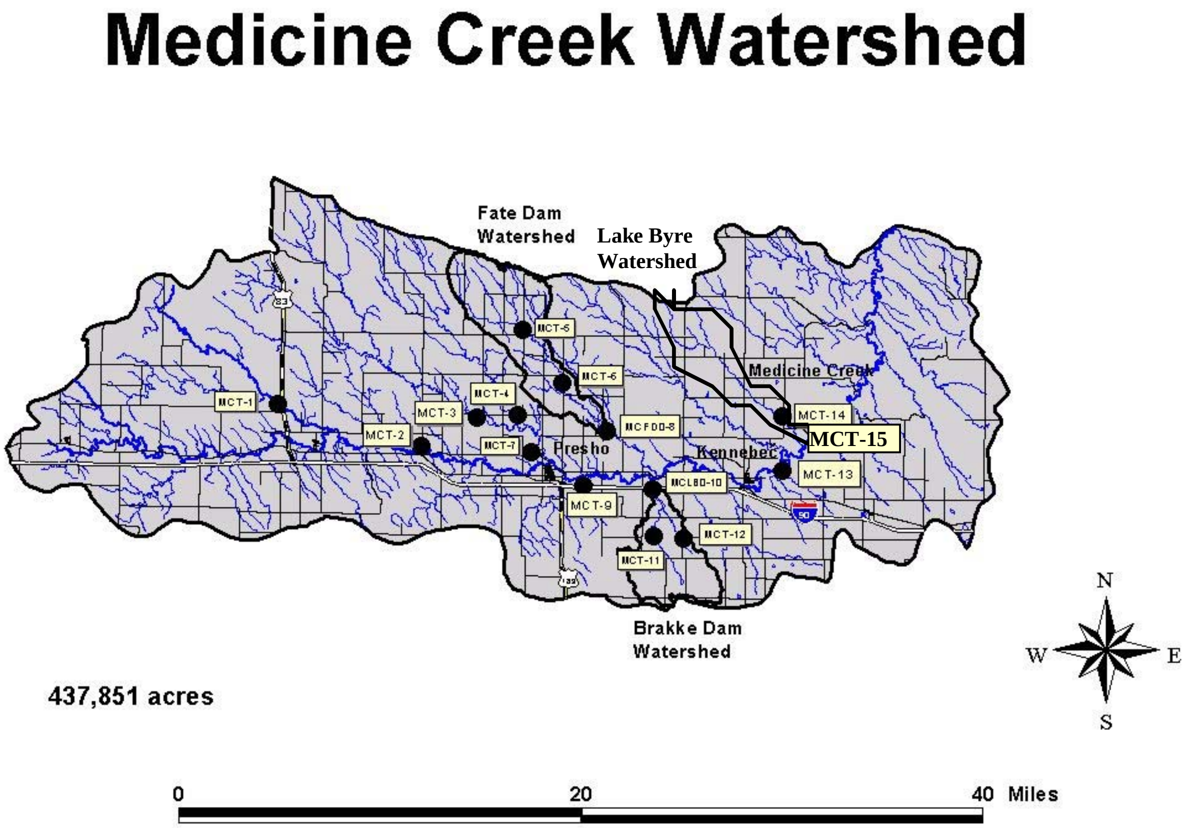


Figure 2. Medicine Creek watershed, Lyman and Jones Counties, South Dakota.

<u>TASK 5</u> Discrete discharge measurements will be taken on a regular schedule and during storm surges. Discharge measurements will be taken with a hand-held current velocity meter.

<u>TASK 6</u> Discharge measurements and water level data will be used to calculate a hydrologic budget for the creek system. This information will be used with concentrations of sediment and nutrients to calculate loadings from the watershed.

<u>TASK 7</u> Collect water quality samples from 15 tributary monitoring sites. Samples will be collected during spring runoff, storm events, and monthly base flows. Proposed water quality monitoring sites may be found in Figure 2.

<u>TASK 8</u> Samples will be collected twice weekly during the first week of spring snowmelt runoff and once a week thereafter until runoff ceases. Storm events and base flows will be sampled throughout the project period for an estimated total number of 148 samples.

PARAMETERS MEASURED FOR TRIBUTARY SAMPLES

PHYSICAL	CHEMICAL	BIOLOGICAL
Air temperature	Total solids	Fecal coliform bacteria
Water temperature	Total suspended solids	E. coli
Discharge	Dissolved oxygen	
Depth	Ammonia	
Visual observations	Un-ionized ammonia (calculated)	
Water level	Nitrate-nitrite	
	TKN	
	Total phosphorus	
	Total dis. phosphorus	
	Field pH	

QUALITY ASSURANCE/QUALITY CONTROL:

Approved QA/QC procedures will be utilized on all sampling and field data collection on the Medicine Creek project. Please refer to the South Dakota Water Resources Assistance Program Quality Assurance Project Plan for the details of the procedures to be followed.

PRODUCTS:

A tributary water quality report, which will include a description of the relationship and influence of chemical and physical data. Hydrologic and nutrient loads will be calculated for the entire watershed.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

Water samples will be collected with a suspended sediment sampler when possible. All sample bottles will be iced and shipped to the lab and collected using the methods described in the "*Standard Operating Procedures for Field Samplers*" by the State of Dakota Water Resources Assistance Program. Nutrient and solids parameters will be sampled at fourteen tributary sites in the Medicine Creek watershed. All samples will be analyzed by the South Dakota State Health Laboratory in Pierre, SD. The watershed water quality data will be integrated with hydrologic loading to provide a complete analysis of the Medicine Creek, Brakke Dam, Fate Dam and Byre Lake hydrologic systems.

OBJECTIVE 3: Ensure that all water quality samples are accurate and defendable through the use of approved Quality Assurance/Quality Control procedures.

<u>TASK 9</u> The collection of all field water quality data will be accomplished in accordance with the "*Standard Operating Procedures for Field Samplers*", South Dakota Water Resources Assistance Program.

<u>TASK 10</u> A minimum of 10 percent of all the water samples collected will be QA/QC samples. QA/QC samples will consist of field blanks and field duplicate samples. An estimated 50 QA/QC samples will be collected during the project.

<u>TASK 11</u> All QA/QC activities will be conducted in accordance with the Water Resources Assistance Program Quality Assurance Project Plan.

<u>TASK 12</u> The activities involved with QA/QC procedures and the results of QA/QC monitoring will be compiled and reported in a section of the final project report and in all project reports.

PRODUCTS:

A Quality Assurance/Quality Control monitoring report.

RESPONSIBLE AGENCIES:

<u>Task Prioritization</u>:

Project Coordinator
Project Sponsor

<u>Design and Technical Assistance</u>:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

Approved QA/QC procedures will be utilized on all sampling and field data collected during the Medicine Creek project. Please refer to the South Dakota Water Resources Assistance Program Quality Assurance Plan and the South Dakota Water Resources Assistance Program Standard Operating Procedures for Field Samplers for details of the procedures to be followed.

OBJECTIVE 4: Evaluation of agricultural impacts on the water quality of the watershed using the Annualized Agricultural Nonpoint Source (AnnAGNPS) model.

TASK 13 The Medicine Creek, Fate Dam, and Brakke Dam watersheds will be modeled using the AnnAGNPS model. AnnAGNPS is a comprehensive land use model which estimates soil loss and delivery and evaluates the impact of livestock feeding areas. The watershed will be divided into cells. Each cell will be analyzed using 21 separate parameters with additional information collected for animal feeding operations.

TASK 14 The model will be used to identify critical areas of nonpoint source pollution to the surface waters in the watershed. Contributors of nutrients and sediment to surface water in the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds will be identified.

PRODUCTS:

Report on land use in the watershed.
Recommendations for remediation of pollution sources in the watershed.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

OBJECTIVE 5: Public participation and involvement will be provided for and encouraged.

TASK 15 Informational meetings will be held on a quarterly basis for the general public and to inform the involved parties of progress on the study. These meetings will provide an avenue for input from the residents in the area.

TASK 16 News releases will be prepared and released to local news media on a quarterly basis. These releases will be provided to local newspapers, radio stations and TV stations.

PRODUCTS:

Public input to the project.
Information and education about the Medicine Creek project.
Involvement and input from the public will be documented.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

Informational meetings will be held on a frequent basis for the general public to inform the involved parties of progress on the study and provide a means of public input.

OBJECTIVE 6: Development of watershed restoration alternatives.

TASK 17 Once the field data is collected, an extensive review of the historical and project data will be conducted.

TASK 18 Loading calculations based on project data will be done and a hydrologic, sediment and nutrient budget will be developed for each watershed.

TASK 19 The results of the AnnAGNPS modeling of the watershed will be used in conjunction with the water quality and hydrologic budget to determine critical areas in the watersheds.

TASK 20 Feasible management practices will be compiled into a list of alternatives for the development of an implementation project and included in the final project report.

PRODUCTS:

A list of viable watershed restoration alternatives and recommendations for the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

An extensive review and study of the historical and current data will be done to determine the Best Management Practices and hydrologic restoration techniques needed to improve water quality and reduce sediment transport in the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds.

OBJECTIVE 7: Produce and publish a final report containing water quality results and restoration alternatives.

TASK 21: Produce loading calculations based on water quality sampling and hydrologic measurements.

TASK 22 Summarize the results of the AnnAGNPS model for the watershed and report locations of critical areas.

TASK 23 Write a summary of historical water quality and land use information and compare with project data to determine any possible trends.

TASK 24 Based on data, evaluate the hydrology of the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds and the chemical, biological, and physical condition of the streams.

TASK 25 Produce a summary report of all QA/QC activities conducted during the project and include in the final project report.

TASK 26 Write a description of feasible restoration alternatives for use in planning watershed nonpoint source implementation.

PRODUCTS:

A final report incorporating all previously described objectives

RESPONSIBLE AGENCIES:

South Dakota Department of Environment and Natural Resources

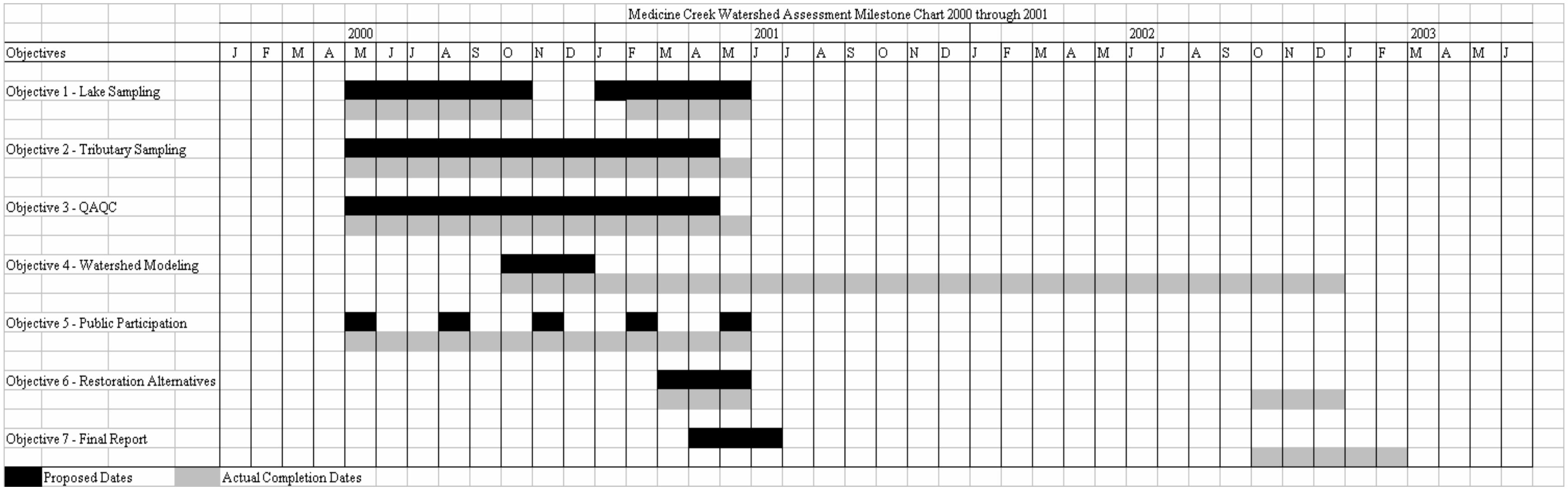
WORK ACTIVITIES:

Statistical evaluation of all water quality and field data produced during the course of the study. A review and compilation of historical data will be completed. Restoration alternatives will be developed. Graphic presentations of the information will be produced.

2.1 Planned and Actual Milestones, Products and Completion Dates

The Medicine Creek Assessment Project was started in April 2000. The sampling effort continued through May 2001. Difficulty was encountered in the collection of Annualized Agricultural Nonpoint Source Model (AnnAGNPS) landuse data which was not completed until fall 2003. This situation resulted in a delay in watershed modeling and report generation. See the attached Fate Dam/Nail Creek Assessment Project milestone table (Table 1).

Table 1. Proposed and actual completion dates for the Fate Dam (Medicine Creek) Watershed Assessment Project, 2000 through 2001.



Medicine Creek Watershed Assessment Milestone Chart 2000 through 2001

	2000												2001												2002												2003					
Objectives	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Objective 1 - Lake Sampling					■	■	■	■	■	■			■	■	■	■	■																									
					▒	▒	▒	▒	▒	▒				▒	▒	▒	▒																									
Objective 2 - Tributary Sampling					■	■	■	■	■	■	■	■	■	■	■	■																										
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Objective 3 - QAQC					■	■	■	■	■	■	■	■	■	■	■	■																										
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Objective 4 - Watershed Modeling										■	■	■																														
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Objective 5 - Public Participation					■			■			■			■			■																									
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Objective 6 - Restoration Alternatives															■	■	■																									
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Objective 7 - Final Report																■	■	■																								
																																			▒	▒	▒	▒	▒				

■ Proposed Dates ▒ Actual Completion Dates

2.2 Evaluation of Goal Achievement

Fate Dam, Brakke Dam and Byre Lake are listed in the State of South Dakota's 2004 Integrated Report (combined 305(B) and 303(d) reports) as a category 5 (water impaired/requires a TMDL) for Trophic State Index (TSI) for increased nutrients from nonpoint source pollution. Medicine Creek is also listed on the states 303(d) list for conductivity and total dissolved solids. This study assessed Medicine Creek, Fate Dam, Brakke Dam, Byre Lake and their watersheds for background data to develop TMDLs, identified targeted areas of increased nutrient and sediment load impacting specific watersheds and recommend specific Best Management Practices (BMPs) for targeted areas in these watersheds. The project meets one of the goals of the Non Point Source (NPS) program by assessing impaired waterbodies on the 303(d) list and has met all project goals outlined above. A future implementation project is planned in the near future.

2.3 Supplemental Information

Loading reduction estimates for suggested BMPs outlined in this report were derived from AnnAGNPS Modeled landuse data. The AnnAGNPS Model estimated the expected load reduction after application of selected BMPs within the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds. These practices should be implemented on targeted areas having increased nutrient and sediment export coefficients (loading). Implementing recommended BMPs within the watershed will have the greatest effect on reducing overall loading to Medicine Creek, Fate Dam, Brakke Dam and Byre Lake.

3.0 Monitoring Results

Tributary Methods

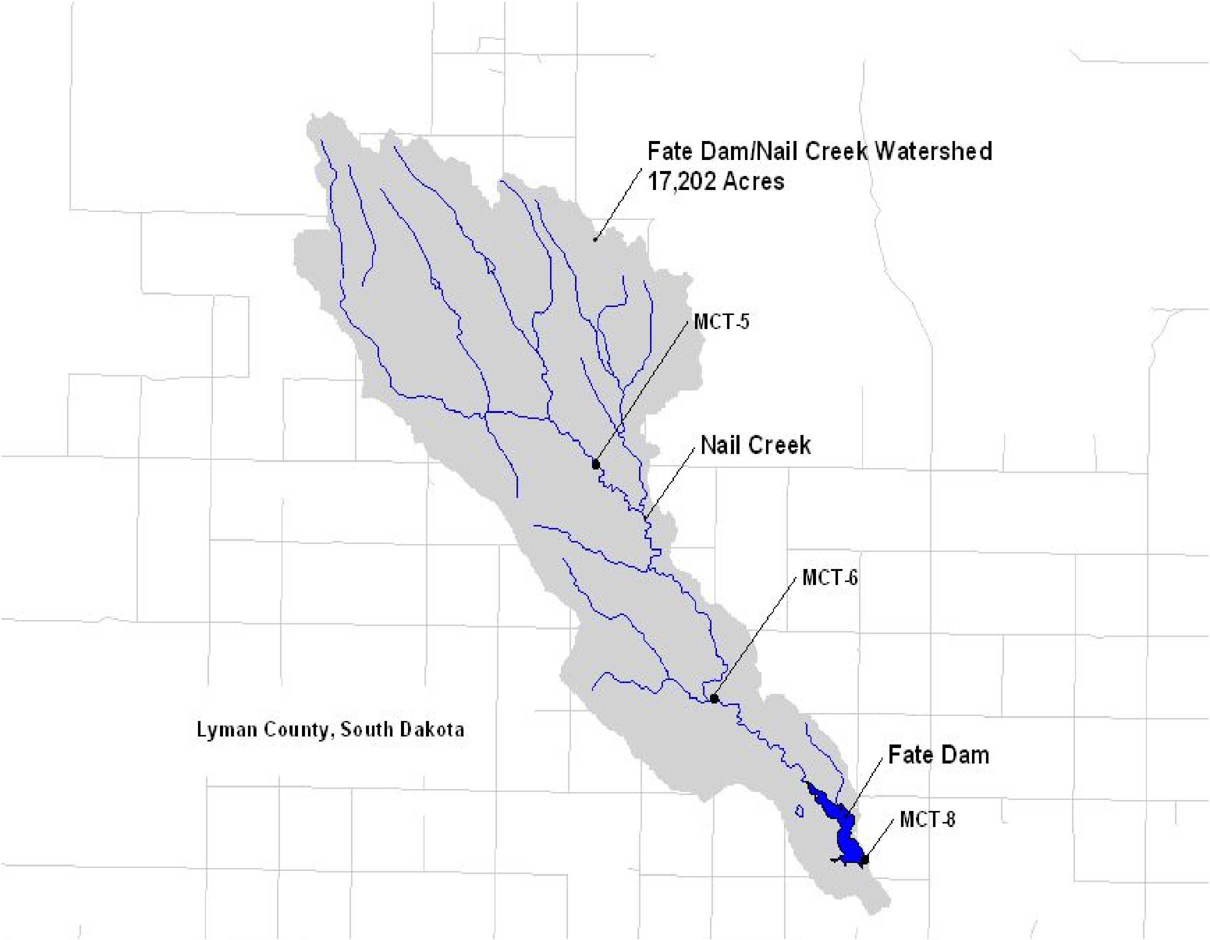

Figure 3. Nail Creek sampling sites and sub-watersheds for 2000 and 2001.

Three tributary locations were chosen for collecting hydrologic and nutrient information from the Fate Dam watershed (Figure 3). Tributary site locations were chosen that would best show watershed managers which sub-watersheds were contributing the largest nutrient and sediment loads to Fate Dam and Medicine Creek. OTT Thalimedes data loggers were placed on Nail Creek in the upper portion of the watershed (MCT-5) and near the inlet to Fate Dam (MCT-6) and near the outlet spillway (MCT-8) to record the lake level (stage) in Fate Dam and to calculate lake discharge back to the Nail Creek loading Medicine Creek. The data loggers were checked and downloaded bi-monthly to update the database and check for mechanical problems. All discharge data was collected according to South Dakota's *Standard Operating Procedures for Field Samples* (SD DENR, 2000). During the project, MCT-5 on Nail Creek was a bridge site; however, immediately after the project was over the county removed the bridge and replaced it with a two seven-foot wide corrugated culverts. Discharge measurements were not collected at this site due to poor access during bad weather. Thus, average daily stage data at

MCT-5 was used as stage inside the corrugated metal conduit to calculate average discharge using the Manning's formula (Equation 1). Manning's formula was also used to calculate average discharge at MCT-6 (Fate Dam inlet).

Equation 1. Manning formula for discharge.

$$Q = \frac{K * A * R^{2/3} * S^{1/2}}{n}$$

Where: Q = Flow rate in cfs
K = 1.49 (cfs)
A = Cross sectional area of flow
R = Hydraulic radius (cross sectional area divided by the wetted parimeter)
S = Slope of the hydraulic gradient
n = Manning's coefficient of roughness dependent upon material of conduit

Average daily outlet (MCT-8) stage data for the Fate Dam spillway was used to calculate discharge using a standard weir equation (Equation 2).

Equation 2. Fate Dam weir discharge equation.

$$\mathrm{Q} = \mathrm{C} * \mathrm{L} * \left(\mathrm{H}^{3/2}\right)$$

Where: Q = Flow rate in cfs
L = Length (width of spillway)
H = Stage Height
C = Coefficient, C = 2.3

Hydrologic Data Collection Methods

Instantaneous discharge measurements were collected for each station during the time each sample was collected. A Marsh-McBirney Model 201 was used to collect the discharge measurements. Average daily stage measurements were used to calculate discharge at MCT-5 and MCT-8.

Tributary Water Quality Sampling

Samples collected at each tributary site were taken according to South Dakota's *Standard Operating Procedures for Field Samplers* (SD DENR, 2000). Tributary physical, chemical and biological water quality sample parameters are listed in Table 2. All water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected for approximately 10 percent of the samples according to South Dakota's EPA approved *Non-Point Source Quality Assurance/Quality Control Plan* (SD DENR, 1998c). These documents can be referenced by contacting the South Dakota Department of Environment and Natural Resources at (605) 773-4254 or at http://www.state.sd.us/denr.

Table 2. Tributary physical, chemical and biological parameters analyzed in Nail Creek, Lyman County, South Dakota in 2000 through 2001.

Physical	Chemical	Biological
Air Temperature	Total Alkalinity	Fecal Coliform
Water Temperature	Field pH	E. coli
Depth	Dissolved Oxygen	
Visual Observations	Total Solids	
	Total Suspended Solids	
	Total Dissolved Solids (calculated)	
	Volatile Total Suspended Solids	
	Ammonia	
	Un-ionized Ammonia (calculated)	
	Nitrate-Nitrite	
	Total Kjeldahl Nitrogen	
	Total Phosphorus	
	Total Dissolved Phosphorus	
	Conductivity	

Tributary Modeling Methods

Tributary Loading Calculations

The FLUX program was used to develop nutrient and sediment loadings for MCT-5 (upper Nail Creek), MCT-6 (Fate Dam inlet) and MCT-8 (Fate Dam outlet to Medicine Creek). The US Army Corp of Engineers developed the FLUX program for eutrophication (nutrient enrichment) assessment and prediction for reservoirs (Walker, 1999). The FLUX program uses six different calculation techniques (methods) for calculating nutrient and sediment loadings. The sample and flow data for this program can be stratified (adjusted) until the coefficient of variation (standard error of the mean loading divided by the mean loading =CV) for all six methods converge or are all similar. The uncertainty in the estimated loading is reflected by the CV value. The lower the CV value the greater the accuracy (less error) there is in loading estimates. This scenario was applied to each relevant sampling parameter to determine the appropriate method (model) for specific parameters. Methods (models) and CV values for each parameter and sampling site are listed in Table 3. These methods were used on the tributary site (inlet site) and the outlet site of Fate Dam to calculate nutrient and sediment loadings and retention for this project.

After the loadings for all sites were completed, export coefficients were developed for each of the parameters. Export coefficients are calculated by taking the total nutrient or sediment load (kilograms) and dividing by the total area of the sub-watershed (in acres). This calculation results in the determination of the number of kilograms of sediment and nutrients per acre delivered from that sub-watershed (kg/acre). These values were used to target areas within the watershed with excessive nutrient and sediment loads. These areas will also be used to target recommended BMPs for a projected implementation project.

Table 3. Model and coefficient of variation by parameter for FLUX analysis in Fate Dam, Lyman County, South Dakota from 2000 through 2001.

	MCT-5 (Upper Nail Creek)		**MCT-6 (Fate Dam Inlet)**		**MCT-8 (Fate Dam Outlet)**	
Parameter	**Model (Method)**	**Coefficient of Variation (CV)**	**Model (Method)**	**Coefficient of Variation (CV)**	**Model (Method)**	**Coefficient of Variation (CV)**
Alkalinity	Q wt C	0.060	IJC	0.003	Q wt C	0.174
Total Solids	Q wt C	0.094	Q wt C	0.536	Q wt C	0.034
Total Dissolved Solids	Q wt C	0.111	Q wt C	0.081	IJC	0.024
Total Suspended Solids	IJC	0.017	Q wt C	1.081	Q wt C	0.530
Volatile Total Suspended Solids	Q wt C	0.198	Q wt C	0.819	Q wt C	0.556
Ammonia	IJC	0.122	Q wt C	1.257	Q wt C	1.501
Nitrate-Nitrite	Q wt C	0.201	Q wt C	0.233	Q wt C	0.481
Total Kjeldahl Nitrogen	Q wt C	0.260	Q wt C	0.193	IJC	0.008
Inorganic Nitrogen	Q wt C	0.195	Q wt C	0.264	Q wt C	0.461
Organic Nitrogen	Q wt C	0.291	Q wt C	.0300	IJC	0.030
Total Nitrogen	Q wt C	0.210	Q wt C	0.103	Q wt C	0.317
Total Phosphorus	Q wt C	0.128	Q wt C	0.610	Q wt C	0.457
Total Dissolved Phosphorus	Q wt C	0.133	Q wt C	0.014	Q wt C	0.451

Q wt C = Flow weighted Concentration model
IJC = International Joint Committee model (modifies Q wt C by a factor to adjust for bias where concentrations varies with flow)

Tributary Statistical Analysis

Tributary data was analyzed using StatSoft® statistical software (STATISTICA version 6.1). Kruskal-Wallis ANOVA (multiple comparison non-parametric analysis) was run on tributary concentration and loading data to determine significant differences between tributary monitoring sites. Statistical results for both concentration and loading data for all parameters are provided in Table 4.

Kruskal-Wallis ANOVA was also used to compare tributaries loading for TMDL lakes in the Medicine Creek watershed (Fate Dam, Brakke Dam and Byre Lake). These lakes also discharge water (via the outlets) back into the tributaries (Nail Creek, Brakke Creek and Grouse Creek) which in turn load Medicine Creek. Analysis was also done to evaluate/compare values and concentrations affecting Medicine Creek. For all tests, differences were considered to be significant when p-values were < 0.05.

Only tributary parameters that were significantly different between sub-watersheds are discussed by parameter when applicable.

Table 4. Kruskal-Wallis (H) values, observations and p values for tributary concentration and loading data for Nail Creek, Lyman County, South Dakota from 2000 through 2001.

		Concentration		Loading	
		Kruskal-Wallis		Kruskal-Wallis	
Parameter	**N**	**(H)**	**p-value**	**(H)**	**p-value**
Dissolved Oxygen	12	1.885	0.390	-	-
pH	12	7.423	0.024	-	-
Specific Conductivity	12	0.500	0.779	-	-
Water Temperature	12	4.962	0.084	-	-
Fecal Coliform Bacteria	12	2.034	0.362	-	-
E. coli Bacteria	12	2.007	0.367	-	-
Alkalinity	12	1.385	0.500	3.507	0.173
Total Solids	12	2.193	0.334	4.023	0.134
Total Dissolved Solids	12	1.853	0.396	3.643	0.162
Total Suspended Solids	12	0.346	0.841	4.617	0.100
Volatile Total Suspended Solids	12	2.217	0.330	5.094	0.078
Ammonia	12	0.727	0.695	4.271	0.118
Un-ionized Ammonia	12	0.962	0.618	-	-
Nitrate-Nitrite	12	3.310	0.191	3.830	0.147
Total Kjeldahl Nitrogen	12	2.000	0.368	4.023	0.134
Organic Nitrogen	12	3.500	0.174	3.830	0.147
Inorganic Nitrogen	12	1.891	0.388	4.023	0.134
Total Nitrogen	12	3.231	0.199	3.804	0.149
Total Phosphorus	12	8.346	0.015	4.213	0.123
Total Dissolved Phosphorus	12	7.423	0.024	3.830	0.147
Total Nitrogen to Total Phosphorus	12	2.923	0.232	-	-

Shaded = significantly different between sampling sites ($p<0.05$).

Landuse Modeling – Annualized Agricultural Non-Point Source Model, version 3.32a.34 (AnnAGNPS) and Agricultural Non-Point Source Model, version 3.65 (AGNPS)

In addition to water quality monitoring, information was collected to complete a comprehensive watershed land use model. AnnAGNPS (Annualized Agricultural Non-Point Source) is a landuse model to simulate/model sediment and nutrient loadings from watersheds. 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 are calculated at the outlet to the watershed.

The input data set for AnnAGNPS Pollutant Loading Model consists of 33 sections of data, which can be supplied by the user in a number of ways. This model execution utilized; digital elevation maps (DEMs) to determine cell and reach geometry, SSURGO soil layers to determine primary soil types and the associated NASIS data tables for each soils properties, and primary land use based on a 40 acre grid pattern, collected initially with the intention of executing the AGNPS version 3.65 model. Impoundment data was obtained using Digital OrthoQuads (DOQs) layers using ArcView Global Information System (GIS)$^{®}$ software.

Climate/weather data from Pierre, South Dakota was used to generate simulated weather data. Model results are based on 3 years of climate data for initializing variables prior to 25-year watershed simulation. Simulated precipitation based on climate data ranged from 13 to 29 inches per year. Mean annual precipitation for this watershed is approximately 17 inches.

Part of the modeling process includes the assessment of Animal Feeding Operations (AFOs) located in the watershed. This assessment was completed with the assistance of the American Creek Conservation District which provided estimates on the number of animal units and duration of use in the Medicine Creek Watershed; however, there were no AFOs identified in the Fate Dam portion of the Medicine Creek Watershed and are not considered a problem in the Fate Dam/Nail Creek watershed.

Findings from the AnnAGNPS report can be found throughout the water quality and landuse modeling discussions of this document. Conclusions and recommendations will rely on both water quality and AnnAGNPS data. The complete AnnAGNPS report can be found in Appendix A.

3.1 Tributary Surface Water Chemistry

Tributary Water Quality Standards

South Dakota's numeric water quality standards are based on beneficial use categories. Beneficial use classifications are listed in Table 5. All streams in the state are assigned the beneficial uses (category 9) fish and wildlife propagation, recreation and stock watering and (category 10) irrigation (ARSD § 74:51:03:01).

Table 5. South Dakota's beneficial use classifications for all waters of the state.

Category	Beneficial Use
1	Domestic water supply waters;
2	Coldwater permanent fish life propagation waters;
3	Coldwater marginal fish life propagation waters;
4	Warmwater permanent fish life propagation waters;
5	Warmwater semi-permanent fish life propagation waters;
6	Warmwater marginal fish life propagation waters;
7	Immersion recreation waters;
8	Limited-contact recreation waters;
9	Fish and wildlife propagation, recreation, and stock watering waters;
10	Irrigation waters; and
11	Commerce and industry waters.

Nail Creek in Lyman County has been assigned the beneficial uses of (9) Fish and wildlife propagation, recreation, and stock watering water and (10) Irrigation water (Table 6).

In addition to physical and chemical standards, South Dakota has developed narrative criteria for the protection of aquatic life uses. *All waters of the state must be free from substances, whether attributable to human-induced point source discharge or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities* (ASRD § 74:51:01:12).

Table 6. Assigned beneficial uses for Nail Creek, Lyman County South Dakota.

Water Body	From	To	Beneficial Uses*	County
All Streams	Entire State	Entire State	9, 10	All

*** = See Table 5 above**

Each beneficial use classification has a set of numeric standards uniquely associated with that specific category. Water quality values that exceed those standards, applicable to specific beneficial uses, impair beneficial use and violate water quality standards. Table 7 lists the most stringent water quality parameters for Nail Creek. Four of the nine parameters (total petroleum hydrocarbon, oil and grease, un-disassociated hydrogen sulfide and sodium adsorption ratio) listed for Nail Creek beneficial use classification were not sampled during this project.

Table 7. The most stringent water quality standards for Nail Creek (Medicine Creek tributary) based on beneficial use classifications.

Water Body	Beneficial Uses	Parameter	Standard Value
Nail Creek (Tributary to Medicine Creek)	9,10	Total alkalinity as calcium carbonate [1]	$\leq$ 1,313 mg/L
		pH	$\geq$ 6.0 - $\leq$ 9.5
		Total dissolved solids [2]	$\leq$ 4,375 mg/L
		Conductivity at 25° C [3]	$\leq$ 4,375 µS/cm[1]
		Nitrates as N [4]	$\leq$ 88 mg/L
		Undisassociated hydrogen sulfide [5]	$\leq$ 0.002 mg/L
		Total petroleum hydrocarbon [5]	$\leq$ 10 mg/L
		Oil and grease [5]	$\leq$ 10 mg/L
		Sodium adsorption ratio [5, 6]	$\leq$ 10 mg/L

[1] = The daily maximum for total alkalinity as calcium carbonate is $\leq$ 1,313 mg/L or $\leq$ 750 mg/L for a 30-day average.

[2] = The daily maximum for total dissolved solids is $\leq$ 4,375 mg/L or $\leq$ 2,500 mg/L for a 30-day average.

[3] = The daily maximum for conductivity at 25° C is $\leq$ 7,000 µS/cm[1]or $\leq$ 4,000 µS/cm[1]for a 30-day average.

[4] = The daily maximum for nitrates is $\leq$ 88 mg/L or $\leq$ 50 mg/L for a 30-day average.

[5] = Parameters not measured during this project.

[6] = The sodium absorption ratio is a calculated value that evaluates the sodium hazard of irrigation water based on the Gapon equation and expressed by the mathematical equation:

Equation 3. Sodium Adsorption Ratio (SAR) (Gapon Equation)

$$\text{SAR}= Na^{+} \Big/ \sqrt{\frac{Ca^{+2} + \text{Mg}^{+2}}{2}}$$

Where Na^{+}, Ca^{+2} and Mg^{+2} are expressed in milliequivalents per liter.

Nail Creek Water Quality Exceedances

There were no tributary water quality standards violations based on assigned beneficial uses for Nail Creek, (9) Fish and wildlife propagation, recreation, and stock watering water and (10) Irrigation water during the project (Appendix B).

All concentrations from Fate Dam outlet (MCT-8) to Nail Creek were mitigated by in-lake hydrologic, nutrient residence time and dilution in Fate Dam before being discharged back into Nail Creek loading Medicine Creek.

Seasonal Tributary Water Quality

Typically, water quality parameters will vary depending upon season due to changes in temperature, precipitation and agricultural practices. Twelve tributary water quality samples were collected during the project. These data were separated seasonally: winter (January – March), spring (April – June), summer (July – September) and fall (October – December). Runoff was recorded during 2000 at MCT-6; however in the 2000 sampling season, no water quality samples were collected at this sampling site. During this project, approximately two discrete samples were collected in the winter, one at MCT-5 (Nail Creek) and one at MCT-6 (Fate Dam inlet) and ten samples were collected in the spring three at MCT-5 (Nail Creek), three at MCT-6 (Fate Dam inlet) and four at MCT-8 (Fate Dam outlet).

Sediment and nutrient concentrations can change dramatically with changes in water volume. Large hydrologic loads at a site may have small concentrations; however, more water usually increases nonpoint source runoff and thus higher loadings of nutrients and sediment may result. Average seasonal tributary concentrations for Nail Creek by year and season are provided in Table 8.

Tributary Concentrations

Table 8. Average seasonal tributary concentrations from the Nail Creek to Fate Dam and Medicine Creek, Lyman County, South Dakota[1] for 2000 and 2001.

Year / Station / Season

	2000						2001									
	MCT-5, MCT-6 and MCT-8						MCT-8 (outlet)				MCT-6 (Fate Dam inlet)				MCT-5 (upper Nail Creek)	
	Spring 00		Summer 00		Fall 00		Winter 01		Spring 01		Winter 01[3]		Spring 01		Winter 01[3]		Spring 01	
Parameter	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average	Count	Average
Water Temperature (oC)	-	-	-	-	-	-	-	-	4	**13.86**	1	2.50	3	7.84	1	2.23	3	5.58
Dissolved Oxygen	-	-	-	-	-	-	-	-	4	**10.44**	1	5.71	3	8.68	1	10.11	3	10.11
pH (su)[2]	-	-	-	-	-	-	-	-	4	**8.51**	1	8.12	3	7.90	1	8.11	3	7.91
Conductivity (µS/cm[1])	-	-	-	-	-	-	-	-	4	492	1	168	3	640	1	277	3	**632**
Fecal Coliform Bacteria (#colonies/100 ml)	-	-	-	-	-	-	-	-	4	24	1	5	3	**535**	1	10	3	70
E. coli Bacteria (#colonies/100 ml)	-	-	-	-	-	-	-	-	4	26	1	3	3	**307**	1	2	3	78
Alkalinity (mg/L)	-	-	-	-	-	-	-	-	4	122	1	50	3	**127**	1	72	3	104
Total Solids (mg/L)	-	-	-	-	-	-	-	-	4	389	1	149	3	**824**	1	205	3	532
Total Dissolved Solids (mg/L)	-	No Samples Collected in 2000[4]				-	-	-	4	361	1	137	3	**500**	1	188	3	477
Total Suspended Solids (mg/L)	-	-	-	-	-	-	-	-	4	28	1	12	3	**324**	1	17	3	55
Volatile Total Suspended Solids (mg/L)	-	-	-	-	-	-	-	-	4	4	1	4	3	**33**	1	7	3	12
Ammonia (mg/L)	-	-	-	-	-	-	-	-	4	0.07	1	**0.26**	3	0.12	1	0.23	3	0.06
Un-ionized Ammonia (mg/L)	-	-	-	-	-	-	-	-	4	**0.00473**	1	0.00345	3	0.00116	1	0.00291	3	0.00051
Nitrate - Nitrite (mg/L)	-	-	-	-	-	-	-	-	4	1.43	1	0.60	3	3.87	1	0.80	3	**5.90**
Total Kjeldahl Nitrogen (mg/L)	-	-	-	-	-	-	-	-	4	0.92	1	1.29	3	1.30	1	**1.36**	3	1.05
Inorganic Nitrogen (mg/L)	-	-	-	-	-	-	-	-	4	1.50	1	0.86	3	3.98	1	1.03	3	**5.96**
Organic Nitrogen (mg/L)	-	-	-	-	-	-	-	-	4	0.85	1	1.03	3	**1.18**	1	1.13	3	0.99
Total Nitrogen (mg/L)	-	-	-	-	-	-	-	-	4	2.34	1	1.89	3	5.17	1	2.16	3	**6.95**
Total Phosphorus (mg/L)	-	-	-	-	-	-	-	-	4	0.158	1	0.565	3	**0.790**	1	0.337	3	0.452
Total Dissolved Phosphorus (mg/L)	-	-	-	-	-	-	-	-	4	0.091	1	**0.479**	3	0.300	1	0.275	3	0.329
Total Nitrogen : Total Phosphorus Ratio	-	-	-	-	-	-	-	-	4	15.7	1	3.3	3	8.3	1	6.4	3	**16.3**

[1] = Highlighted areas are the highest recorded average concentration or value for a given parameter in 2001.

[2] = pH is highest concentration not average.

[3] = One sample not an average.

[4] = MCT-6 had intermittent flow from April through July 2000; however, no water quality samples were collected.

Fecal coliform bacteria are an indicator of waste material from warm-blooded animals and usually indicate the presence of animal or human wastes. Average fecal coliform concentrations were highest in the spring at MCT-6. All average seasonal concentrations were elevated at both sampling sites. Wildlife and agricultural practices were the most likely sources of sporadic increased fecal coliform counts.

Higher total, dissolved solids, total suspended solids and volatile total suspended solids concentrations were observed in the spring at MCT-6. Intense rains on agricultural lands and harvested crops typically cause higher erosion and higher total suspended solids in streams.

Average nitrate-nitrite, inorganic nitrogen and total nitrogen concentrations were higher in the spring while average Total Kjeldahl Nitrogen (TKN) concentrations were higher in the winter at MCT-5 (upper Nail Creek). The highest average organic nitrogen concentrations during the project occurred in the spring at MCT-6 (Table 8).

Ammonia was highest in the winter at MCT-6 and was also relatively high at MCT-5 while un-ionized ammonia concentrations were higher in the spring at MCT-8 (Fate Dam Outlet). Sources for high ammonia concentrations could be wildlife, decomposition of organic matter or runoff from land applied fertilizer and/or manure.

Total phosphorus concentrations were higher in the spring at MCT-6; however, the highest average dissolved phosphorus concentrations were in the winter of 2001, also at MCT-6 (Table 8).

Seasonalized Tributary Hydrologic Loadings

Two tributary monitoring sites were set up on Nail Creek (MCT-5 and MCT-6) and one (MCT-8) at the outlet of Fate Dam. All sites were monitored 394 days from April 2000 through May 2001 excluding the winter months. Approximately 3.7 million cubic meters (3,069 acre-feet) of water flowed into Fate Dam from Nail Creek over the project period. The overall tributary export coefficient (amount of water delivered per acre) was 479.9 m^3/acre (0.39 acre-foot/acre). Export coefficients and seasonal loading percentages for MCT-5, MCT-6 and MCT-8 are provided in Table 9.

The peak hydrologic load for Fate Dam and Medicine Creek (MCT-5, MCT-6 and MCT-8) occurred during the spring of 2001. Approximately 58.6 percent of the hydrologic load was delivered to Fate Dam and 100 percent of the hydrologic load was delivered to Medicine Creek during the spring sampling period.

Table 9. Cumulative hydrologic loading and export coefficients for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota in 2000 and 2001.

		Hydrologic Loading			**Export Coefficient**	
Site	**Season**	**Meters^3**	**Acre-feet**	**Percent**	**Meters^3/acre**	**Acre-feet/acre**
MCT-5	**Spring - 00**	0	0	0	0	0
	Summer - 00	0	0	0	0	0
	Fall - 00	0	0	0	0	0
	Winter - 01	64,000	51.8	3.7	8.1	0.01
	Spring - 01	1,653,000	1,338.9	96.3	208.1	0.17
MCT-5	**Total**	**1,717,000**	**1,390.7**	**100.0**	**216.2**	**0.18**
MCT-6	**Spring - 00**	1,095,000	886.9	28.9	138.7	0.11
	Summer - 00	244,000	197.6	6.4	30.9	0.03
	Fall - 00	0	0	0	0	0
	Winter - 01	227,000	183.9	6.0	28.7	0.02
	Spring - 01	2,224,000	1,800.6	58.7	281.6	0.23
	Total	**3,790,000**	**3,069.0**	**100.0**	**479.9**	**0.39**
Fate Dam	**Inlet Total**	**3,790,000**	**3,069.0**	**100.0**	**479.9**	**0.39**
MCT-8	**Spring - 00**	0	0	0	0	0
	Summer - 00	0	0	0	0	0
	Fall - 00	0	0	0	0	0
	Winter - 01	0	0	0	0	0
	Spring - 01	3,379,000	2,736.9	100.0	194.7	0.16
	Total	**3,379,000**	**2,736.9**	100.0	194.7	0.16
Load to Medicine Creek	**Total**	**3,379,000**	**2,736.9**	**100.0**	**194.7**	**0.16**

Tributary Water Quality and Loadings

Dissolved Oxygen

Dissolved oxygen concentrations in most unpolluted streams and rivers remain above 80 percent saturation. Solubility of oxygen generally increases as temperature decreases and decreases with decreasing atmospheric pressure (either by a change in elevation or barometric pressure) (Hauer and Hill, 1996). Stream morphology, turbulence and flow can also have an effect on oxygen concentrations. Dissolved oxygen concentrations are not uniform within or between stream reaches. Upwelling of interstitial waters at the groundwater and streamwater mixing zone (hyporheic zone) or side flow of ground waters may create patches within a stream reach where dissolved oxygen concentrations are significantly lower than surrounding water (Hauer and Hill, 1996). Nail Creek dissolved oxygen concentrations averaged 9.49 mg/L (median 9.41 mg/L) during this study.

Seasonal and daily concentrations of chemicals (biotic and abiotic) in water can also affect dissolved oxygen concentrations. Higher chemical concentrations also increase Biochemical and

Sediment Oxygen Demand (BOD and SOD). These processes use oxygen in the system to break down or convert organic and inorganic compounds.

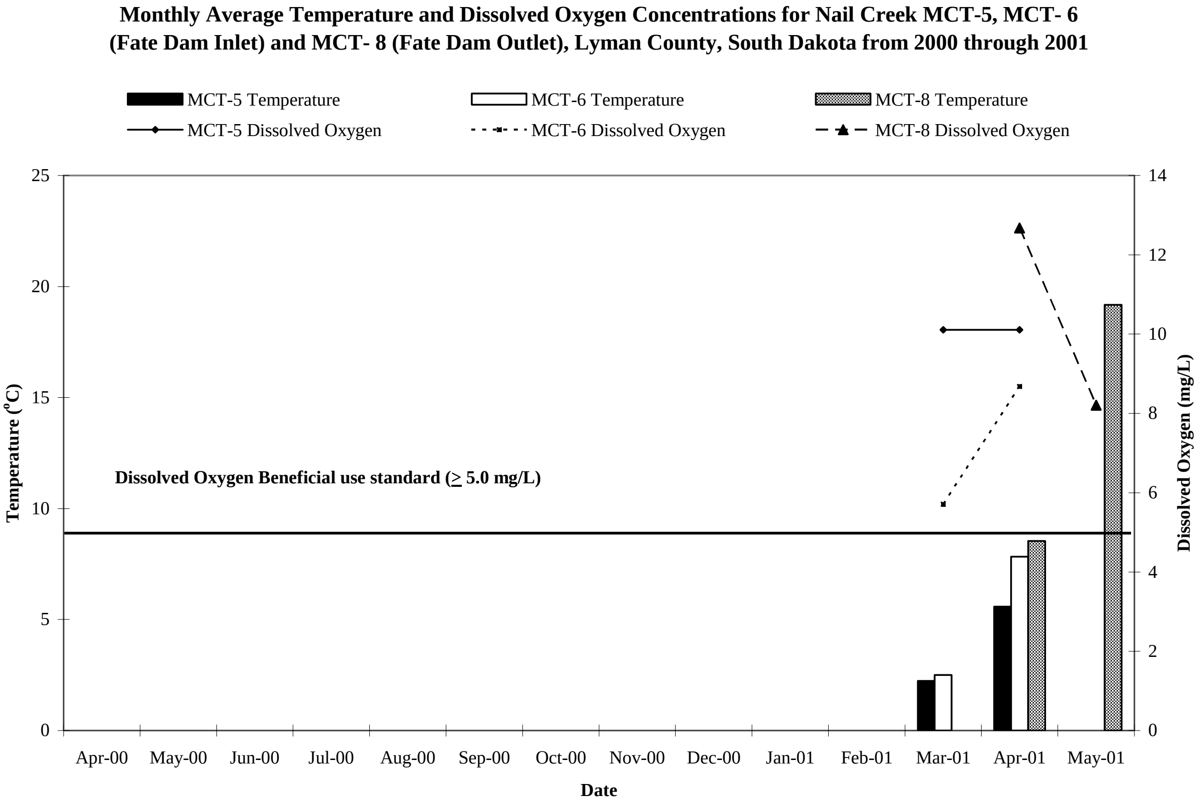

Figure 4. Monthly average dissolved oxygen concentrations and temperature for Nail Creek, Lyman County, South Dakota from 2000 through 2001.

The maximum dissolved oxygen concentration in Nail Creek was 13.68 mg/L. The sample was collected at site MCT-15 on April 10, 2001 (Appendix B). The minimum dissolved oxygen concentration was 7.47 mg/L at MCT-14 on March 13, 2001. April tributary samples had the highest average dissolved oxygen concentrations (Figure 4). No dissolved oxygen exceedances were observed at either sampling site on Nail Creek (MCT-5, MCT-6 (Fate Dam inlet) and MCT-8 (outlet of Fate Dam)) during the project. Fate Dam with its increased hydrologic retention time and algae production modified/increased dissolved oxygen concentrations at the downstream (MCT-8) sampling site (Figure 4).

Table 8 shows seasonal tributary average dissolved oxygen concentrations by tributary monitoring site for Nail Creek during the project. Seasonal average oxygen levels were lowest in the winter 2001 at MCT-6 (averaged 5.71 mg/L) and were the highest below Fate Dam (MCT-8) in the spring of 2001 (averaged 10.44 mg/L).

pH

pH is a measure of hydrogen ion concentration, the more free hydrogen ions, (i.e. more acidic) the lower the pH in water. The pH concentrations in Nail Creek were not extreme in any tributary sample. The relatively high alkalinity concentrations in Nail Creek work to buffer dramatic pH changes. Lower pH values are normally observed during increased decomposition of organic matter.

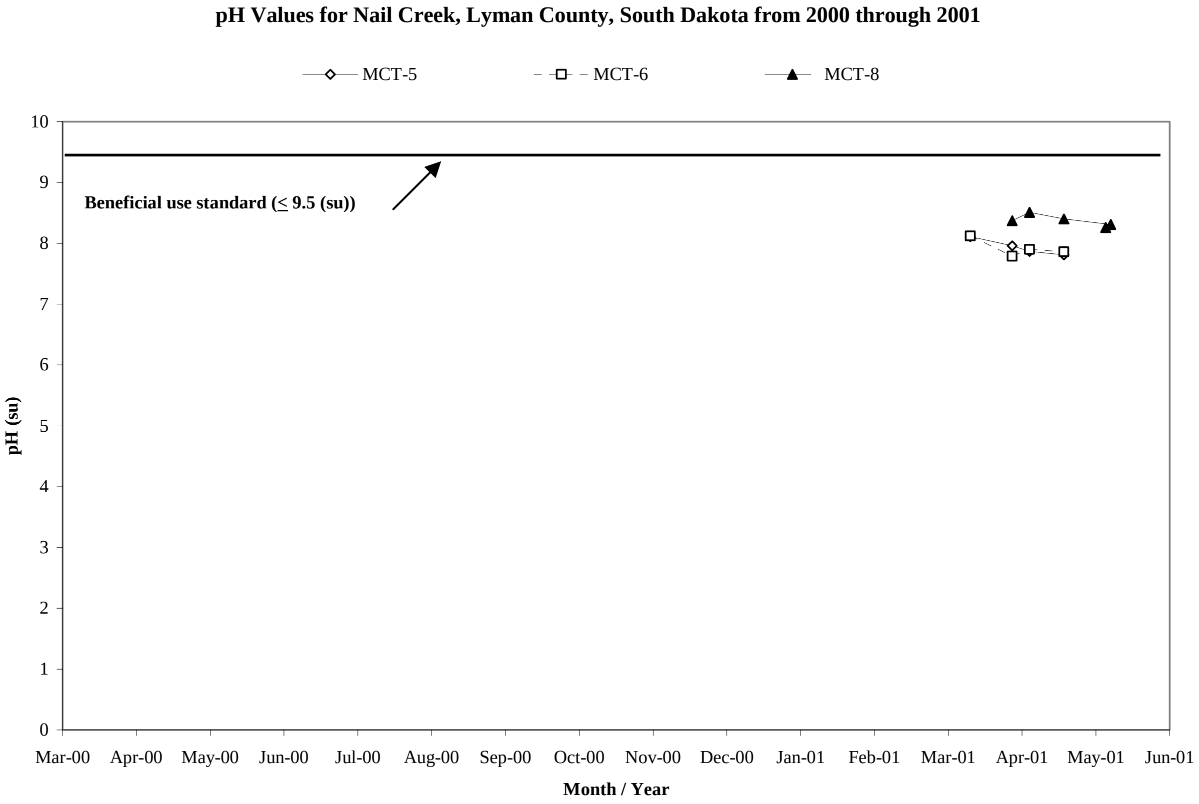

Figure 5. Monthly pH values for Nail Creek, Lyman County, South Dakota from 2000 through 2001.

The pH concentrations in Nail Creek had a maximum pH of 8.51 su and a minimum pH of 7.79 su. Generally throughout this project, pH concentrations were higher at MCT-8 (Fate Dam outlet) than both up stream sampling sites (Figure 5). Table 8 lists seasonal maximum pH concentrations by tributary sampling site. The highest concentrations were in the spring of 2001 at MCT-8 and were significantly different (higher) than MCT-5 and MCT-6 (Figure 6 and Table 4). This was may be attributed to increased algal concentrations in Fate Dam. Algae are known to increase pH in lakes (Wetzel, 2001 and Cole, 1988).

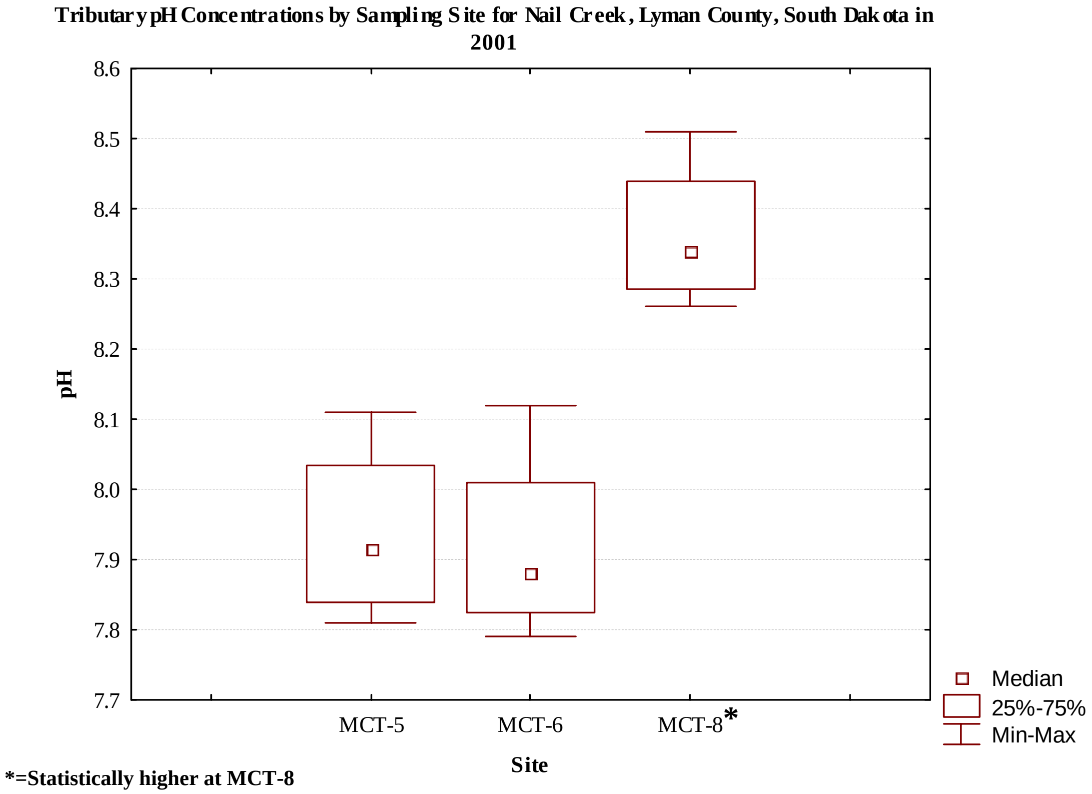

Figure 6. Median, quartile and range for pH concentrations by tributary monitoring site for Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Specific Conductivity

Conductivity is a measure of electrical conductance of water, and an approximate predictor of total dissolved ions. Increased ion concentrations reduce the resistance to electron flow; thus, differences in conductivity result mainly from the concentration of charged ions in solution, and to a lesser degree ionic composition and temperature (Allan, 1995). The temperature of an electrolyte affects ionic velocities and conductance increases approximately 2 percent per degree Celsius (Wetzel, 2001). Specific conductivity is conductivity adjusted to temperature (25° C) and is reported in micro-Siemens/centimeter ($\mu S/cm^1$).

Typically, there is a good relationship between total dissolved solids and specific conductance (conductivity). Current data indicate an excellent relationship ($R^2 = 0.99$) between conductivity and total dissolved solids for Nail Creek, or 99 percent of the variability in conductivity is explained in total dissolved solids (Figure 7). The in-lake relationship for conductivity and total dissolved solids was also extremely good with an $R^2 = 0.87$ (Figure 7).

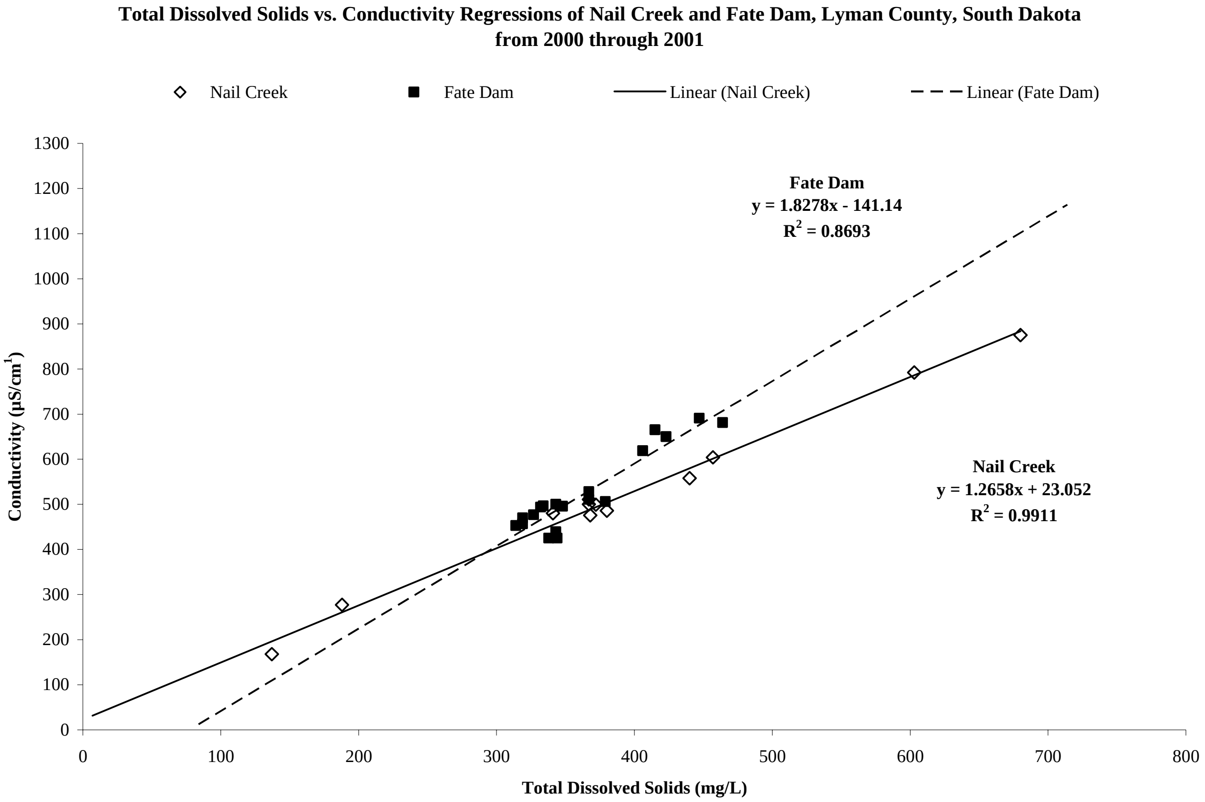

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Figure 7. Relationship of total dissolved solids to specific conductivity (µS/cm^1) for Nail Creek and Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Specific conductivity values in Nail Creek tributary monitoring sites (MCT-5, MCT-6 and MCT-8) were below the beneficial use standard for conductivity (Figure 8). Medicine Creek is listed in The 2004 South Dakota Integrated Report for Surface Water Quality Assessment (305(b) report and 303(d) list combined) as impaired for conductivity and Total Dissolved Solids (2004 Integrated Report (page 131)). Data indicate that neither Fate Dam nor Nail Creek (a tributary of Medicine Creek) appear to contribute increased TDS concentrations and/or conductivity values to Medicine Creek. TDS and conductivity values for Nail Creek and Fate Dam collected during this project are provided in Appendix B (Nail Creek) and Appendix C (Fate Dam).

A comparison of tributaries for TMDL (lakes) within the Medicine Creek watershed (Nail Creek (Fate Dam), Brakke Creek (Brakke Dam) and Grouse Creek (Byre Lake)) indicate specific conductivity values in Brakke Creek tributary were significantly lower (H=11.162, (α = 0.05, N=33), p=0.0038) than either Grouse or Nail Creek (Figure 9). No TMDL (lakes) sub-watersheds of Medicine Creek contributed increased specific conductivity values to Medicine Creek during the project.

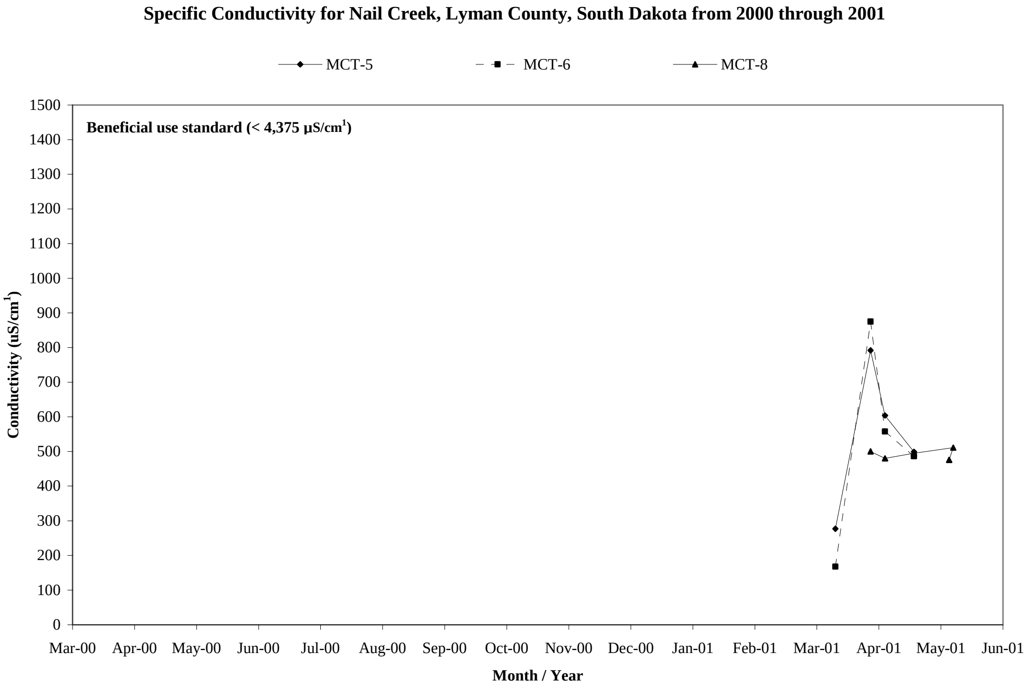


Figure 8. Monthly specific conductivity values for Nail Creek, Lyman County, South Dakota from 2000 through 2001.

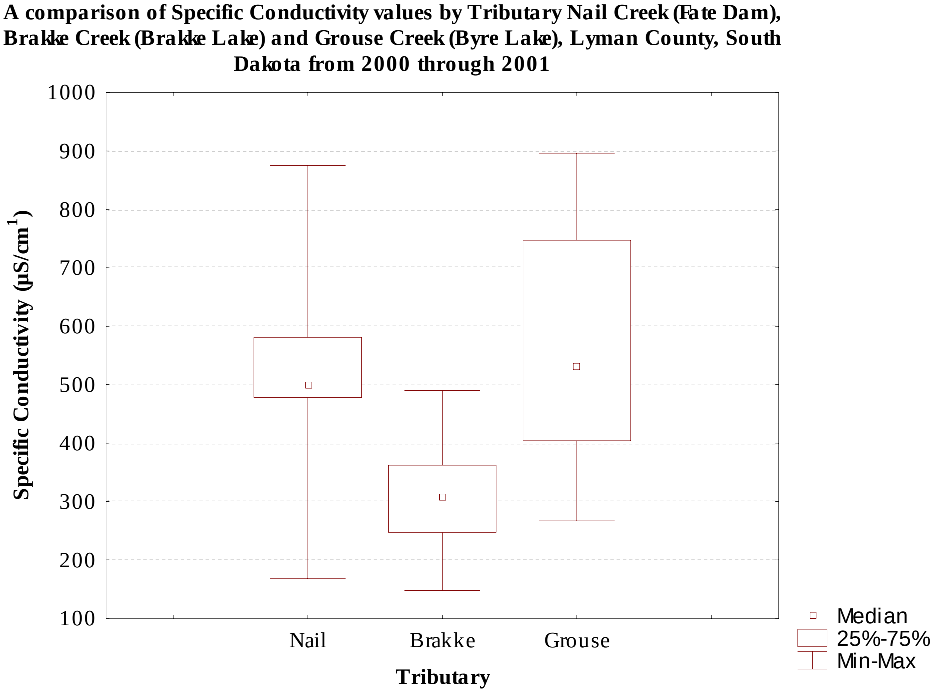


Figure 9. A comparison of specific conductivity by TMDL lake tributary in the Medicine Creek Watershed, Lyman County, South Dakota from 2000 through 2001

Total Alkalinity

Alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7.00 su). These various bicarbonate and carbonate compounds generally originate from dissolution of sedimentary rock (Allan, 1995). Alkalinity in natural environments usually ranges from 20 to 200 mg/L (Lind, 1985).

Table 10. Total alkalinity loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	149,833	19.0
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	277,734	35.2
Total Gauged Loading to Fate Dam		**15,869**	100.0	427,667	54.2
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	382,597	48.4
Fate Dam Reduction Coefficient*	**1.12**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

The median alkalinity in Nail Creek was 113.5 mg/L (average, 108.4 mg/L). The minimum alkalinity concentration was 50 mg/L and was collected at site MCT-6 on March 19, 2001 while the maximum alkalinity sample (153) mg/L was also collected at site MCT-6 on April 5, 2001 (Appendix B). Alkalinity concentrations were statistically similar between sampling sites (Table 4). Seasonally, Nail Creek average alkalinity concentrations were higher in the spring for MCT-6 and MCT-8 (Table 8)

Total alkalinity loading to Fate Dam by site was highest at site MCT-6 with 277,734 kg/year or 53.9 percent of the total alkalinity load (Table 10). Figure 10 indicates alkalinity loads at the outlet of Nail Creek was highest in April 2001. Alkalinity loading between sampling sites were statistically similar (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-6 (35.2 kg/acre) sub-watershed (Table 10). Fate Dam reduces/modifies Nail Creek alkalinity loading to Medicine Creek (reduction coefficient) by approximately 1.12 times or 45,070 kg.

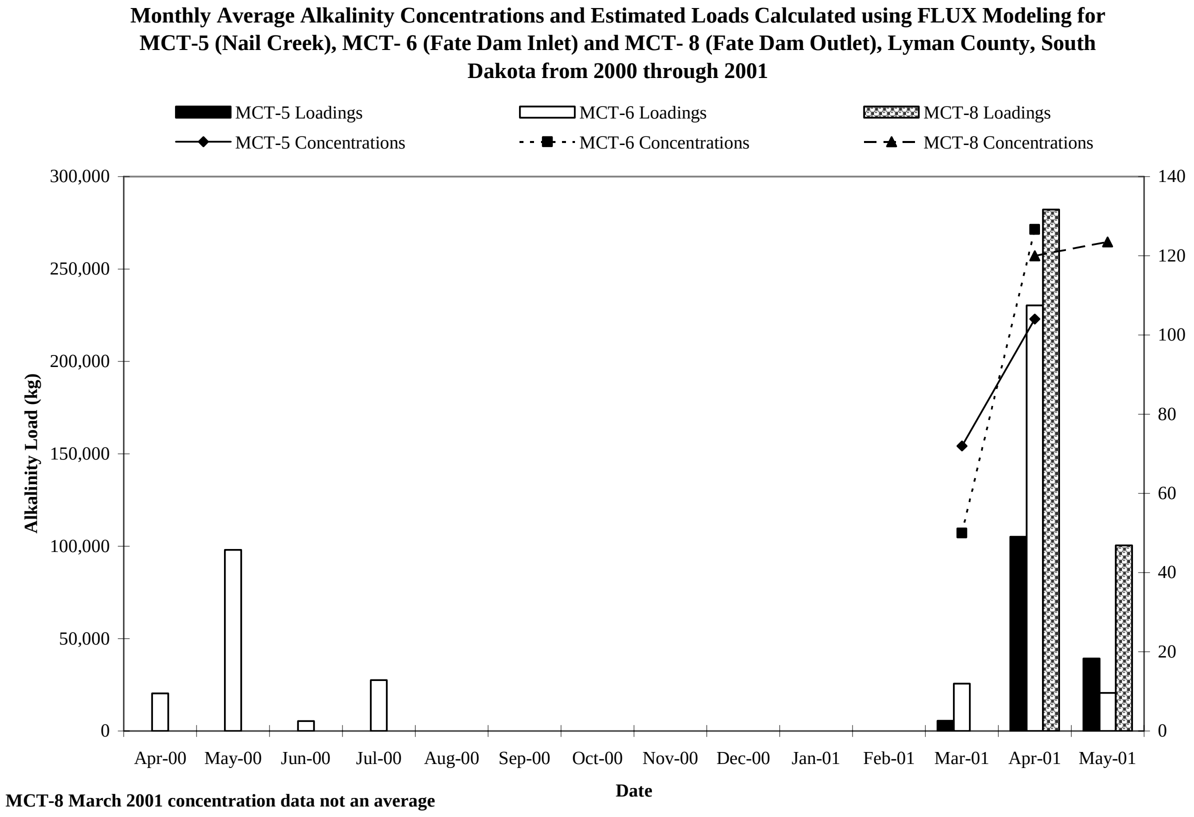


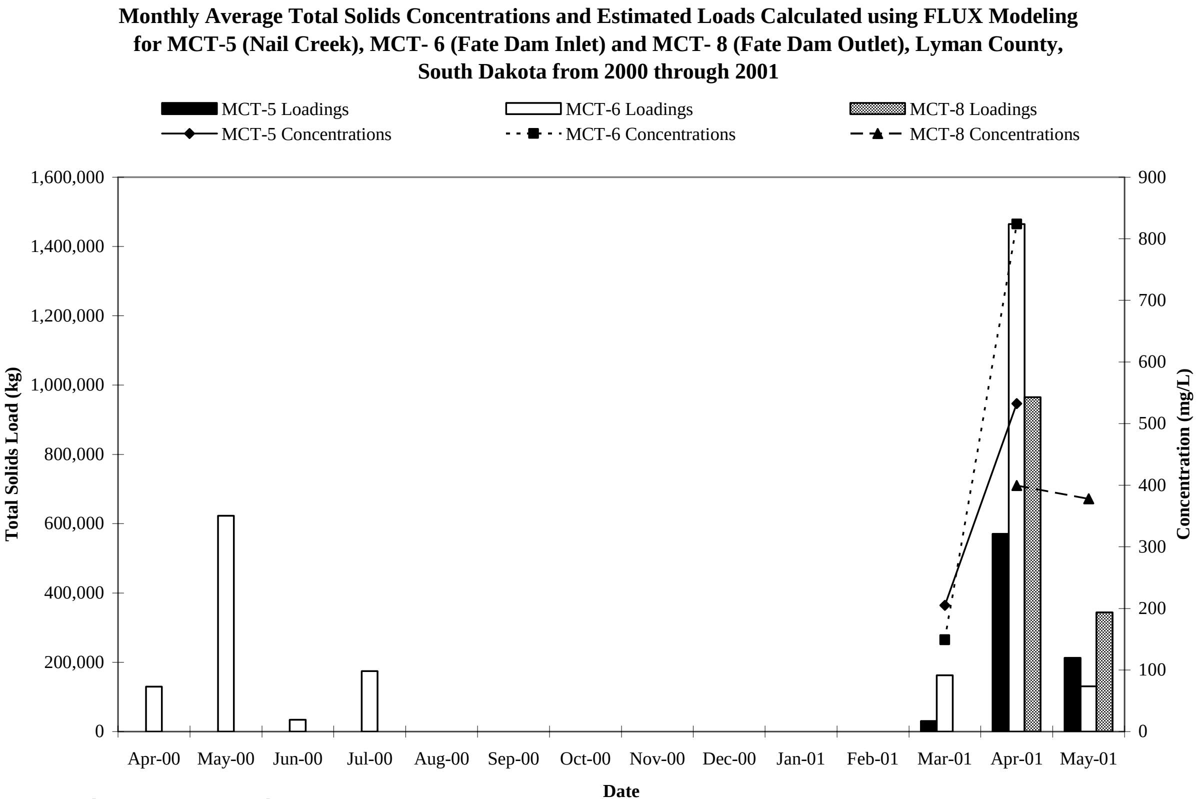
Figure 10. Monthly average total alkalinity concentrations and estimated loads by tributary to Fate Dam and Medicine Creek from Nail Creek and Fate outlet, Lyman County, South Dakota in 2000 and 2001.

Solids

Total solids are materials, suspended or dissolved, present in natural water and include materials that pass through a filter. Suspended solids are the materials that do not pass through a filter, e.g. sediment and algae. Subtracting suspended solids from total solids derives total dissolved solids concentrations. Volatile total suspended solids are that portion of suspended solids that are organic (organic matter that burns in a 500^o C muffle furnace).

The median total solids concentrations in Nail Creek was 431 mg/L (average 498 mg/L) with a maximum of 1,210 mg/L and a minimum of 149 mg/L. Median total dissolved solids concentration was 370 mg/L (average 392 mg/L) with a maximum of 680 mg/L and a minimum concentration of 137 mg/L. With no flow/loading occurring in the 2000 sampling season, seasonality in concentration and loading data could not be ascertained; however, monthly estimations could be made using spring of 2001 data. Generally, total and dissolved solids concentrations peaked in April 2001 at both tributary sites (Figure 11 and Figure 13). Concentrations were higher at MCT-6 for all dates data was available, although not significantly (Table 4). Seasonal averages for total and dissolved solids concentrations were highest in the spring at MCT-6 (Table 8).

A comparison of tributaries for TMDL (lakes) within the Medicine Creek watershed (Nail Creek (Fate Dam), Brakke Creek (Brakke Dam) and Grouse Creek (Byre Lake)) indicate total and total dissolved solids concentrations in Brakke Creek tributary were significantly lower (H=12.491, (α = 0.05, N=33)), p=0.0019 and H=13.216, (α = 0.05, N=33)), p=0.0013, respectively) than either Grouse Creek or Nail Creek (Figure 12 and Figure 14).



MCT-8 March 2001 concentration data not an average

Figure 11. Monthly average total solids concentrations and estimated loads by tributary to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 and 2001.

Table 11. Total solids loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	814,196	102.5
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	1,906,090	241.4
Total Gauged Loading to Fate Dam		**15,869**	100.0	2,720,286	171.4
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	1,308,754	76.1
Fate Dam Reduction Coefficient*	**2.08**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

Total solids loading by site was highest at site MCT-6 with 1,906,090 kg/year (Table 11). Total dissolved solids loadings were also the highest at site MCT-14 with 745,931 kg/year (Table 12). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-6 sub-watershed 241.4 kg/acre for total solids and 94.5 kg/acre for total dissolved solids. Total solids and total dissolved solids loads were not significantly different (Table 4). The highest loading of both total and dissolved solids to Fate Dam (MCT-6) occurred in April 2001 (Figure 11 and Figure 13).

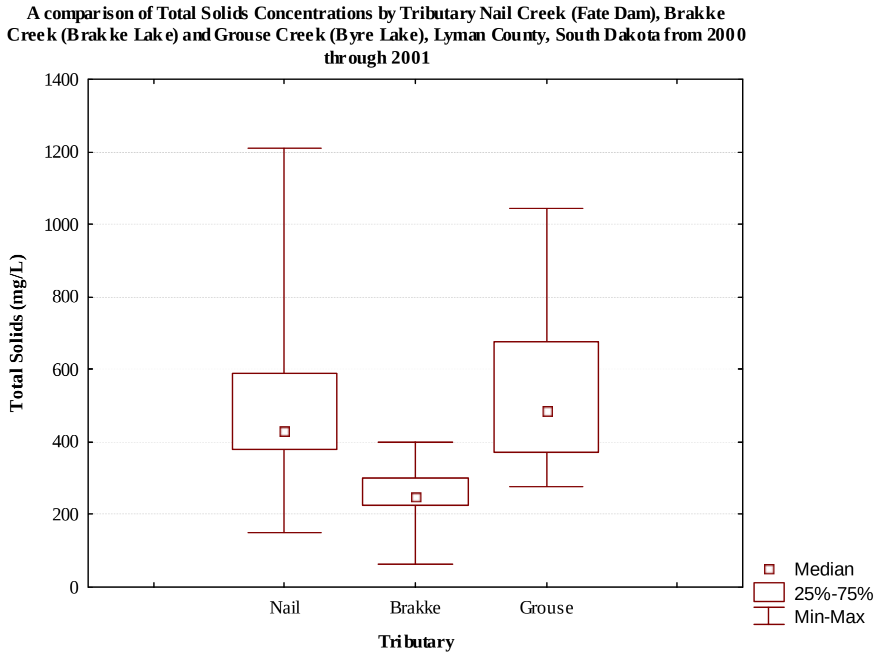
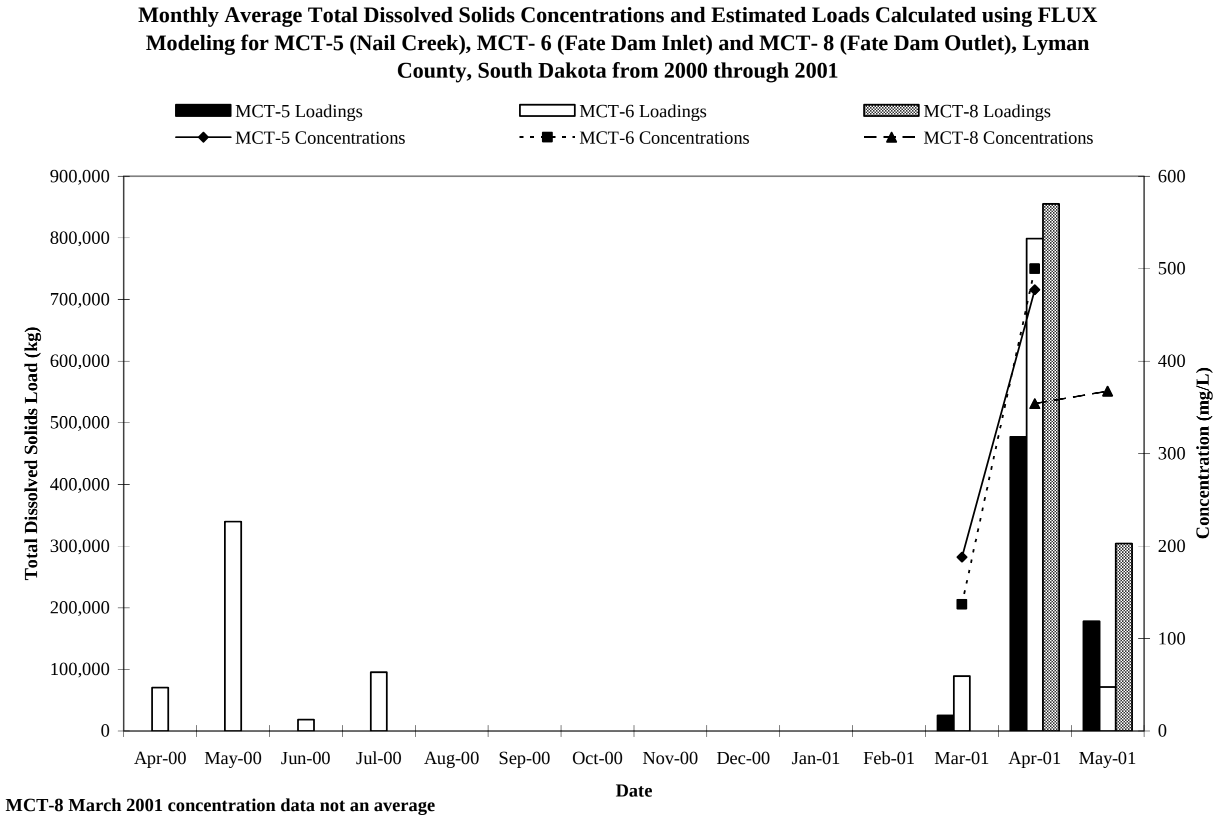


Figure 12. A comparison of total solids concentrations by TMDL lake tributary in the Medicine Creek Watershed, Lyman County, South Dakota from 2000 through 2001.

Table 12. Total dissolved solids loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	737,189	92.8
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	745,931	94.5
Total Gauged Loading to Fate Dam		**15,869**	100.0	1,483,120	93.5
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	1,159,247	67.4
Fate Dam Reduction Coefficient*	**1.28**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**


Monthly Average Total Dissolved Solids Concentrations and Estimated Loads Calculated using FLUX Modeling for MCT-5 (Nail Creek), MCT- 6 (Fate Dam Inlet) and MCT- 8 (Fate Dam Outlet), Lyman County, South Dakota from 2000 through 2001

MCT-8 March 2001 concentration data not an average

Figure 13. Monthly average total dissolved solids concentrations and estimated loads by tributary to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Fate Dam reduces/modifies Nail Creek total solids loading to Medicine Creek (reduction coefficient) by approximately 2.08 times or 1,411,532 kg and reduces/modifies Nail Creek total dissolved solids loading to Medicine Creek by approximately 1.28 times or 323,873 kg (Table 11 and Table 12).

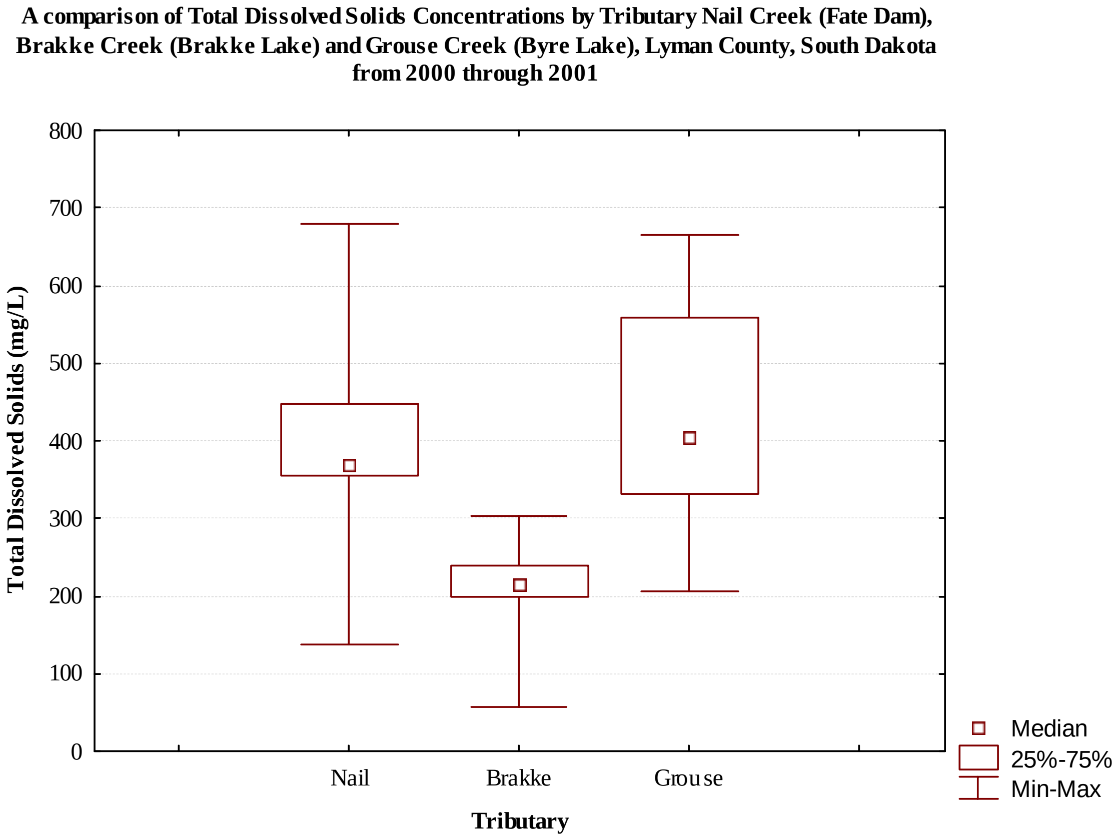


Figure 14. A comparison of total dissolved solids concentrations by TMDL lake tributary in the Medicine Creek Watershed, Lyman County, South Dakota from 2000 through 2001.

The median total suspended solids concentration in Nail Creek was 30 mg/L (average 106 mg/L) with a maximum of 770 mg/L and a minimum of 3 mg/L. Volatile total suspended solids median concentration was 7 mg/L (average 13 mg/L) with a maximum of 70 mg/L and a minimum concentration of 0.5 mg/L. Total suspended and volatile total suspended solids concentrations between sampling sites were not significantly different (Table 4). Generally, average total suspended and volatile total suspended solids concentrations peaked in April 2001 (Figure 15 and Figure 16). Table 8 indicates that seasonal averages for total suspended solids and volatile total suspended solids had higher concentrations at MCT-6 in the spring of 2001 (324 mg/L and 33 mg/L, respectively).

Table 13. Total suspended solids loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	541,273	68.2
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	695,893	88.1
Total Gauged Loading to Fate Dam		**15,869**	100.0	1,237,166	78.0
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	141,533	8.2
Fate Dam Reduction Coefficient*	**8.74**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

Total suspended solids loading by site was highest at site MCT-6 with 695,893 kg/year or 53.8 percent of the total suspended load (Table 13). Volatile total suspended solids loadings were also the highest at site MCT-6 with 102,946 kg/year or 79 percent of the total volatile load (Table 14). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-6 sub-watershed (88.1 kg/acre) for total suspended solids and 13.0 kg/acre at MCT-6 for volatile total suspended solids (Table 13 and Table 14). Total suspended and volatile total suspended solids loads at MCT-5, MCT-6 and MCT-8 were similar (Table 4). The highest loading of both total suspended solids and volatile total suspended solids to Fate Dam occurred in April 2001 (Figure 15 and Figure 16).

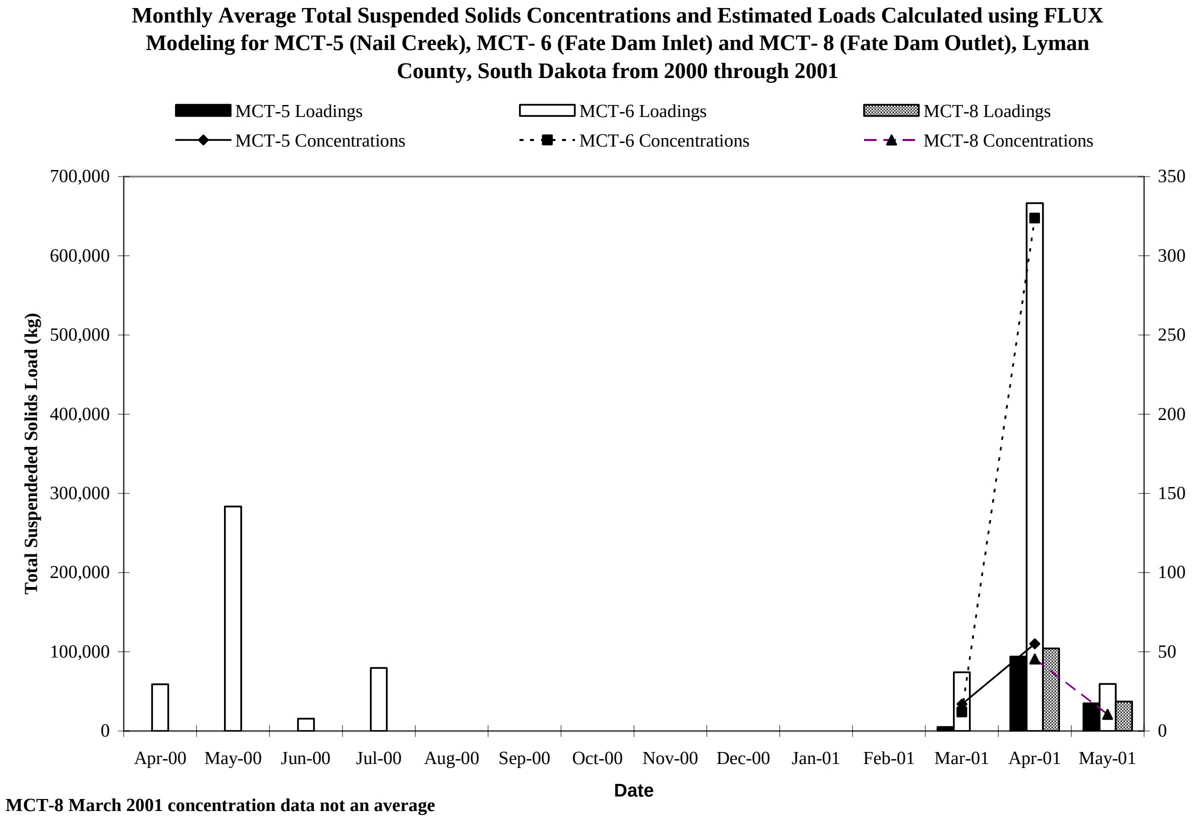


Figure 15. Monthly average total suspended solids concentrations and estimated loads by tributary to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Fate Dam dramatically reduced/modifies Nail Creek total suspended solids loading to Medicine Creek (reduction coefficient) by approximately 8.74 times or 1,095,633 kg and reduced/modifies Nail Creek volatile total suspended solids loading to Medicine Creek by approximately 5.54 times or 106,840 kg (Table 13 and Table 14).

Table 14. Volatile total suspended solids loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	27,412	3.5
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	102,946	13.0
Total Gauged Loading to Fate Dam		**15,869**	100.0	130,358	8.2
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	23,518	1.4
Fate Dam Reduction Coefficient*	**5.54**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

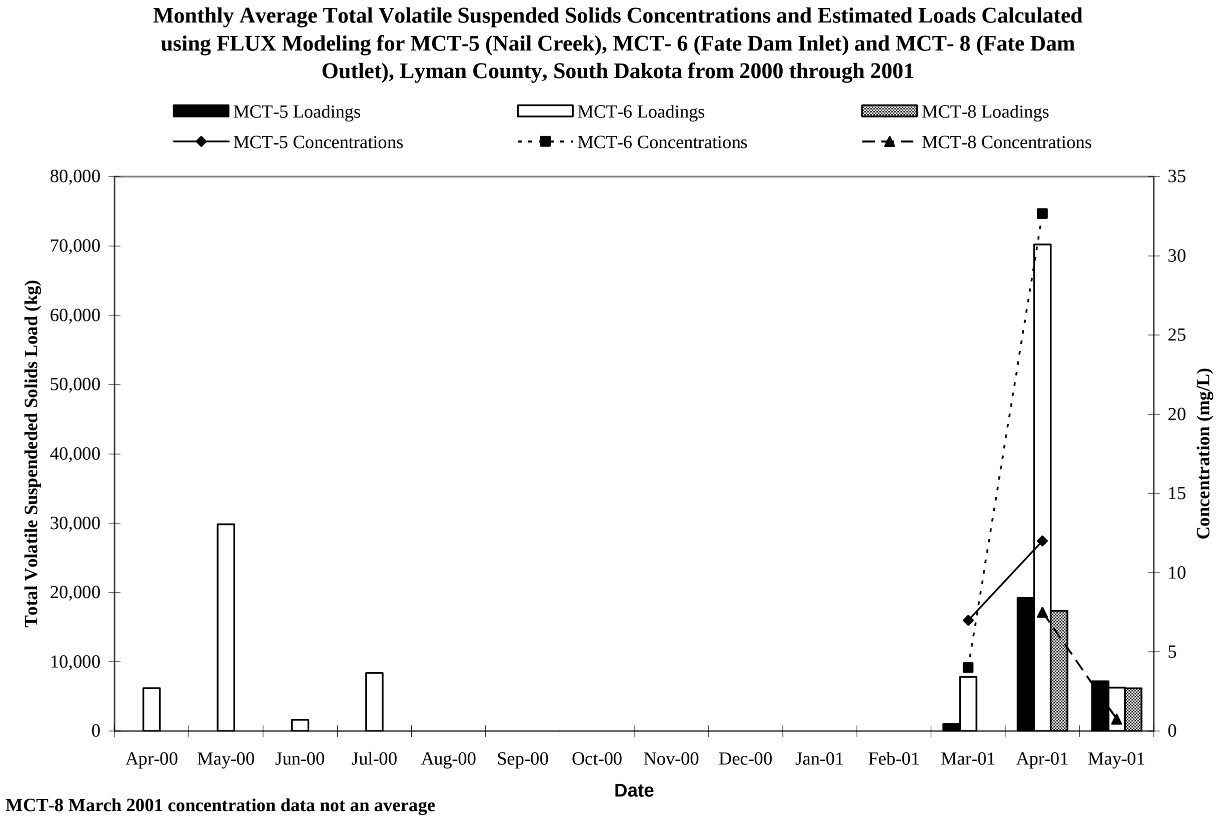


Figure 16. Monthly average total volatile suspended solids concentrations and estimated loads by tributary to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Fate Dam is currently listed in the 2004 Integrated Report for TSI (Trophic State Index) values above the ecoregion targeted values for full support (page 128). In-lake ecoregion targeted TSI values collected during this study indicate a mean TSI value (mean TSI 59.91) exceeds the ecoregion 43 TSI full support threshold (mean TSI $\leq$ 55.00) (SD DENR, 2000). Decreasing sediment (erosion) inputs from Nail Creek will improve (lower) TSI values. Reducing sediment will improve non-algal turbidity, which will increase Secchi transparency, decreasing Secchi TSI values. Increasing transparency should also increase the growth of submerged macrophytes, which would increase the uptake of nitrogen and phosphorus, reducing available nutrients that could cause algal blooms. Reducing sediment also reduces sediment-related phosphorus, which may lower in-lake phosphorus concentrations and phosphorus TSI values. Reductions in sediment-related available phosphorus for algae growth and uptake will have a two-fold effect on TSI values. Dramatically decreasing sediment-related phosphorus could lessen algal densities and blooms in Fate Dam, which will reduce algal turbidity, improving Secchi TSI values. Lower algal densities will also decrease chlorophyll-*a* concentrations, reducing chlorophyll-*a* TSI values. These reductions over time should reverse the increasing TSI trend observed in Fate Dam.

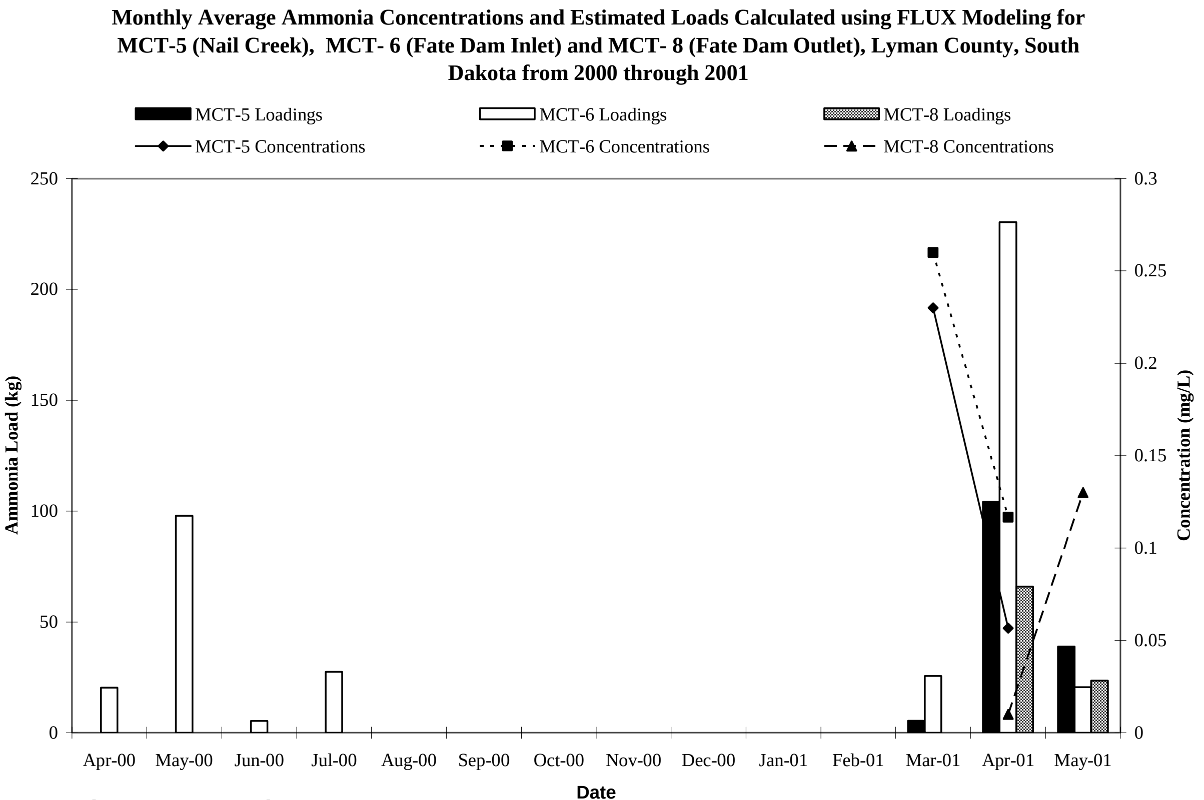
Sub-watersheds that should be targeted for sediment (erosion) mitigation, based on delivered loads and not watershed assessment export coefficients due to the mitigating factors of Fate Dam, are presented in priority ranking in Table 15:

Table 15. Dam/Nail Creek watershed mitigation priority sub-watersheds for sediment (total suspended solids), based on the 2000 and 2001 watershed assessment.

Priority Ranking	Sub-watershed	Total Suspended Solids Export Coefficient (kg/acre)	Total Suspended Solids Kilograms Delivered
1	MCT-6	88.1	695,893
2	MCT-5	68.2	541,273

Ammonia

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



MCT-8 March 2001 concentration data not an average

Figure 17. Monthly average ammonia concentrations and estimated loads to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

The median ammonia concentration in Nail Creek was 0.08 mg/L (average 0.11 mg/L). The standard deviation was 0.10 mg/L which indicates a large variation in sample concentrations. Ammonia concentrations were high in March, declined in April 2001 for MCT-5 (upper Nail Creek) and MCT-6 (Fate Dam inlet) and increased at MCT-8 (Fate Dam outlet) from April to May 20001 (Figure 17). Ammonia concentrations between sampling sites in Nail Creek were statistically similar (Table 4). Seasonally the highest concentrations of ammonia occurred in the winter of 2001 at MCT-6 (0.26 mg/L). Average spring concentrations at both sampling sites were above laboratory detection limits (Table 8).

Table 16. Ammonia loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	149	0.02
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	279	0.04
Total Gauged Loading to Fate Dam		**15,869**	100.0	428	0.03
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	89	0.01
Fate Dam Reduction Coefficient*	**4.81**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

Ammonia loading by sampling site was highest at site MCT-6 with 279 kg/year or 53.8percent of the total ammonia load (Table 16). Sub-watershed export coefficients (kilograms/acre) were also highest at the Fate Dam inlet (MCT-6) with 0.04 kg/acre. Ammonia loading between sampling sites were statistically similar (Table 4). Like most parameters, peak ammonia loading occurred in April 2001 at MCT-6 (Figure 17).

Fate Dam reduced/modified Nail Creek ammonia loading to Medicine Creek (reduction coefficient) by approximately 4.81 times or 202.6 kg (Table 16).

Un-ionized Ammonia

Un-ionized ammonia (NH_4-OH) is the fraction of ammonia that is toxic to aquatic organisms. The concentration of un-ionized ammonia is calculated and dependent on temperature and pH. As temperature and pH increase so does the percent of ammonia which is toxic to aquatic organisms. Since pH, temperature and ammonia concentrations are constantly changing, un-ionized ammonia is calculated instantaneously (by sample) to determine compliance with tributary water quality standards rather than from a loading basis.

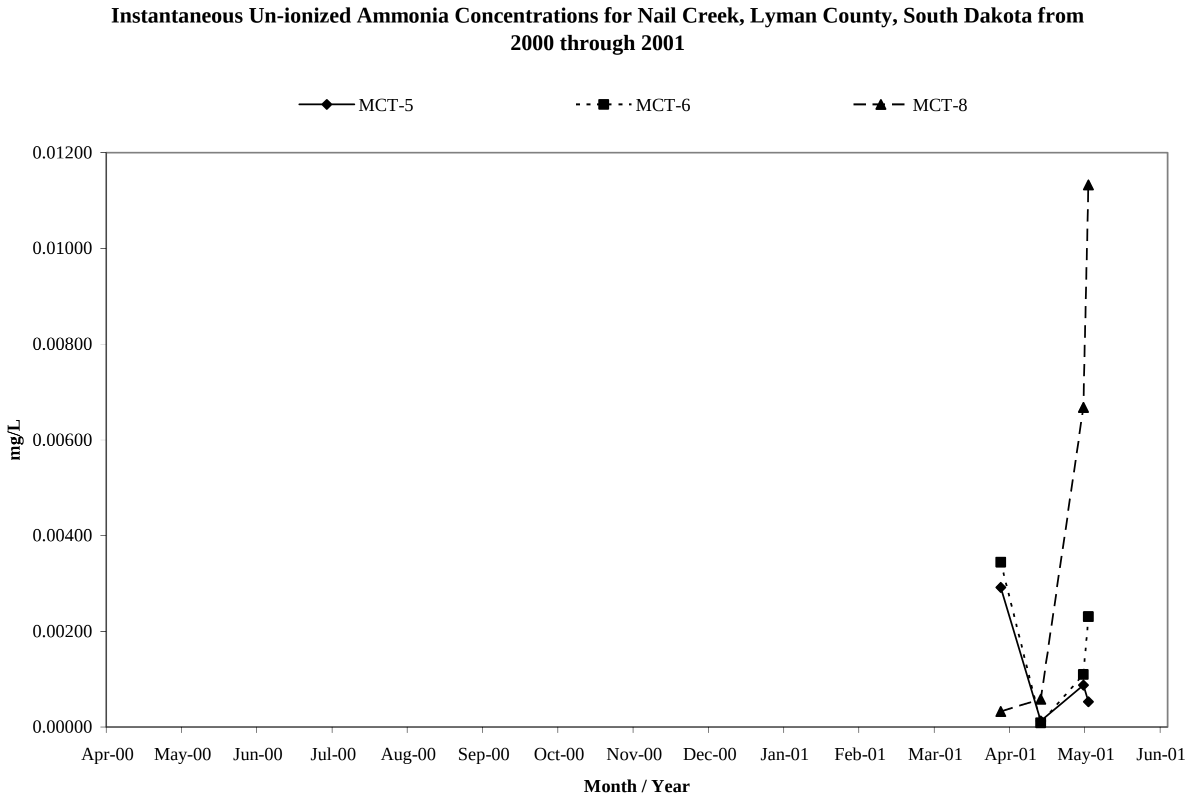
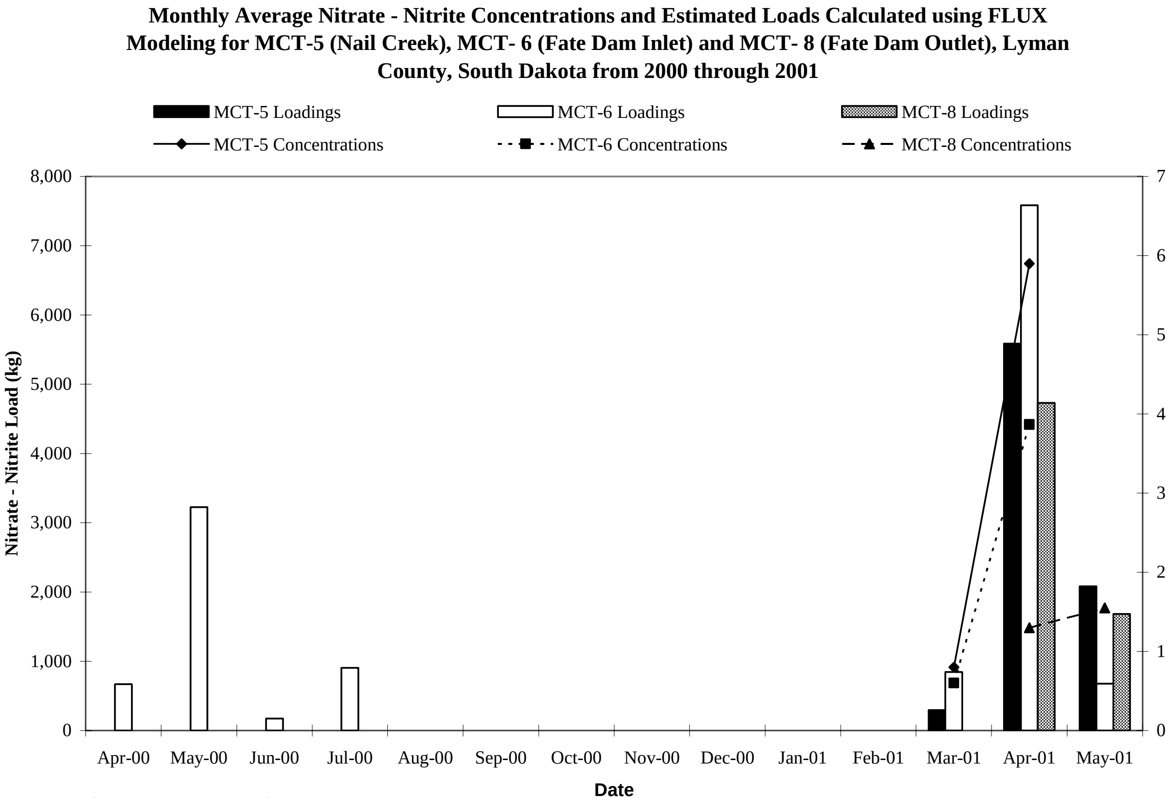


Figure 18. Monthly average un-ionized ammonia concentrations to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

The median un-ionized ammonia concentration for Nail Creek was 0.0010 mg/L (average 0.0025 mg/L). The maximum concentration was 0.011 mg/L and the minimum concentration was 0.0001 mg/L. Average un-ionized ammonia concentrations peaked in May 2001 at MCT-8 (Figure 18).

Nitrate-Nitrite

Nitrate and nitrite (NO_3^- and NO_2^-) are inorganic forms of nitrogen easily assimilated by algae and macrophytes. Sources of nitrate and nitrite can be from agricultural practices and direct input from septic tanks, precipitation, groundwater, and from decaying organic matter. Nitrate-nitrite can also be converted from ammonia through de-nitrification by bacteria. This process increases with increasing temperature and decreasing pH.



MCT-8 March 2001 concentration data not an average

Figure 19. Monthly average nitrate-nitrite concentrations and estimated loads to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

The median nitrate-nitrite concentration for Nail Creek was 2.65 mg/L (average 3.03 mg/L) during the project. The maximum concentration of nitrate-nitrite was 7.70 mg/L on April 5, 2001 at MCT-5 and a minimum of 0.60 mg/L in one sample collected on April 10, 2001 at MCT-8 (Appendix B). One peak was observed in monthly average tributary nitrate-nitrite concentrations in April 2001 at both MCT-5 and MCT-6 (Figure 19). Nitrate-nitrite concentrations between sampling sites were statistically similar (Table 4). Seasonally, average nitrate-nitrite concentrations (Table 8) were elevated in the spring of 2001 at MCT-5 (5.90 mg/L).

Nitrate-nitrite loading by site was highest at site MCT-5 at 7,966 kg (Table 17). Sub-watershed export coefficients (kilograms/acre) were also highest in the MCT-5 sub-watershed at 1.0 kg/acre. Nitrate-nitrite loadings between sampling sites were statistically similar (Table 4).

Fate Dam reduced/modified Nail Creek nitrate-nitrite loading to Medicine Creek (reduction coefficient) by approximately 2.20 times or 7,672 kg (Table 17).

Periodic elevated nitrate-nitrite concentrations in this watershed may have origins in geologic formations. Soils in the Medicine Creek watershed, of which the Fate Dam watershed is apart, were/are developed from Pierre shale. Layers have been identified in the bedded material that are high in and contributes to nitrate-nitrites to groundwater that seeps through these areas. There are three possible sources for increased nitrate-nitrites to enter seepage water in the watershed. (1.) Natural seeps that occur along the drainage ways may deliver nitrate-nitrites to the draws and the nitrate-nitrites are flushed downstream when runoff occurs. (2.) The water table that occurs below and downstream of impoundments (stock dams) may be intercepting some of these layers high in nitrate-nitrites and cause it to flow to the surface downstream of the dam. (3.) There may be seeps that developed in cropland. The Pierre soils have a history of seeps developing and enlarging where native range has been converted to cropland. This is caused where the annual moisture exceeds the cropland needs and a water table develops bringing seep water to the ground surface (Lorenzen et al., 2004).

Table 17. Nitrate-nitrite loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	7,966	1.0
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	6,119	0.8
Total Gauged Loading to Fate Dam		**15,869**	100.0	14,085	0.9
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	6,413	0.4
Fate Dam Reduction Coefficient*	**2.20**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

A comparison of tributaries for TMDL (lakes) within the Medicine Creek watershed (Nail Creek (Fate Dam), Brakke Creek (Brakke Dam) and Grouse Creek (Byre Lake)) indicate nitrate/nitrite concentrations in Brakke Creek tributary were significantly lower ($H=12.22$, $(\alpha = 0.05, N=33)$, $p=0.0022$) than Nail Creek (Figure 20) but were similar to Grouse Creek.

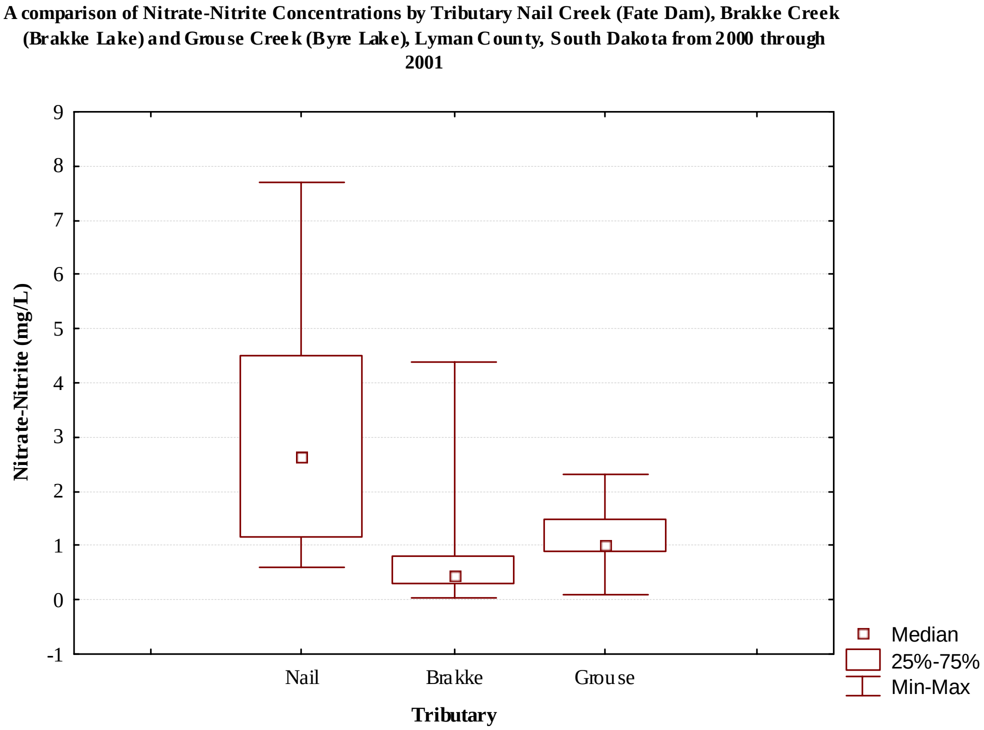


Figure 20. A comparison of nitrate-nitrite concentrations by TMDL (lake) tributary in the Medicine Creek Watershed, Lyman County, South Dakota from 2000 through 2001.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is organic nitrogen including ammonia. Sources of TKN can include release from dead or decaying organic matter, septic systems or agricultural waste.

Table 18. Total Kjeldahl Nitrogen loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	1,803	0.2
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	4,419	0.6
Total Gauged Loading to Fate Dam		**15,869**	100.0	6,222	0.4
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	3,166	0.2
Fate Dam Reduction Coefficient*	**1.97**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

The median TKN concentration in Nail Creek was 1.10 mg/L (average 1.11 mg/L) with a maximum concentration of 1.76 mg/L and a minimum of 0.53 mg/L. Total Kjeldahl Nitrogen concentrations between sampling sites were not statistically different (Table 4). Seasonal TKN concentrations were highest in the winter at MCT-5 (Table 8).

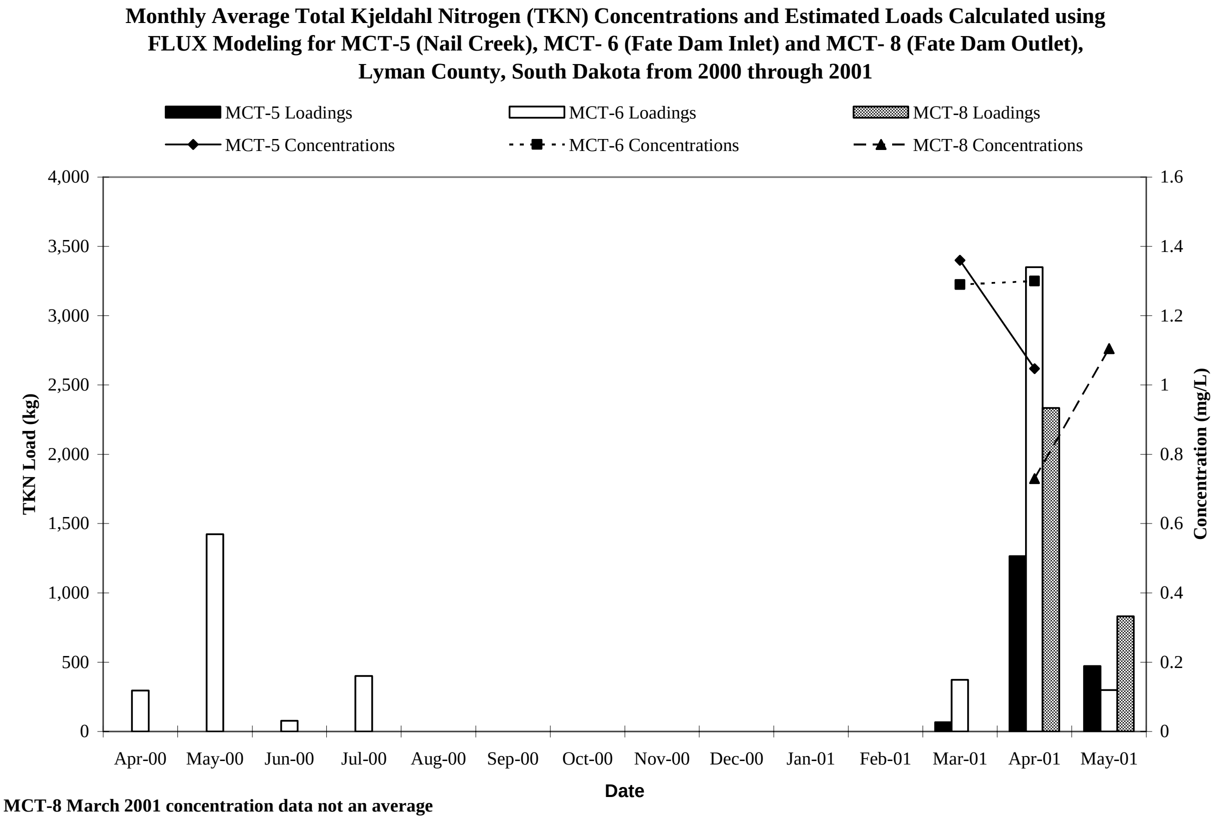


Figure 21. Monthly average Total Kjeldahl Nitrogen concentrations and estimated loads to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

TKN loading by site was highest at site MCT-6 at 4,419 kg or 71.0 percent of the total load to Fate Dam (Table 18). Approximately 53.9 percent of the total TKN load occurred in April 2001 at MCT-6 (Figure 21). TKN loading between sampling sites were not statistically different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-6 sub-watershed at 0.6 kg/acre.

Fate Dam dramatically reduced/modified Total Kjeldahl Nitrogen loading to Medicine Creek (reduction coefficient) by approximately 1.97 times or 3,056 kg (Table 18).

Organic Nitrogen

Organic nitrogen is calculated using TKN and ammonia (TKN minus ammonia). Organic nitrogen is broken down to more usable ammonia and other forms of inorganic nitrogen by bacteria.

The median organic nitrogen concentration in Nail Creek was 0.97 mg/L (average 1.01 mg/L) with a maximum of 1.70 mg/L and a minimum concentration of 0.52 mg/L. Since organic nitrogen is calculated from TKN, Figure 21 and Figure 22 are similar. Organic nitrogen concentrations between sampling sites were not statistically different (Table 4). Seasonal averages for organic nitrogen concentrations were highest in the spring at MCT-6 (Table 8).

Table 19. Organic nitrogen loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	1,652	0.2
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	4,142	0.5
Total Gauged Loading to Fate Dam		**15,869**	100.0	5,794	0.4
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	3,105	0.2
Fate Dam Reduction Coefficient*	**1.87**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

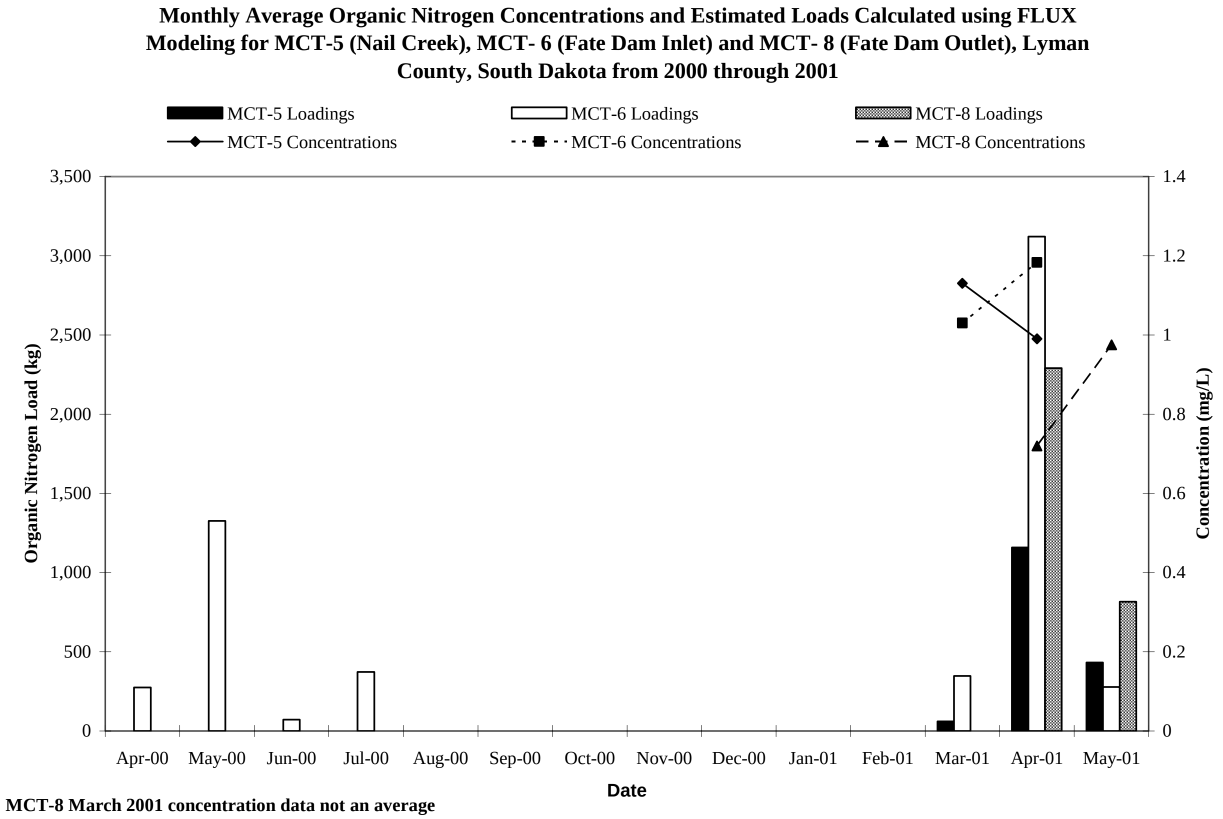


Figure 22. Monthly average organic nitrogen concentrations and estimated loads to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Organic nitrogen loading by site was highest at site MCT-6 at 4,142 kg (Table 19) with the majority of the total load to Fate Dam occurring in April 2001 at MCT-6 (Figure 22). Organic nitrogen loading between sampling sites were statistically similar (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-6 sub-watershed at 0.5 kg/acre.

Fate Dam reduced/modified Nail Creek organic nitrogen loading to Medicine Creek (reduction coefficient) by approximately 1.87 times or 2,689 kg (Table 19).

Inorganic Nitrogen

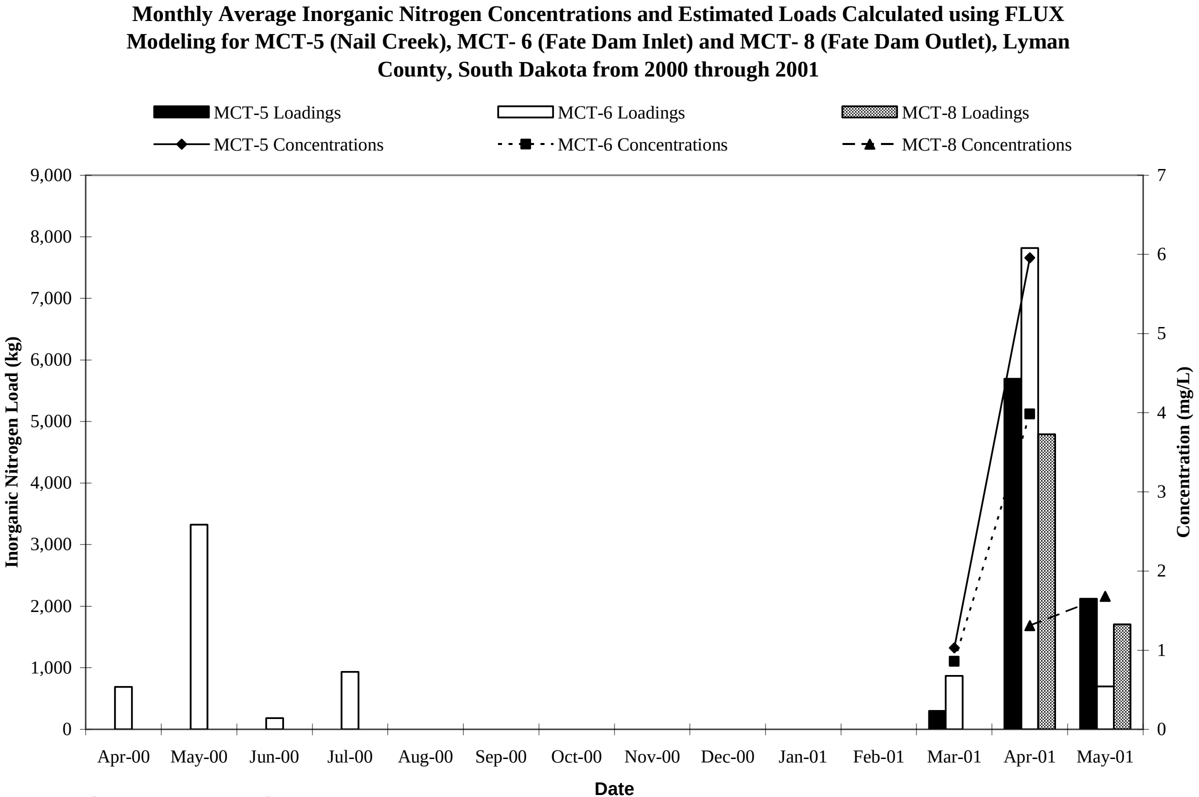
Inorganic nitrogen is calculated adding ammonia plus nitrate-nitrite. Inorganic nitrogen is readily broken down to more usable ammonia by biological dissimilation.

Inorganic nitrogen median concentration in Nail Creek was 2.66 mg/L (average 3.14 mg/L) with a maximum of 7.71 mg/L and a minimum concentration of 0.61 mg/L. Inorganic nitrogen concentrations between sampling sites were not significantly different (Table 4). Seasonal averages for inorganic nitrogen concentrations were highest in the spring of 2001 at MCT-5 (Table 8).

Table 20. Inorganic nitrogen loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	**Gauged Watershed Acreage (Acres)**	**Percent Hydrologic Load (%)**	**Kilograms by site (kg)**	**Export Coefficient (kg/acre)**
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	8,117	1.0
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	6,395	0.8
Total Gauged Loading to Fate Dam		**15,869**	100.0	14,512	0.9
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	6,503	0.4
Fate Dam Reduction Coefficient*	**2.23**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**



MCT-8 March 2001 concentration data not an average

Figure 23. Monthly average inorganic nitrogen concentrations and estimated loads to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Inorganic nitrogen loading by site was highest at site MCT-5 at 8,117 kg (Table 20). Approximately 53.8 percent of the total load to Fate Dam occurred in April 2001 at MCT-6 (Figure 23). Organic nitrogen loading between sampling sites were not statistically different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-5 sub-watershed at 1.0 kg/acre.

Fate Dam slightly reduced/modified Nail Creek inorganic nitrogen loading to Medicine Creek (reduction coefficient) by approximately 2.23 times or 8,009 kg (Table 20). This may indicate that biological processes minimally utilized/converted inorganic nitrogen into biomass in Fate Dam suggesting a phosphorus-limited system.

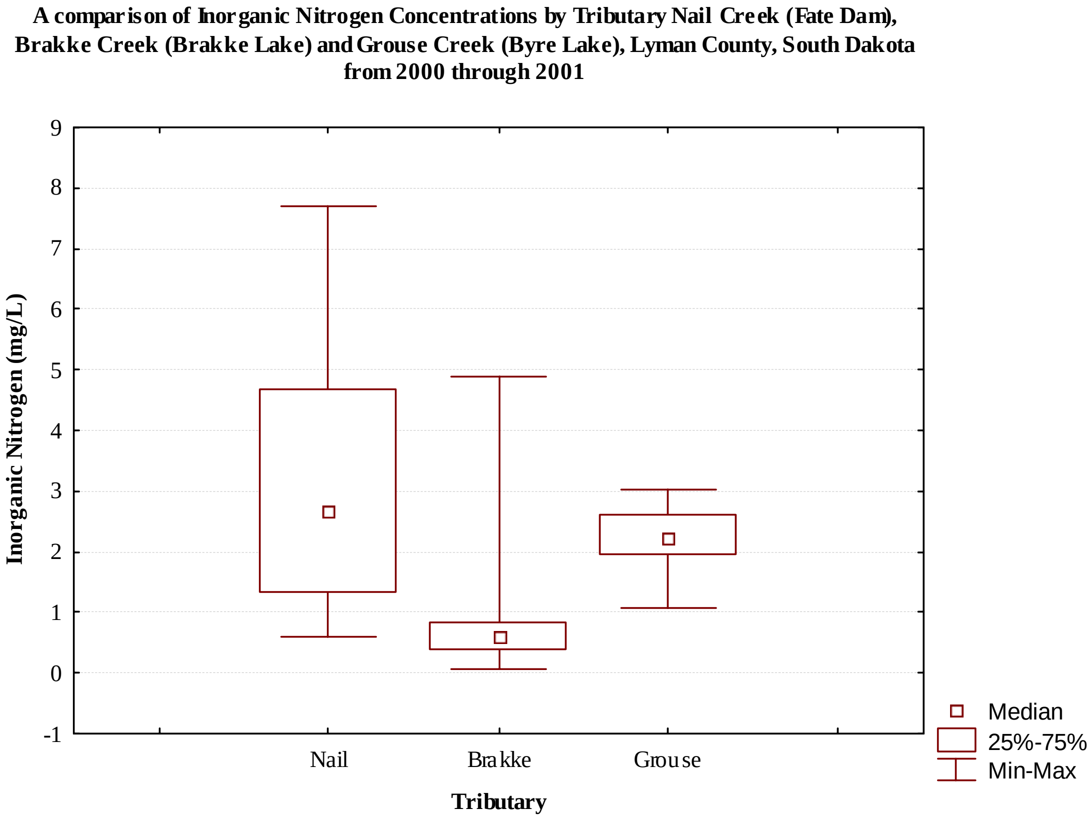


Figure 24. A comparison of inorganic nitrogen concentrations by TMDL (lake) tributary in the Medicine Creek Watershed, Lyman County, South Dakota from 2000 through 2001.

A comparison of tributaries for TMDL (lakes) within the Medicine Creek watershed (Nail Creek (Fate Dam), Brakke Creek (Brakke Dam) and Grouse Creek (Byre Lake)) indicate inorganic nitrogen concentrations in Brakke Creek tributary were significantly lower (H=11.696, $_{(\alpha = 0.05, N=33)}$, p=0.0029) than Nail and Grouse Creeks (Figure 24).

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used mostly in determining the limiting nutrient (nitrogen or phosphorus) and will be discussed later in this section and in the lake section of this report. The maximum total nitrogen concentration found in Nail Creek was 8.67 mg/L at MCT-5 on April 5, 2001 (Appendix B). The median concentration for the entire project was 3.55 mg/L (average 4.15 mg/L) with a standard deviation of 2.33 mg/L. Total nitrogen concentrations between sampling sites were not significantly different (Table 4). The organic nitrogen fraction (percent of organic nitrogen in total nitrogen (concentrations)) ranged from 11.1 percent to 54.5 percent and averaged 24.3 percent, while the inorganic nitrogen fraction ranged from 45.5 percent to 88.9 percent and averaged 75.7 percent. Seasonally, average total nitrogen concentrations were higher in the spring of 2001 at MCT-5 (Table 8).

Total nitrogen loading by site was highest at site MCT-6 at 10,538 kg (Table 21). Approximately 53.8 percent of the total nitrogen load to Fate Dam (MCT-6) occurred in April 2001 while total nitrogen loads decreased over time leaving Fate Dam (Figure 25). Total nitrogen loading between sampling site were not statistically different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-6 sub-watershed at 1.3 kg/acre.

Fate Dam reduced/modified Nail Creek total nitrogen loading to Medicine Creek (reduction coefficient) by approximately 2.11 times or 10,705 kg (Table 21).

Table 21. Total nitrogen loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	9,769	1.2
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	10,538	1.3
Total Gauged Loading to Fate Dam		**15,869**	100.0	20,307	1.3
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	9,602	0.6
Fate Dam Reduction Coefficient*	**2.11**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

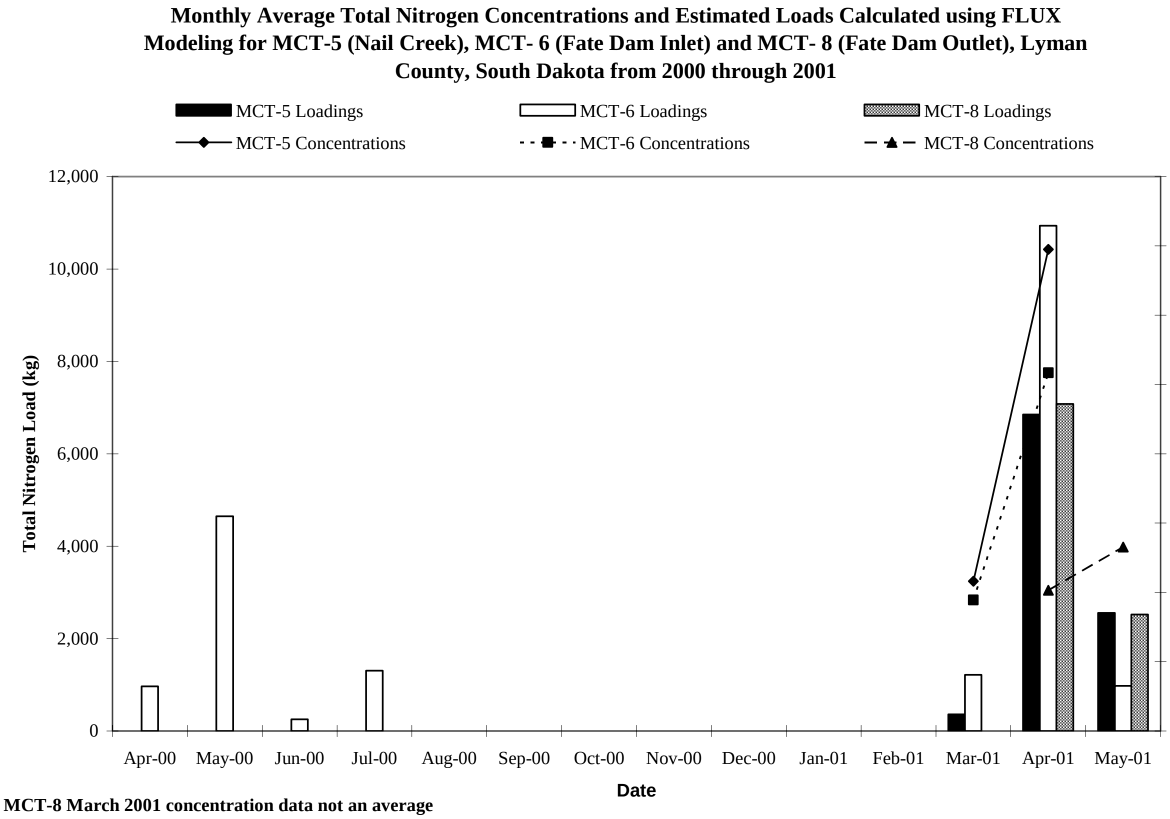


Figure 25. Monthly average total nitrogen concentrations and estimated loads to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

A comparison of tributaries for TMDL (lakes) within the Medicine Creek watershed (Nail Creek (Fate Dam), Brakke Creek (Brakke Dam) and Grouse Creek (Byre Lake)) indicate total nitrogen concentrations in Nail Creek were significantly higher (H=12.806, $_{(\alpha = 0.05, N=33)}$, p=0.0017) than Brakke and Grouse Creeks (Figure 26).

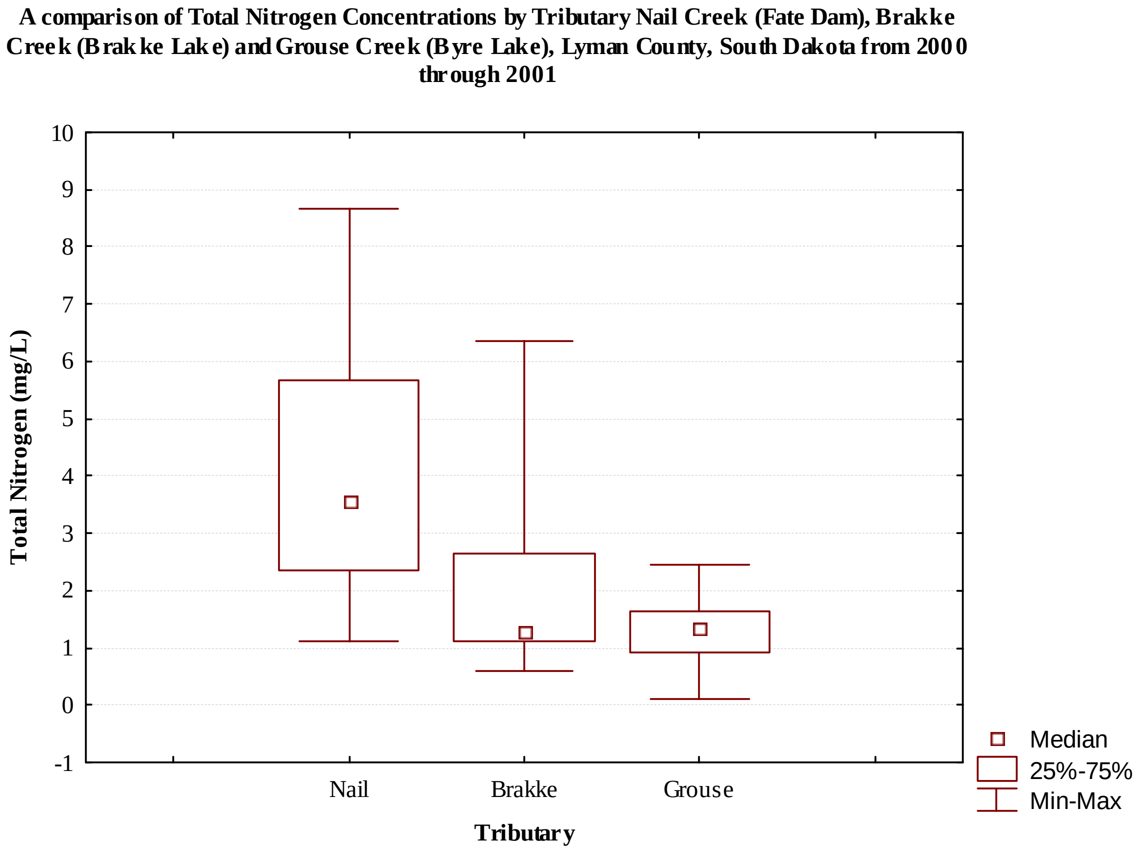


Figure 26. A comparison of total nitrogen concentrations by TMDL (lake) tributary in the Medicine Creek Watershed, Lyman County, South Dakota from 2000 through 2001.

Decreasing nitrogen inputs from the Nail Creek watershed may improve (lower) in-lake TSI values. Reducing nitrogen (especially organic nitrogen) could improve non-algal turbidity, which would decrease Secchi TSI values. Increasing transparency could increase the growth of submerged macrophytes, which would increase the uptake of nitrogen and phosphorus, reducing available nutrients that could cause algal blooms in Fate Dam. A dramatic reduction in both nitrogen and phosphorus is needed to reduce algal growth in Fate Dam. Reduced densities of algae should decrease chlorophyll-*a* concentrations. Reducing available in-lake nitrogen, phosphorus and algal densities should decrease all TSI values. These reductions over time should reverse the long-term TSI trend. Increasing the densities of submerged macrophytes in Fate Dam will also create littoral zone cover for macroinvertebrates, forage fish and ambush points for predator species.

Sub-watersheds that should be targeted for total nitrogen mitigation based on delivered loads and not watershed assessment export coefficients due to the mitigating factors of Fate Dam are presented by priority ranking in Table 22.

Table 22. Nail Creek watershed mitigation priority sub-watersheds for total nitrogen based on 2000 – 2001 watershed assessment modeling.

Priority Ranking	Sub-watershed	Total Nitrogen Export Coefficient (kg/acre)	Total Nitrogen Kilograms Delivered
1	MCT-6	1.3	10,538
2	MCT-5	1.2	9,769

Total Phosphorus

Phosphorus differs from nitrogen in that it is not as water-soluble and will sorb on to sediments and other substrates. Once phosphorus sorbs on to any substrate, it is not readily available for uptake and utilization. Phosphorus sources in the Fate Dam watershed can be natural from geology and soil, from decaying organic matter, waste from septic tanks or agricultural runoff. Nutrients such as phosphorus and nitrogen tend to accumulate during low flows because they are associated with fine particles whose transport is dependent upon discharge (Allan, 1995). These nutrients are also retained and released on stream banks and floodplains within the watershed. Phosphorus will remain in the stream sediments unless released by increased stage (water level), discharge or current. Re-suspending phosphorus and other nutrients associated with sediment into the water column (stream) should show increased concentrations during rain events (increased stage and flow). Reduced flows and discharge may deposit phosphorus and other nutrients associated with sediment on the stream banks and floodplains of Nail Creek. Rain events increase flows and re-suspend sediment and phosphorus stored in the floodplain and stream banks. These concentrations combine with event-based concentrations to increase overall nutrient loading, producing peak concentrations of total phosphorus and total nitrogen in Nail Creek.

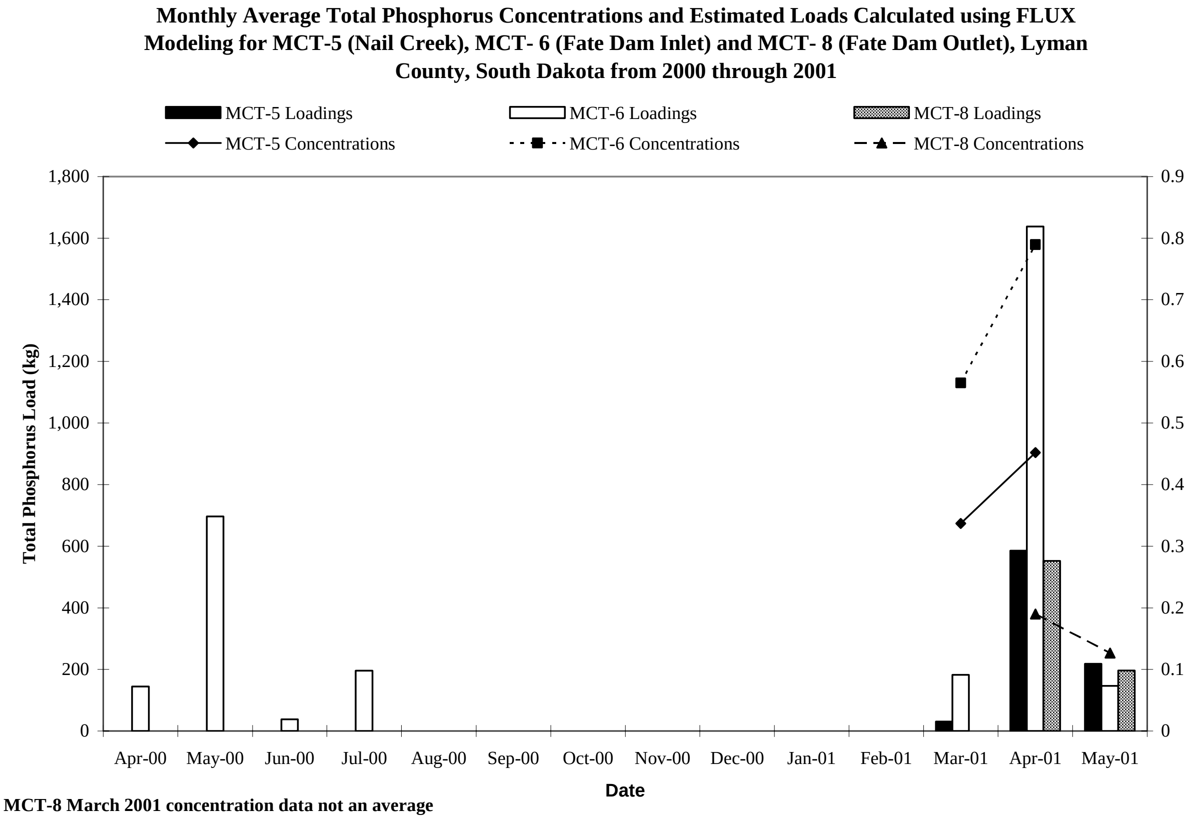


Figure 27. Monthly average total phosphorus concentrations and estimated loads to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

The median total phosphorus concentration for Nail Creek was 0.341 mg/L (average 0.438 mg/L) during the project. The maximum concentration of total phosphorus was 1.410 mg/L on April 12, 2001 at MCT-6 and a minimum of 0.112 mg/L at MCT-8 (Fate Dam outlet) on May 15, 2000 (Appendix B). Total phosphorus concentrations between sampling sites were statistically different (Table 4 and Figure 28). Since algae/periphyton only need 0.02 mg/L of phosphorus to produce algal blooms in lakes (Wetzel, 2001), Nail Creek average delivery concentration was 21.9 times the phosphorus needed to produce algal blooms in Fate Dam. Seasonally, average total phosphorus concentrations were elevated in the spring of 2001 at 0.790 mg/L at site MCT-6 (Table 8).

Table 23. Total phosphorus loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	835	0.1
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	2,205	0.3
Total Gauged Loading to Fate Dam		**15,869**	100.0	3,040	0.2
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	749	0.04
Fate Dam Reduction Coefficient*	**4.06**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

The highest yearly total phosphorus loading occurred at MCT-6 with 2,205 kg/year (Figure 27). Approximately 53.9 percent of the total phosphorus load to Fate Dam occurred in April 2001. Total phosphorus loading between sampling sites was not significantly different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-6 sub-watershed (0.3 kg/acre). The estimated loading to Fate Dam via the ungauged portion of the watershed based on MCT-6 export coefficient (0.3 kg/acre) was 400 kg/year. Monthly total phosphorus loading was similar to most other parameter observations in Nail Creek.

Fate Dam dramatically reduced/modified Nail Creek total phosphorus loading to Medicine Creek (reduction coefficient) by approximately 4.06 times or 2,292 kg (Table 23). This reduction suggests that phosphorus (total and dissolved) were utilized in biological processes and biomass production in Fate Dam and the excess discharged back into Nail Creek.

Reductions in total phosphorus loads are needed in both the watershed and in Fate Dam to maintain phosphorus-limitation throughout the year and improve TSI reductions in Fate Dam. Alterations should be implemented in existing management practices to improve current conditions in both the watershed and Fate Dam. Every effort should be made to reduce total phosphorus loads to meet TMDL goals in the Fate Dam watershed.

Decreasing total phosphorus inputs from Nail Creek should improve (lower) TSI values. Reducing total phosphorus will decrease algal turbidity, which should increase Secchi transparency and decrease Secchi TSI values. Reducing phosphorus input should lower in-lake phosphorus concentrations and phosphorus TSI values. Reduced phosphorus concentrations may reduce available phosphorus for algae growth and uptake, which could lower algal densities that in turn decreases chlorophyll-*a* concentrations, reducing chlorophyll-*a* TSI values. Reductions in phosphorus over time should reverse increased TSI values observed in Fate Dam.

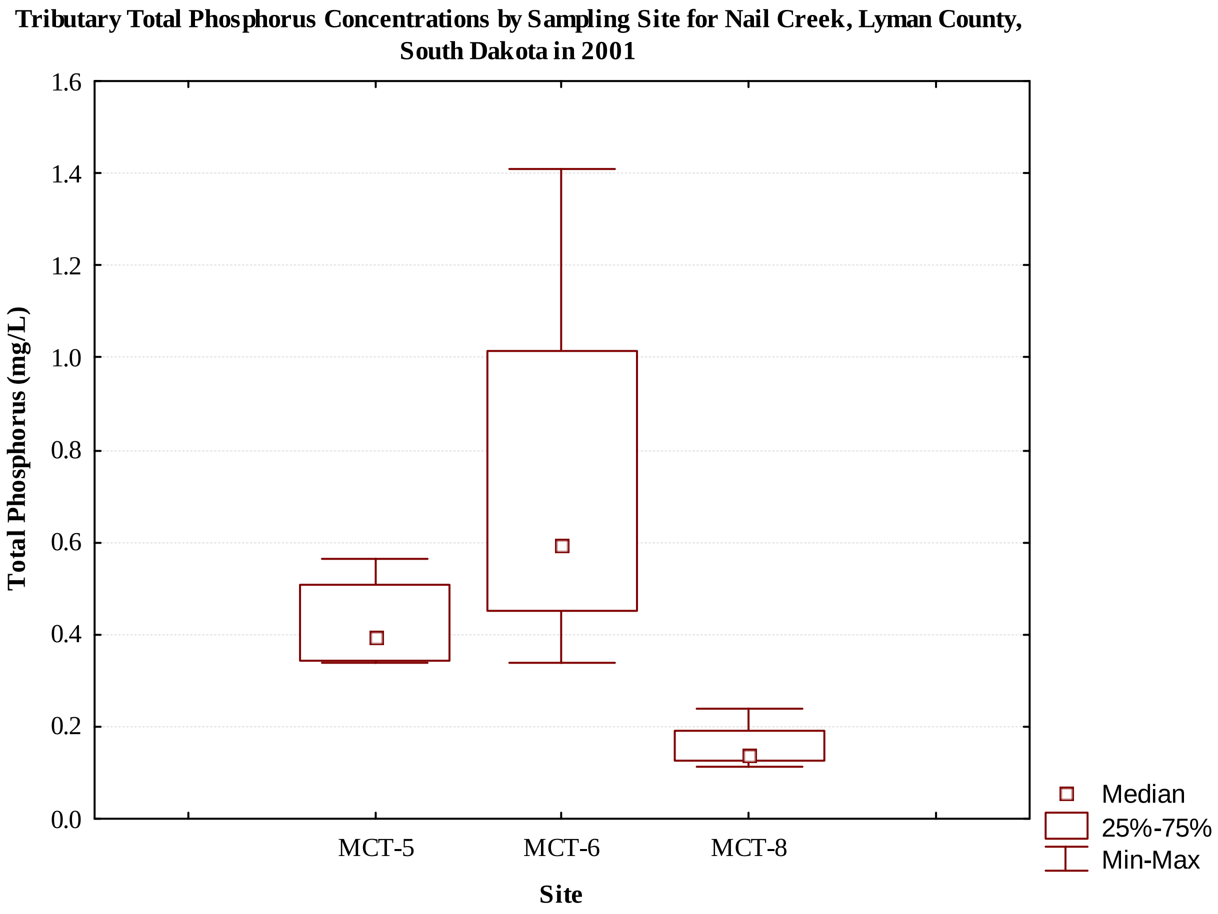


Figure 28. Median, quartile and range for total phosphorus concentrations by tributary monitoring site for Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Sub-watersheds that should be targeted for phosphorus mitigation based on delivered loads and not watershed assessment export coefficients due to the mitigating factors of Fate Dam and are presented in Table 24.

Table 24. Nail Creek watershed mitigation priority sub-watersheds for total phosphorus based on 2000 through 2001 watershed assessment modeling.

Priority Ranking	Sub-watershed	Total Phosphorus Export Coefficient (kg/acre)	Total Phosphorus Kilograms Delivered
1	MCT-6	0.3	2,206
2	MCT-5	0.1	835

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae. Dissolved phosphorus will sorb on suspended materials (both organic and inorganic) if they are present in the water column and if they are not already saturated with phosphorus.

The median total dissolved phosphorus concentration for Nail Creek was 0.296 mg/L (average 0.251 mg/L). The maximum concentration of total phosphorus was 0.479 mg/L on March 19, 2001 at MCT-6 and a minimum of 0.035 mg/L at MCT-8 (Fate Dam outlet) on April 10, 2001 (Appendix B). Total dissolved phosphorus concentrations between sampling sites were statistically Different (Table 4 and Figure 30). During this study, the percentage of total dissolved phosphorus to total phosphorus ranged from 25.5 percent in the summer to 90.6 percent in spring and averaged 57.2 percent over the project. Seasonally, total dissolved phosphorus concentrations were elevated in the winter of 2001 with 0.479 mg/L (Table 8).

Table 25. Total dissolved phosphorus loading per year by site for Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Sub-watershed MCT-5	**MCT-5**	**7,942**	45.3	562	0.07
Sub-watershed MCT-6	**MCT-6**	**7,897**	54.7	594	0.08
Total Gauged Loading to Fate Dam		**15,869**	100.0	1,156	0.07
Total Gauged Load to Medicine Creek	**MCT-8**	**17,202**	100.0	411	0.02
Fate Dam Reduction Coefficient*	**2.81**				

*** = Reduction coefficient is the estimated reduction efficiency of Fate Dam on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

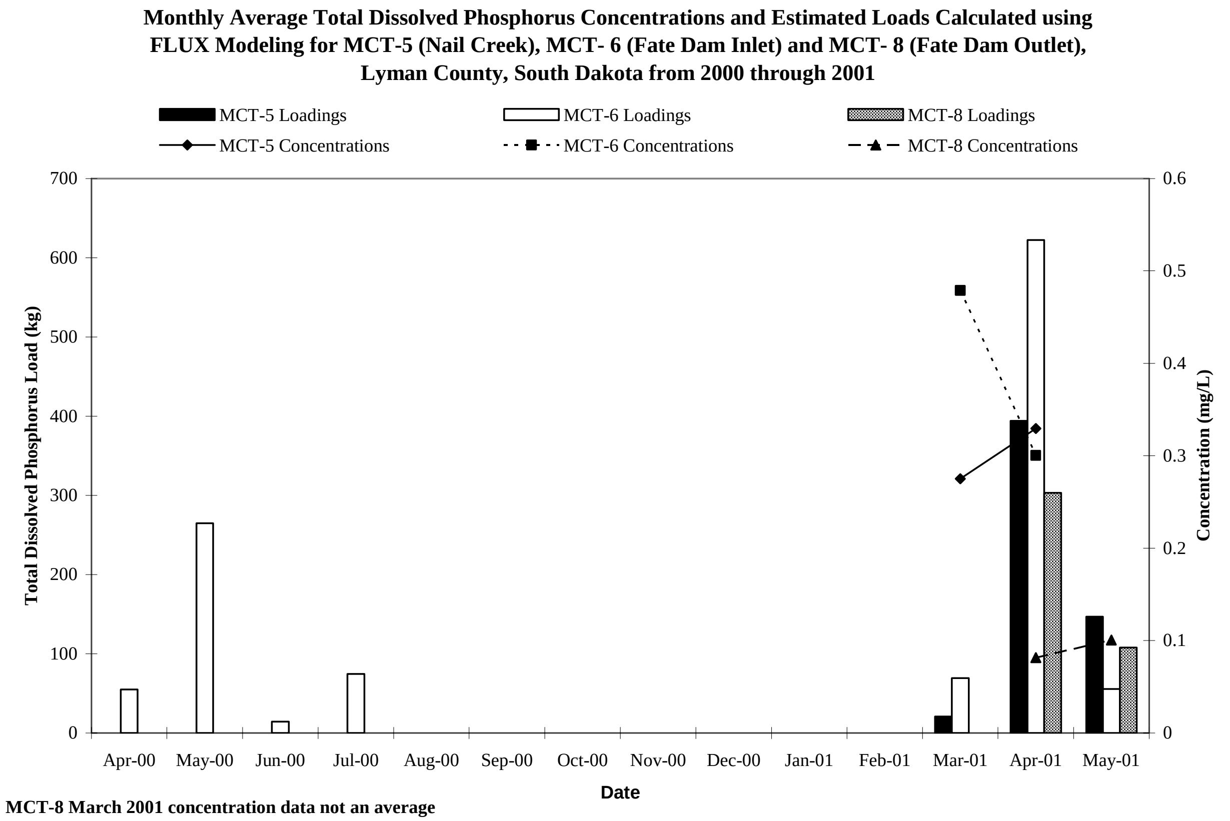


Figure 29. Monthly average total dissolved phosphorus concentrations and estimated loads to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Total dissolved phosphorus loading by site was highest at site MCT-6 with 594 kg/year (Table 25). Total phosphorus loading between sampling sites was not statistically different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest (0.8 kg/acre) at MCT-6 (Table 25). Again, monthly total dissolved phosphorus loading was similar to most other parameter observations in Nail Creek, with the greatest monthly total dissolved phosphorus loading occurring in April 2001 (Figure 29).

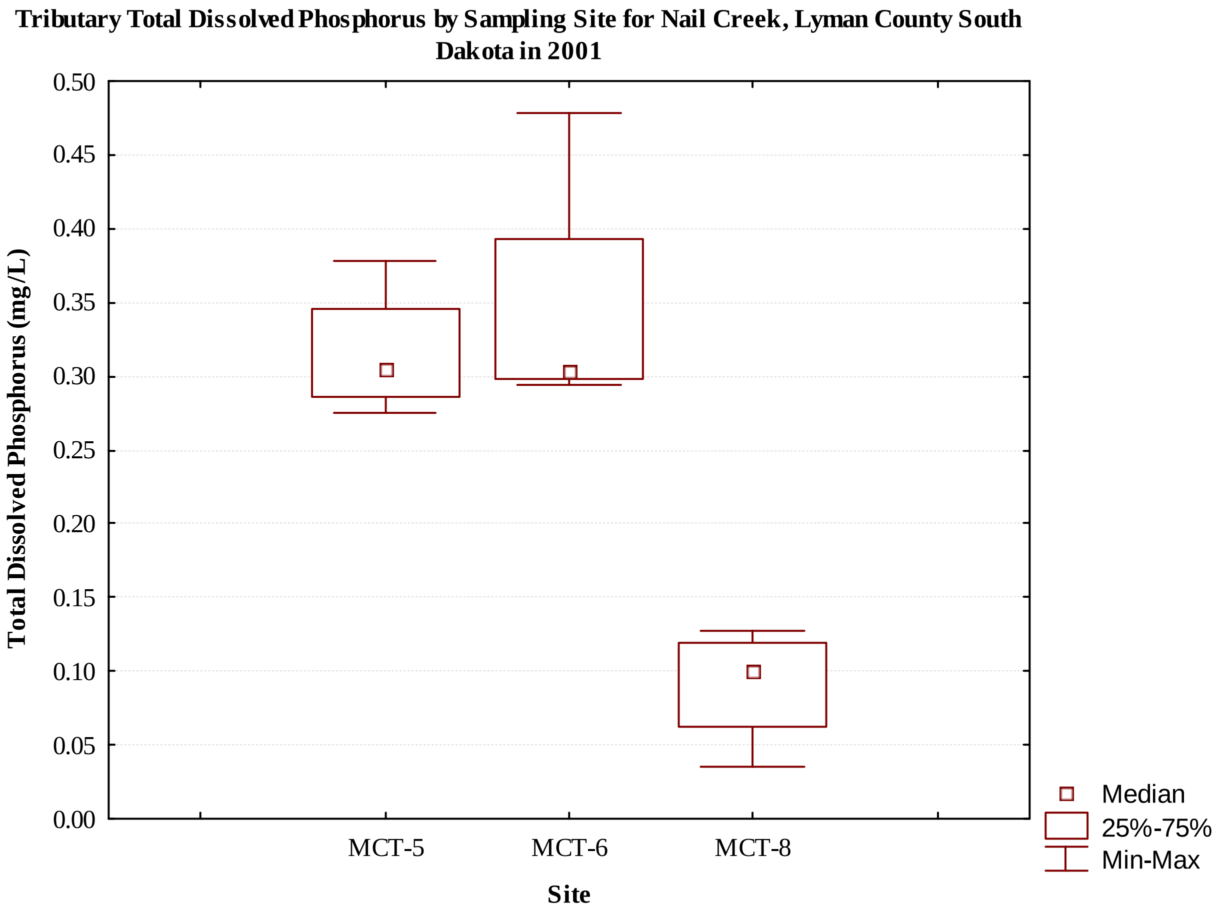


Figure 30. Median, quartile and range for total dissolved phosphorus concentrations by tributary monitoring site for Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Fate Dam dramatically reduced/modified Nail Creek total dissolved phosphorus loading to Medicine Creek (reduction coefficient) by approximately 2.81 times or 745 kg (Table 25).

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals and are used as indicators of waste and presence of pathogens in a waterbody. Many outside factors can influence the concentration of fecal coliform. Sunlight and time can lessen fecal coliform concentrations although nutrient concentrations may remain high. As a rule, just because fecal bacteria concentrations are low or non-detectable, does not mean animal waste is not present in a waterbody. South Dakota water quality standards for fecal coliform are in effect from May 1 through September 30.

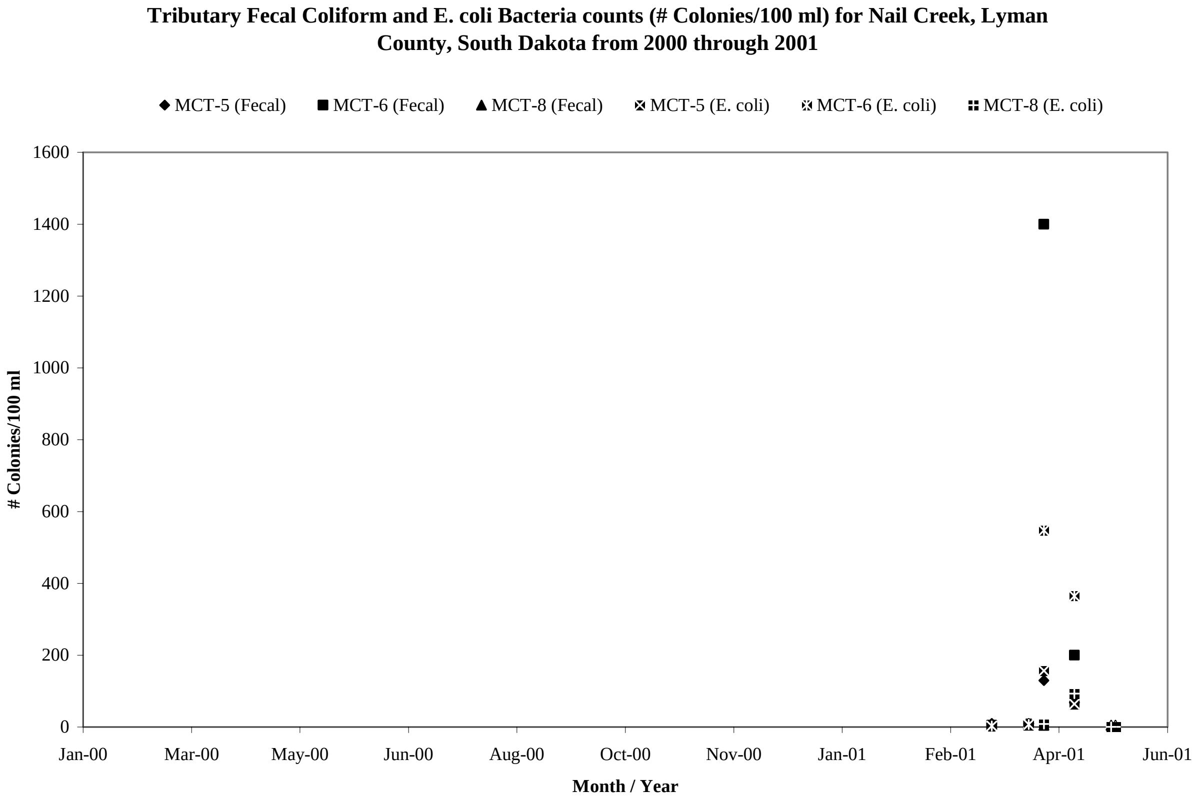


Figure 31. Monthly fecal coliform concentrations (# colonies/100 ml) to Fate Dam and Medicine Creek from Nail Creek, Lyman County, South Dakota in 2000 and 2001.

Figure 31 and Table 26 identify one elevated fecal coliform sample collected in mid April of 2001 in Nail Creek. One fecal coliform sample collected at MCT-6 detected 1,400 colonies/100 ml. This sample was collected during peak hydrologic flows. Fecal coliform bacteria counts were statistically similar between Nail Creek tributary sampling sites (Table 4). This suggests that elevated fecal coliform concentrations/loadings may be related to watershed runoff events. However, in-lake fecal coliform samples during this period were at or below laboratory detection limits (Figure 62 and Table 32). This indicates that fecal decay rate, sunlight and in-lake dilution affect tributary fecal coliform loading to Fate Dam.

Table 26. Elevated fecal coliform bacteria count in Nail Creek above Fate Dam in 2001.

Site	Date	Hydrologic Event	Fecal Coliform (#Colonies/100 ml)
MCT-6	4/12/01	Increasing flow	1,400

Tributary Total Nitrogen /Total Phosphorus Ratios (Limiting Nutrient)

Nutrients are inorganic materials necessary for life, the supply of which is potentially limiting to biological activity within lotic (stream) and lentic (lake) ecosystems. Lakes that have average concentrations of total phosphorus of 0.01 mg/L or less are considered oligotrophic, while lakes with more than 0.030 mg/L, usually eutrophic (Wetzel, 2001). The conventions of oligotrophic and eutrophic states do not have the same utility for running water that they do for lakes, nor is there evidence for a natural process of eutrophication corresponding to lake succession (Hynes, 1969). Studies from diverse regions of North America (Omernik, 1977, Stockner and Shortreed, 1978 and Pringle and Bowers, 1984) imply that phosphorus limitation is widespread in streams. It is apparent that variations in nutrient concentrations and nitrogen-to-phosphorus ratios have predictable consequences for algae/periphyton community structure and metabolism in running waters (Allan, 1995).

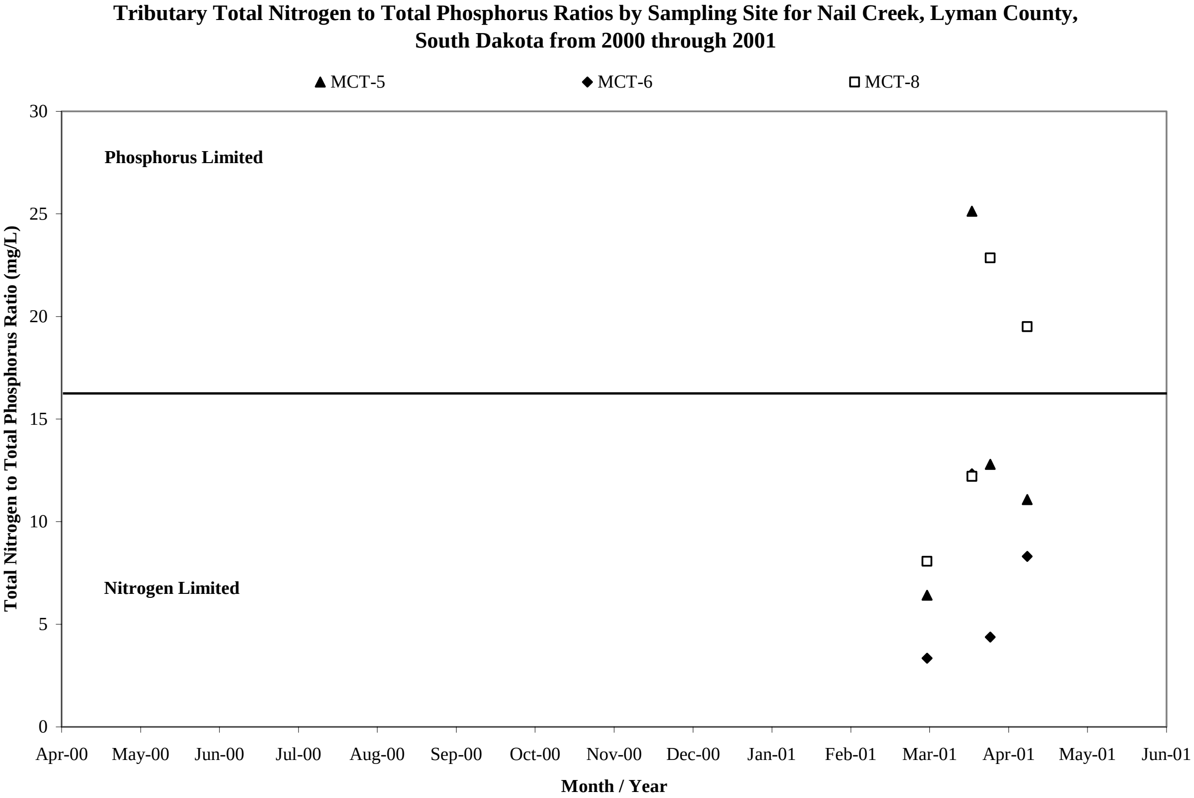


Figure 32. Total nitrogen-to-total phosphorus ratios based on tributary concentrations in Nail Creek, Lyman County, South Dakota from 2000 and 2001.

Most estimates of the total nitrogen-to-total phosphorus ratio in freshwaters are above 16:1, based on the Redfield ratio (Redfield, et. al., 1963) and numerous bioassay experiments (Allan, 1995). This suggests that nitrogen is in surplus and phosphorus is in limited supply. The Environmental Protection Agency (EPA) has suggested total nitrogen-to-total phosphorus ratios for lakes of 10:1 as being the break for phosphorus limitation (US EPA, 1990). For tributary samples, total nitrogen-to-total phosphorus ratio of 16:1 was used to determine phosphorus limitation.

Total nitrogen and total phosphorus ratios were calculated for all tributary samples (12 samples), however, only data from MCT-6 was evaluated because those concentrations (ratios) influence Fate Dam directly (MCT-6 ratio 7.1:1). Individual ratios for MCT-5, MCT-6 and MCT-8 (Fate Dam outlet) are shown in Figure 32. Total nitrogen-to-total phosphorus ratios were not statistically different between tributary monitoring sites (Table 4). All total nitrogen-to-total phosphorus ratios at MCT-6 were considered to nitrogen limited based on a 16:1 ratio.

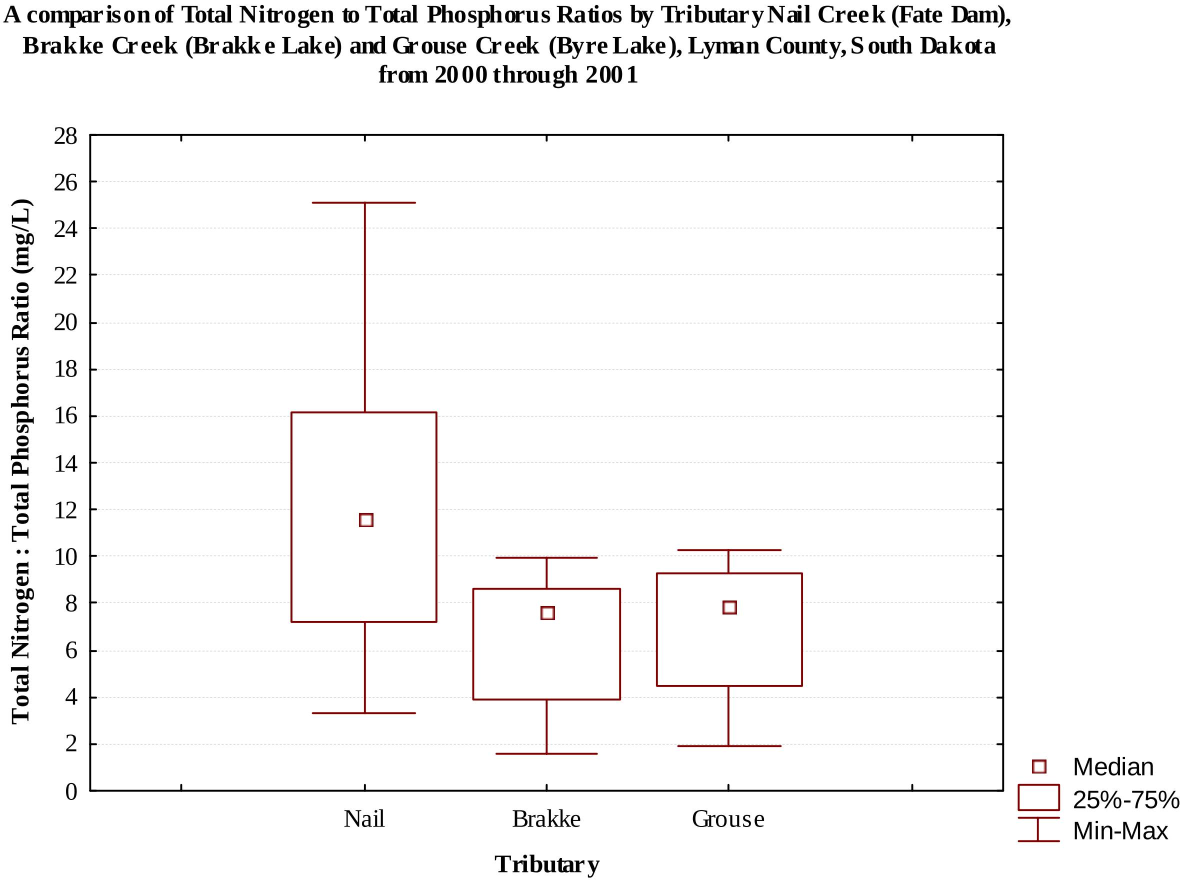


Figure 33. A comparison of total nitrogen to total phosphorus ratios (mg/L) by TMDL (lake) tributary in the Medicine Creek Watershed, Lyman County, South Dakota from 2000 through 2001.

A comparison of tributaries for TMDL (lakes) within the Medicine Creek watershed (Nail Creek (Fate Dam), Brakke Creek (Brakke Dam) and Grouse Creek (Byre Lake)) indicate total nitrogen to total phosphorus ratios (mg/L) in Nail Creek were significantly higher (H=6.101, (α = 0.05, N=33), p=0.0473) than Brakke and Grouse Creeks (Figure 33).

In-lake Methods

Fate Dam is a 60.7 ha (150 acre) impoundment in Lyman County, South Dakota. Two in-lake sample locations were chosen for collecting nutrient, biological and sediment data from Fate Dam during the study. The locations of the in-lake sampling sites are shown in Figure 34. A sample set consisted of one surface and one bottom sample collected from each site (FD-1 and FD-2) each month. These samples were used to analyze seasonal water quality trends over time.

Chlorophyll *a*, total phosphorus and Secchi disk samples were used to evaluate the trophic status of Fate Dam (Carlson, 1977).

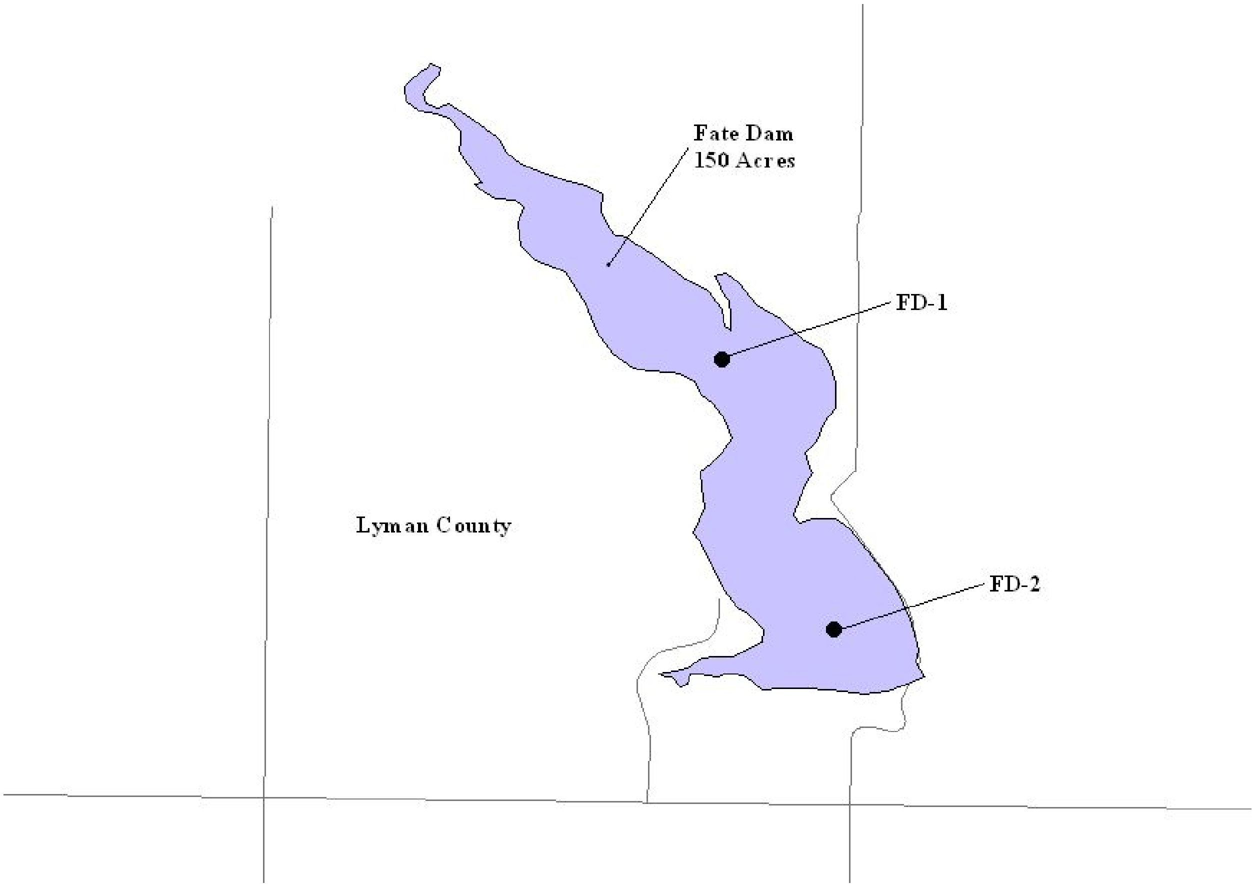


Figure 34. Fate Dam in-lake sampling sites for 2000 and 2001.

In-lake Water Quality Sampling

Samples collected at each in-lake site were taken according to South Dakota's *Standard Operating Procedures for Field Samplers* (SD DENR, 2000). In-lake physical, chemical and biological water quality sample parameters are listed in Table 27. All water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected for approximately ten percent of the samples according to South Dakota's EPA-approved *Non-Point Source Quality Assurance/Quality Control Plan* (SD DENR, 1998c). These documents can be referenced by contacting the South Dakota Department of Environment and Natural Resources at (605) 773-4254 or online at www.state.sd.us/denr.

Table 27. In-lake physical, chemical and biological parameters analyzed in Fate Dam, Lyman County, South Dakota in 2000 and 2001.

Physical	**Chemical**	**Biological**
Air Temperature	Total Alkalinity	Fecal Coliform
Water Temperature	Field pH	E. coli
Secchi Transparency	Dissolved Oxygen	Chlorophyll-*a*
Total Depth	Total Solids	Aquatic Macrophytes
Visual Observations	Total Suspended Solids	Algae
	Total Dissolved Suspended Solids (calculated)	
	Volatile Total Suspended Solids	
	Ammonia	
	Un-ionized Ammonia (calculated)	
	Nitrate-Nitrite	
	Total Kjeldahl Nitrogen	
	Total Phosphorus	
	Total Dissolved Phosphorus	
	Conductivity	

Algae samples were analyzed by a private contractor (Aquatic Analysts) and SD DENR staff with enumeration results entered into a database to calculate biovolume (Section 3.3, Fate Dam Phytoplankton).

In-lake Modeling Methods

The reduction response model used to predict in-lake response to reductions in tributary loading was BATHTUB (Walker, 1999). BATHTUB is predictive in that it will assess impacts of changes in water and/or nutrient loadings, and estimate nutrient loadings consistent with given water quality management objectives. In-lake and tributary data collected from the assessment project was used to calculate existing conditions and to predict parameter-specific and mean TSI values based on general reductions in loadings from 2000 through 2001.

In-lake Statistical Analysis

In-lake data was analyzed using StatSoft® statistical software (STATISTICA version 6.1). Mann-Whitney U (non-parametric analysis) was run on in-lake concentration and Trophic State Index (TSI) data to determine significant differences between in-lake monitoring sites and surface and bottom samples for each sample parameter.

Statistical results for surface concentrations for all parameters are provided in Table 28. There was not enough bottom samples collected during the project to test for significance between surface and bottom.

Kruskal-Wallis ANOVA (multiple comparison non-parametric analysis) was run to compare all in-lake parameters for all lakes within the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam). Only parameter comparisons that were significantly different are addressed in respective sections of this report.

Table 28. Mann-Whitney U values, observations and p values for in-lake concentrations and TSI data between sampling sites for Fate Dam, Lyman County, South Dakota from 2000 through 2001[1].

	Surface Concentration			
Parameter	**(N) FD-1**	**(N) FD-2**	**Mann-Whitney (U)**	**p-value**
Water Temperature (ºC)	11	11	56.0	0.768
Dissolved Oxygen (mg/L)	10	10	50.0	1.000
pH (su)	11	11	52.5	0.599
Conductivity (µS/cm^3)	10	10	46.5	0.791
Secchi Depth (m)	9	9	39.0	0.894
Fecal Coliform Bacteria (# colonies/100 ml)	11	11	55.0	0.317
E. coli Bacteria (# colonies/100 ml)[2]	2	2	-	-
Alkalinity (mg/L)	11	11	49.5	0.469
Total Solids (mg/L)	11	11	50.0	0.491
Total Dissolved Solids (mg/L)	11	11	46.5	0.378
Total Suspended Solids (mg/L)	11	11	54.0	0.667
Volatile Total Suspended Solids (mg/L)	11	11	53.5	0.639
Ammonia (mg/L)	11	11	49.0	0.361
Un-ionized Ammonia (mg/L)	11	11	60.0	0.974
Nitrate-Nitrite (mg/L)	11	11	57.0	0.796
Total Kjeldahl Nitrogen (mg/L)	11	11	54.5	0.693
Organic Nitrogen (mg/L)	11	11	47.0	0.375
Inorganic Nitrogen (mg/L)	11	11	49.5	0.440
Total Nitrogen (mg/L)	11	11	56.5	0.793
Total Phosphorus (mg/L)	11	11	48.5	0.430
Total Dissolved Phosphorus (mg/L)	11	11	55.0	0.717
Chlorophyll-*a* (µg/L)	10	4	17.0	0.733
Phosphorus TSI	11	11	48.5	0.430
Chlorophyll-*a* TSI	10	4	17.0	0.773
Secchi TSI	9	9	40.0	1.000
Total Nitrogen-to-Total Phosphorus Ratio	11	11	49.0	0.478

Shaded = significantly different between sampling sites ($p<0.05$).

[1] = not enough bottom samples collected to analyzed

[2] = not enough samples to test

3.1.1. In-lake Surface Water Chemistry

In-lake Water Quality Standards

South Dakota’s numeric water quality standards are based on beneficial use categories. Beneficial use classifications are listed in Table 29. All lakes in the state are assigned the beneficial uses (category 9) fish and wildlife propagation, recreation and stock watering (ARSD § 74:51:02:01).

Table 29. South Dakota's beneficial use classifications for all waters of the state.

Category	Beneficial Use
1	Domestic water supply waters;
2	Coldwater permanent fish life propagation waters;
3	Coldwater marginal fish life propagation waters;
4	Warmwater permanent fish life propagation waters;
5	Warmwater semipermanent fish life propagation waters;
6	Warmwater marginal fish life propagation waters;
7	Immersion recreation waters;
8	Limited contact recreation waters;
9	Fish and wildlife propagation, recreation, and stock watering waters;
10	Irrigation waters; and
11	Commerce and industry waters.

Fate Dam in Lyman County has been assigned the beneficial uses of (4) Warmwater permanent fish life propagation water, (7) Immersion recreation water, (8) Limited contact recreation water and (9) Fish and wildlife propagation, recreation, and stock watering water (Table 29 and Table 30).

In addition to physical and chemical standards, South Dakota has developed narrative criteria for the protection of aquatic life uses. *All waters of the state must be free from substances, whether attributable to human-induced point sources discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities* (ARSD § 74:51:01:12).

Table 30. Assigned beneficial uses for Fate Dam, Lyman County, South Dakota.

Water Body	To	Beneficial Uses*	County
Fate Dam	Fate Dam	4, 7, 8	Lyman
All Lakes	Entire State	9	All

*** = See Table 29 above**

Each beneficial use classification has a set of numeric standards uniquely associated with that specific category. Water quality values that exceed those standards unique to specific beneficial uses impair beneficial use and violate water quality standards. Table 31 lists the most stringent water quality parameters for Fate Dam. Seven of the seventeen parameters (un-disassociated hydrogen sulfide, barium, fluoride, sulfate, total petroleum hydrocarbon and oil and grease) listed for Fate Dam beneficial use classifications were not in the scope of this project and were not sampled.

Table 31. The most stringent water quality standards for Fate Dam based on beneficial use classifications.

Water Body	Beneficial Uses	Parameter	Standard Value
Fate Dam	4, 7, 8, 9	Un-ionized ammonia nitrogen as N [1]	≤ 0.04 mg/L
		Dissolved oxygen	≥ 5.0 mg/L
		pH	≥ 6.5 - ≤ 9.0
		Total Suspended Solids [2]	≤ 158 mg/L
		Temperature (°C)	≤ 26.7°C
		Fecal coliform [3]	≤ 400 colonies/100mL
		Total alkalinity as calcium carbonate [4]	≤ 1313 mg/L
		Total dissolved solids [5]	≤ 4,375 mg/L
		Conductivity at 25° C [6]	≤ 7,000 µS/cm
		Nitrates as N [7]	≤ 88 mg/L
		Undisassociated hydrogen sulfide [8]	≤ 0.002 mg/L
		Total petroleum hydrocarbon [8]	≤ 1 mg/L
		Oil and grease [8]	≤ 10 mg/L

[1] = Un-ionized ammonia is the fraction of ammonia that is toxic to aquatic life. The concentration of un-ionized ammonia is calculated and dependent on temperature and pH. As temperature and pH increase so does the percent of ammonia which is toxic. The 30-day standard is ≤ 0.04 mg/L and the daily maximum is 1.75 times the applicable criterion in the South Dakota Surface Water Quality Standards in mg/L based upon the water temperature and pH where the sample was taken.

[2] = The daily maximum for total suspended solids is ≤ 158 mg/L or ≤ 90 mg/L for a 30-day average (an average of 5 samples (minimum) taken in separate 24-hour periods).

[3] = The fecal coliform standard is in effect from May 1 to September 30. The ≤ 400 counts/100 ml is for a single sample or ≤ 200 counts/100 ml over a 30-day average (an average of 5 samples (minimum) taken in separate 24-hour periods).

[4] = The daily maximum for total alkalinity as calcium carbonate is ≤ 1,313 mg/L or ≤ 750 mg/L for a 30-day average.

[5] = The daily maximum for total dissolved solids is ≤ 4,375 mg/L or ≤ 2,500 mg/L for a 30-day average.

[6] = The daily maximum for conductivity at 25° C is ≤ 7,000 µS/cm or ≤ 4,000 µS/cm for a 30-day average.

[7] = The daily maximum for nitrates is ≤ 88 mg/L or 50 mg/L for a 30-day average.

[8] = Parameters not measured during this project.

Fate Dam Surface Water Quality Exceedances

Fate Dam in-lake samples did not exceed South Dakota’s numeric surface water quality standards during this project (Appendix C).

Seasonal In-lake Water Quality

Typically, water quality parameters will vary with season due to changes in temperature, precipitation and agricultural practices. Twenty-six in-lake water quality samples were collected during the project (22 surface and 4 bottom samples). These data were separated seasonally into winter (January – March), spring (April – June), summer (July – September), and fall (October – December). During the project, six discrete surface samples were collected in the summer, four samples in the fall, four in the winter and eight samples in the spring from 2000 through 2001 (Table 32).

Seasonal In-lake Concentrations

Sediment and nutrient concentrations can change dramatically with changes in season. Hydrologic loads to the lake in the spring may have low nutrient and sediment concentrations; however, more water during spring runoff usually results in higher loadings of nutrients and sediment. In-lake concentrations are also affected by internal loading, especially in lakes that seasonally stratify. Based on this study, Fate Dam does not usually stratify. Some oxygen stratification was observed in July and August 2001 at FD-2 (Appendix D). Average concentrations of in-lake sampling sites and sampling parameters by season and are listed in Table 32.

Dissolved oxygen concentrations were highest in the winter of 2001 at FD-1 due to cooler water temperatures (cooler water can hold more oxygen).

The highest seasonal surface pH value recorded at Fate Dam during the project was 8.70 su recorded in the summer of 2000 at FD-1.

Medicine Creek is listed in the 2004 Integrated Report for conductivity. Fate Dam is within the Medicine Creek watershed and the outlet drains into Medicine Creek thus influencing water quality. Seasonal conductivity values in Fate Dam were highest at FD-1 in the winter of 2001 (Table 32). The conductivity values observed in Fate Dam during the project were well below water quality standards for Medicine Creek.

Average seasonal alkalinity concentrations were highest in the winter of 2001 at FD-2. The lowest average seasonal alkalinity concentrations occurred in the spring of 2001 which correlates with increased algal densities. Carbonates and bicarbonates are utilized by algae during blooms which reduce buffering capacity (alkalinity).

Total solids and total dissolved solids average concentrations were highest in the winter of 2001 at FD-2 while average total suspended solids and volatile total suspended solids concentrations were highest in the spring of 2001 at FD-2 (Table 32). Increased total suspended and volatile total suspended solids can be attributed to increased tributary flow and a peak in-lake algal bloom.

Average nitrate-nitrite, total nitrogen and inorganic nitrogen concentrations were highest in the spring of 2001 at FD-2 while Total Kjeldahl Nitrogen (TKN) and organic nitrogen concentrations were highest in the spring of 2000 at FD-1.

Ammonia concentrations were highest at FD-1 in the winter of 2001, similar to Byre Lake and Brakke Dam which are also in the Medicine Creek watershed. Generally in lakes, ammonia concentrations increase in the winter due to macrophyte decay releasing ammonia and low densities of algae to utilize ammonia for growth. Un-ionized ammonia (NH_4-OH) is the fraction of ammonia that is toxic to aquatic organisms. The highest un-ionized ammonia fractions were in the spring of 2001 at FD-1. The increased fraction of un-ionized ammonia during this period is the result of increased water temperature and pH concentrations at this site.

During this study, in-lake fecal coliform bacteria counts (fecal coliform colonies/100 ml) were generally below 10 colonies per 100 ml (detection limit). The highest average seasonal concentrations of fecal coliform bacteria during this study were in the spring of 2000 at FD-2 (Table 32).

Seasonal total and total dissolved phosphorus average concentrations were highest in the spring of 2001 at FD-2 and were attributed to tributary flow carrying increased nutrients.

Two of the three Trophic State Index (TSI) values (total phosphorus and Secchi TSI) were highest in the spring of 2001 at FD-2. These coincide with increased total phosphorus and lower Secchi values from which specific indices are calculate. The third TSI value is calculated using chlorophyll-. The highest seasonal chlorophyll-a concentration was collected in the spring of 2000 at FD-1 and thus the highest seasonal chlorophyll-a TSI value was also in the spring of 2000.

Table 32. Average[1] seasonal surface water concentrations of measured parameters by site from Fate Dam, Lyman County, South Dakota for 2000 through 2001[2,3].

	Spring 2000				Summer 2000				Fall 2000				Winter 2001				Spring 2001			
Parameter	**Sample Count**	**FD-1**	**Sample Count**	**FD-2**	**Sample Count**	**FD-1**	**Sample Count**	**FD-2**	**Sample Count**	**FD-1**	**Sample Count**	**FD-2**	**Sample Count**	**FD-1**	**Sample Count**	**FD-2**	**Sample Count**	**FD-1**	**Sample Count**	**FD-2**
Water Temperature (°C)	2	17.89	2	16.87	3	22.87	3	23.18	2	9.10	2	9.36	2	2.90	2	3.98	2	13.66	2	14.19
Dissolved Oxygen (mg/L)	2	8.43	2	9.05	2	7.35	2	7.17	2	11.70	2	10.91	2	16.99	2	15.72	2	10.02	2	10.21
pH (su)	2	8.67	2	8.61	3	8.70	3	8.65	2	8.44	2	8.41	2	8.22	2	8.2	2	8.53	2	8.38
Conductivity (µS/cm[1])	1	439	1	496	3	473	3	476	2	538	2	522	2	679	2	673	2	503	2	520
Secchi Depth (m)	2	0.69	2	0.69	3	1.10	3	1.02	2	1.16	2	1.16	-	-	-	-	2	0.76	2	0.76
Fecal Coliform Bacteria (# colonies/100 ml)	2	5	2	8	3	5	3	5	2	5	2	5	2	5	2	5	2	5	2	5
E. coli Bacteria (# colonies/100 ml)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	2	5
Alkalinity (mg/L)	2	163	2	164	3	138	3	140	2	166	2	164	2	144	2	186	2	128	2	127
Total Solids (mg/L)	2	351	2	352	3	332	3	335	2	383	2	380	2	355	2	445	2	375	2	393
Total Dissolved Solids (mg/L)	2	343	2	344	3	322	3	326	2	381	2	375	2	337	2	440	2	361	2	367
Total Suspended Solids (mg/L)	2	8	2	8	3	9	3	9	2	2	2	5	2	5	2	6	2	14	2	26
Volatile Total Suspended Solids (mg/L)	2	2	2	1	3	4	3	3	2	1	2	1	2	1	2	2	2	3	2	4
Ammonia (mg/L)	2	0.01	2	0.01	3	0.01	3	0.04	2	0.01	2	0.03	2	0.19	2	0.03	2	0.08	2	0.08
Un-ionized Ammonia (mg/L)	2	0.00112	2	0.00097	3	0.00159	3	0.00678	2	0.00042	2	0.00142	2	0.00338	2	0.00034	2	0.00942	2	0.00584
Nitrate-Nitrite (mg/L)	2	0.05	2	0.05	3	0.05	3	0.05	2	0.05	2	0.08	2	0.25	2	0.10	2	0.95	2	1.05
Total Kjeldahl Nitrogen (mg/L)	2	0.93	2	0.86	3	0.42	3	0.46	2	0.67	2	0.71	2	0.66	2	0.90	2	0.72	2	0.80
Organic Nitrogen (mg/L)	2	0.92	2	0.85	3	0.41	3	0.41	2	0.66	2	0.69	2	0.47	2	0.87	2	0.64	2	0.72
Inorganic Nitrogen (mg/L)	2	0.06	2	0.06	3	0.06	3	0.09	2	0.06	2	0.10	2	0.44	2	0.13	2	1.03	2	1.13
Total Nitrogen (mg/L)	2	0.98	2	0.91	3	0.47	3	0.51	2	0.72	2	0.79	2	0.91	2	1.00	2	1.67	2	1.85
Total Phosphorus (mg/L)	2	0.047	2	0.046	3	0.043	3	0.040	2	0.030	2	0.037	2	0.021	2	0.051	2	0.119	2	0.126
Total Dissolved Phosphorus (mg/L)	2	0.012	2	0.013	3	0.027	3	0.018	2	0.012	2	0.029	2	0.014	2	0.023	2	0.060	2	0.063
Chlorophyll-*a* (µg/L)	2	21.01	2	15.03	3	4.04	-	-	2	3.47	1	4.04	1	0.58	1	2.68	2	12.68	-	-
Phosphorus TSI	2	59.36	2	59.16	3	57.68	3	57.36	2	53.21	2	55.90	2	47.37	2	56.20	2	72.98	2	73.83
Chlorophyll-*a* TSI	2	63.92	2	61.12	3	53.29	-	-	2	51.79	1	53.30	1	34.21	1	49.28	2	61.07	-	-
Secchi TSI	2	66.29	2	64.98	3	58.86	3	60.27	2	57.88	2	58.64	-	-	-	-	2	67.14	2	67.14
Total Nitrogen-to-Total Phosphorus Ratio	2	21.75	2	20.48	3	12.06	3	12.48	2	23.60	2	23.27	2	44.64	2	32.00	2	13.38	2	15.46

[1] = Highlighted areas are the highest recorded average concentration or value for a given parameter in 200 through 2001.

[2] = pH is highest seasonal concentration not average.

[3] = A one in the sample count column is actual number and not an average.

In-lake Water Quality

Water Temperature

Water temperature is an essential component to the health of a lake. Temperature affects and regulates many chemical and biological processes in the aquatic environment. Increased temperatures have the potential to raise the fraction of un-ionized ammonia in water; increased concentrations of un-ionized ammonia are toxic to fish. Biological processes such as algal succession and growth are also regulated by water temperature. Certain species of diatoms are more abundant in cooler waters while blue-green algae are more prevalent in warmer waters. Fish life and propagation are also temperature dependent.

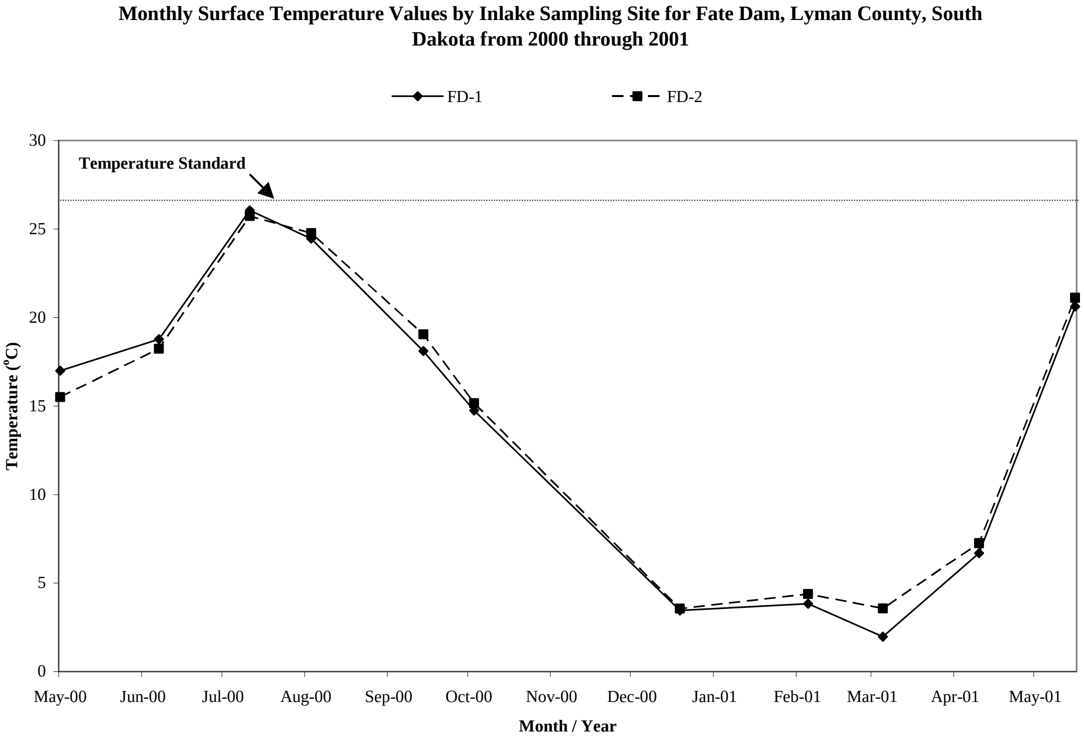


Figure 35. Monthly Surface water temperatures by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

The median surface water temperature in Fate Dam over the sampling season was 16.2° C (mean 14.3° C). Figure 35 shows surface water temperatures throughout the project period for both in-lake sampling sites. No significant differences were detected between sampling sites in Fate Dam (Table 28). The maximum surface water temperature measured during the sampling season was 26.0° C taken in mid-July 2000. During this study, surface water temperature samples did not exceed surface water quality standards (26.7° C).

Dissolved Oxygen

Dissolved oxygen concentrations normally change with the growth and decomposition of living organisms in a lake system. As algae and plants grow and photosynthesize, they release oxygen into the water. When organisms die and decompose, the bacteria involved in the decomposition process use oxygen from the system and replace it with carbon dioxide (CO_2). This process usually takes place near the sediment-water interface. Dissolved oxygen concentrations also change at the surface air-water interface. Wave action and other turbulence can also increase surface oxygen levels of a lake.

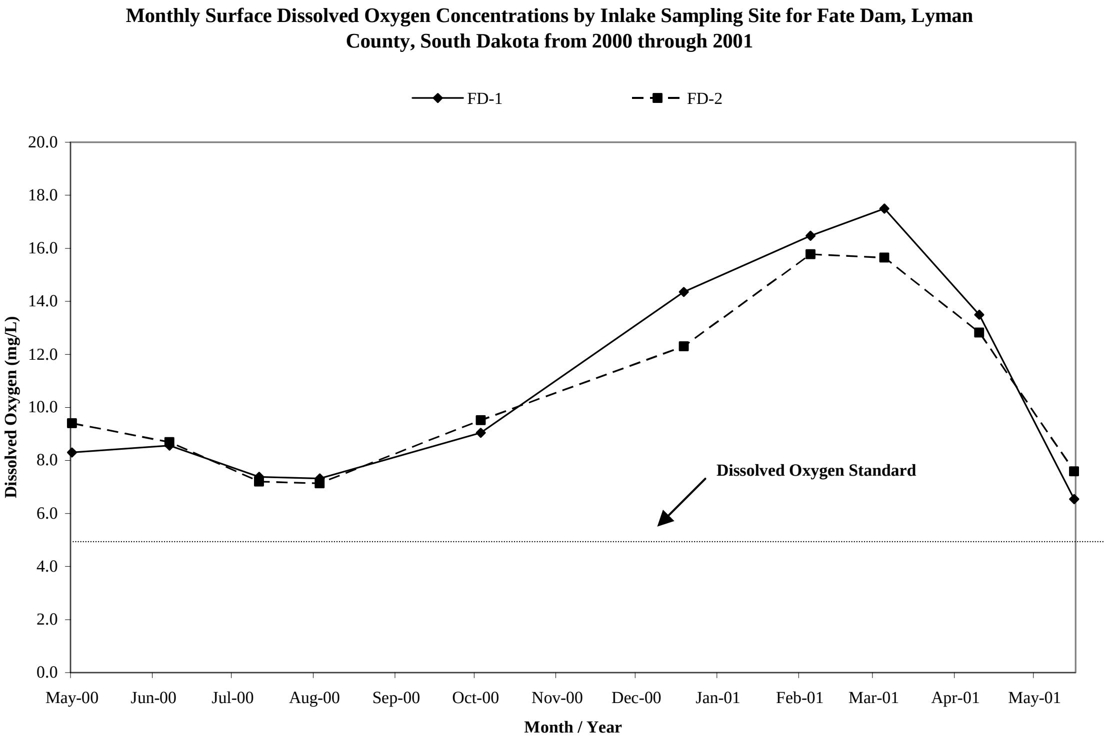


Figure 36. Monthly surface dissolved oxygen concentrations by sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

The median surface water dissolved oxygen concentration was 9.22 mg/L (average 10.75 mg/L) over the duration of the study (Appendix C). The maximum surface-water oxygen concentration in Fate Dam was 17.5 mg/L. That sample was collected at FD-1 on March 5, 2001. The minimum dissolved oxygen concentration was 6.54 mg/L at the surface of FD-1 on May 15, 2001 (Figure 36). Typically, the amount of oxygen produced by photosynthesis in a day is used in respiration or the uptake of oxygen at night. The maximum oxygen concentration usually occurs in the afternoon on clear days, and the minimum immediately after dawn (Reid, 1961).

Rarely during the study did Fate Dam exhibit oxygen stratification (Appendix D). Surface water dissolved oxygen samples were not statistically different between sites (Table 28). Appendix F has all the dissolved oxygen profiles collected in Fate Dam in 1999 and 2000.

pH

pH is the measure of hydrogen ion concentrations. More free hydrogen ions lower the pH in water. During decomposition, carbon dioxide is released from the sediments. The carbon dioxide (CO_2) reacts with water to create carbonic acid. Carbonic acid creates hydrogen ions. Bicarbonate can be converted to carbonate and another hydrogen ion. Extra hydrogen ions created from decomposition will tend to lower pH in the hypolimnion (bottom).

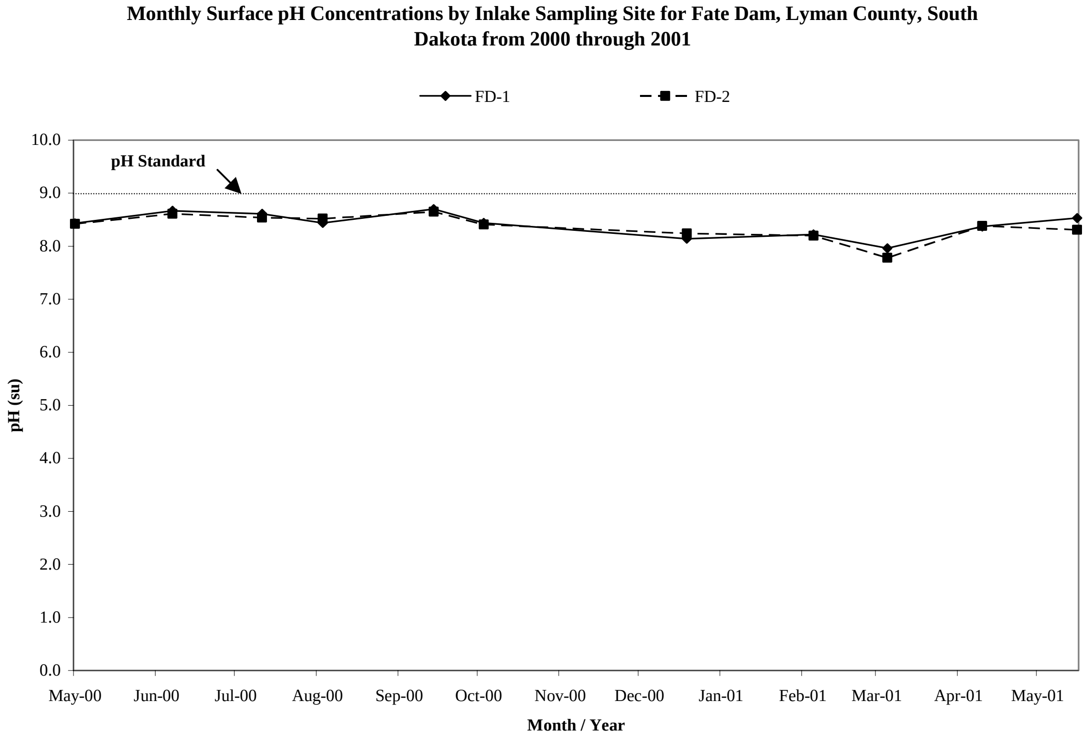


Figure 37. Monthly surface pH concentrations by date and sampling site for Fate Dam Lyman County, South Dakota from 2000 through 2001.

Increases in the different species of carbon come at the expense of oxygen. Decomposers will use oxygen to break down the material into different carbon species. In addition, the lack of light in the hypolimnion prevents plant growth, so no oxygen can be created through photosynthesis. Typically, the higher the decomposition and respiration rates the lower the oxygen concentrations and the lower the pH in the hypolimnion. The inverse occurs when photosynthesizing plants increase pH. Plants use carbon dioxide for photosynthesis and release oxygen to the system. This process can reverse the process discussed previously, increasing pH.

During the project, surface pH concentrations ranged from 7.78 su to 8.70 su with a median of 8.42 su. pH concentrations were slightly lower in the winter than in the spring and summer in Fate Dam (Figure 37). In-lake pH concentrations were statistically similar between sites (Table 28).

Conductivity

Conductivity is a measure of electrical conductance of water, and an approximate predictor of total dissolved ions. Increased ion concentrations reduce the resistance to electron flow; thus, differences in conductivity result mainly from the concentration of charged ions in solution, and to a lesser degree ionic composition and temperature (Allan, 1995). Typically, in-lake specific conductivity values and by default total dissolved solids concentrations tend to increase in the winter due to ice (freezing water expels particles that were dissolved in water increasing charged ions). Specific conductivity is conductivity adjusted by temperature (25° C) and is reported in micro-Siemens/centimeter (µS/cm^1).

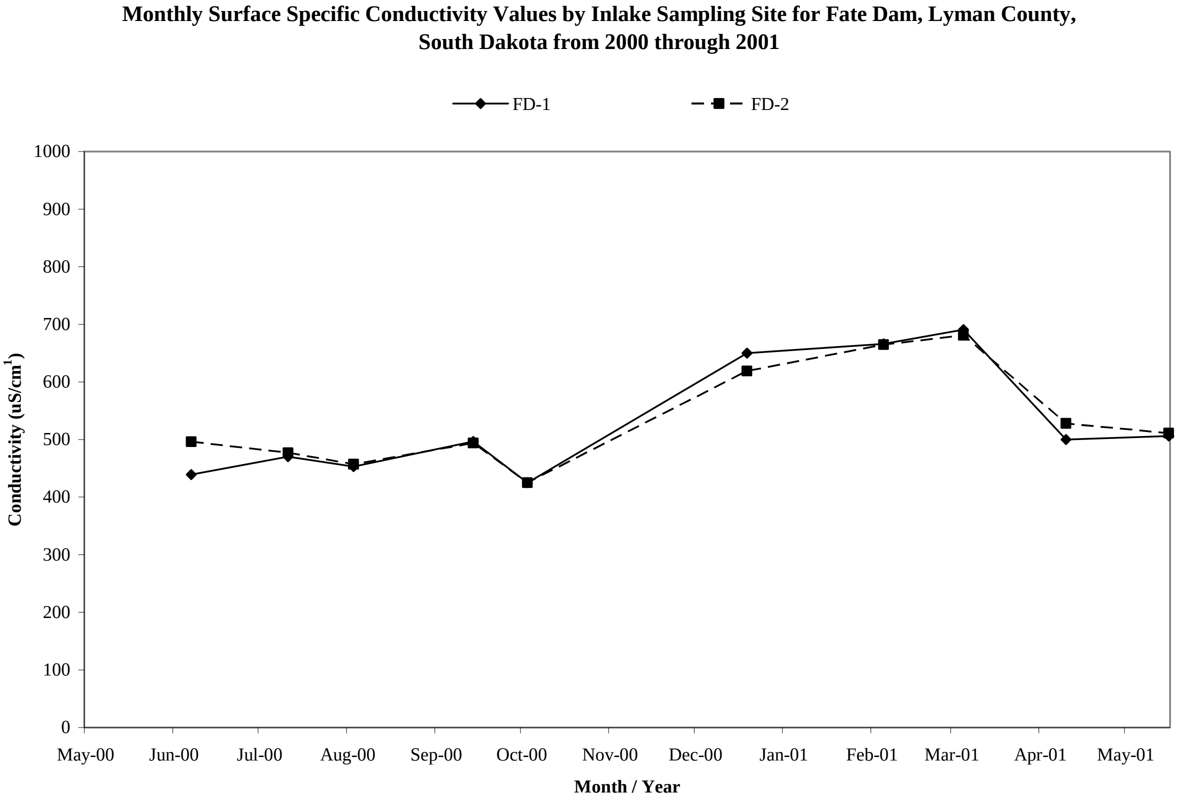


Figure 38. Monthly specific conductivity values for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

As discussed in the tributary section, Medicine Creek is listed in the 2002 South Dakota Total Maximum Daily Load Waterbody List (303(d) as impaired for conductivity and Total Dissolved Solids (TDS). In-lake specific conductivity values in Fate Dam directly affect tributary monitoring site MCT-8 (Fate Dam outlet) and Medicine Creek. Typically, there is a good relationship between total dissolved solids and specific conductance (conductivity). Current data indicate an extremely good relationship ($R^2 = 0.87$) between conductivity and total dissolved solids for Fate Dam (Figure 7). Fate Dam data indicate in-lake conductivity values were below the beneficial use standard for conductivity (Figure 38 and Table 31).

The median in-lake surface water specific conductivity for Fate Dam over the sampling period was 498.3 µS/cm^1 (average 532.5 µS/cm^1). Figure 38 shows surface water conductivity values throughout the project period for both in-lake sampling sites. No significant differences were detected between in-lake sampling sites (Table 28). The maximum surface water specific conductivity measured during the sampling season was 691.0 µS/cm^1 taken in early March 2001 at FD-1.

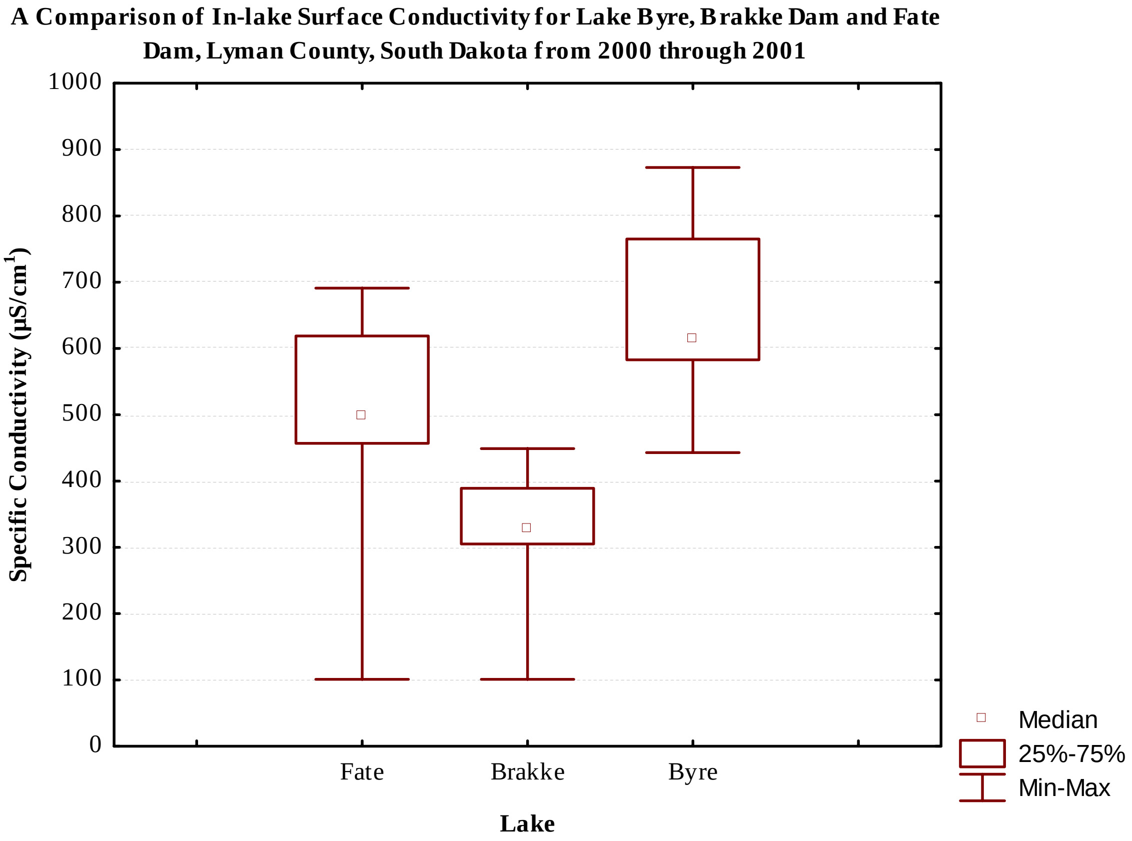


Figure 39. Comparing in-lake specific conductivity values between lakes in the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam), Lyman County, South Dakota from 2000 through 2001.

A statistical comparison between lakes within the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam) indicated Brakke Dam had significantly lower specific conductivity values than Byre Lake and Fate Dam (H=39.528, $(\alpha = 0.05, N=62)$, p=0.0000) while Fate Dam and Byre Lake were statistically similar (Figure 39).

In-lake water quality standard for specific conductivity is $\leq$ 7,000 µmhos/cm (µS/cm^1) for any one sample (Table 31). Data indicate that Fate Dam does not to contribute increased specific conductivity values that would impair/impact Medicine Creek

Secchi Depth

Secchi depth is a measure of in-lake water clarity and turbidity. The Secchi disk is 20 cm in diameter and usually painted with opposing black and white quarters (Lind, 1985). The Secchi disk is used worldwide for comparison of the clarity of water. Secchi disk readings are also used in Carlson’s Trophic State Index (TSI). Carlson’s TSI is a measure of trophic condition and overall health of a lake. One limitation of the Secchi disk method is that it cannot distinguish whether organic or inorganic matter is limiting transparency. Low Secchi depth readings may indicate hyper-eutrophic conditions because of suspended sediments and/or high algal biomass.

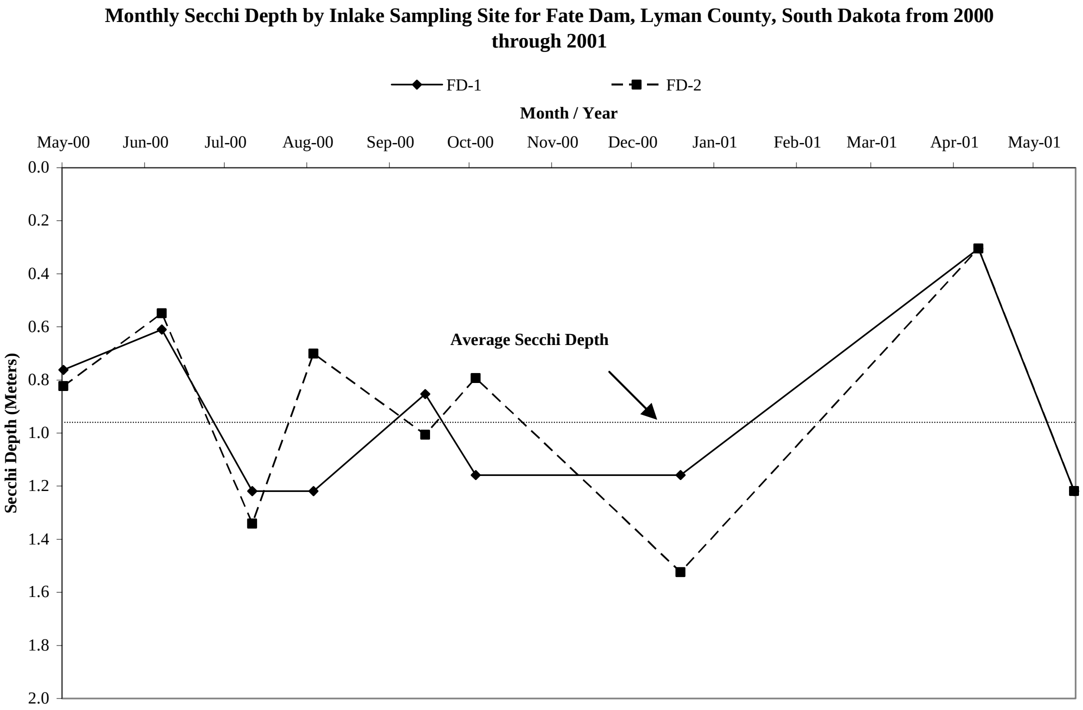


Figure 40. Monthly Secchi depth by date and sampling site for Fate Dam, Lyman County, South Dakota in 2000 through 2001.

Figure 40 indicates lower (shallower) Secchi depth readings in June of 2000 and April 2001. The highest (deepest) Secchi disk reading was 1.52 meters (5.0 feet) at FD-2 on December 19, 2000. This relates to the lower total suspended solids, volatile total suspended solids and chlorophyll-*a* concentrations in December 2000 at both in-lake sampling sites increasing Secchi depth (Figure 48, Figure 50 and Figure 63). Secchi transparency between sampling sites were not statistically different in Fate Dam (Table 28). Average seasonal Secchi depths were highest in the fall of 2000 at both sampling sites (Figure 40 and Table 32). Since Secchi transparency depth is one parameter used in measuring trophic state, Secchi TSI values between sites were also statistically similar (Table 28).

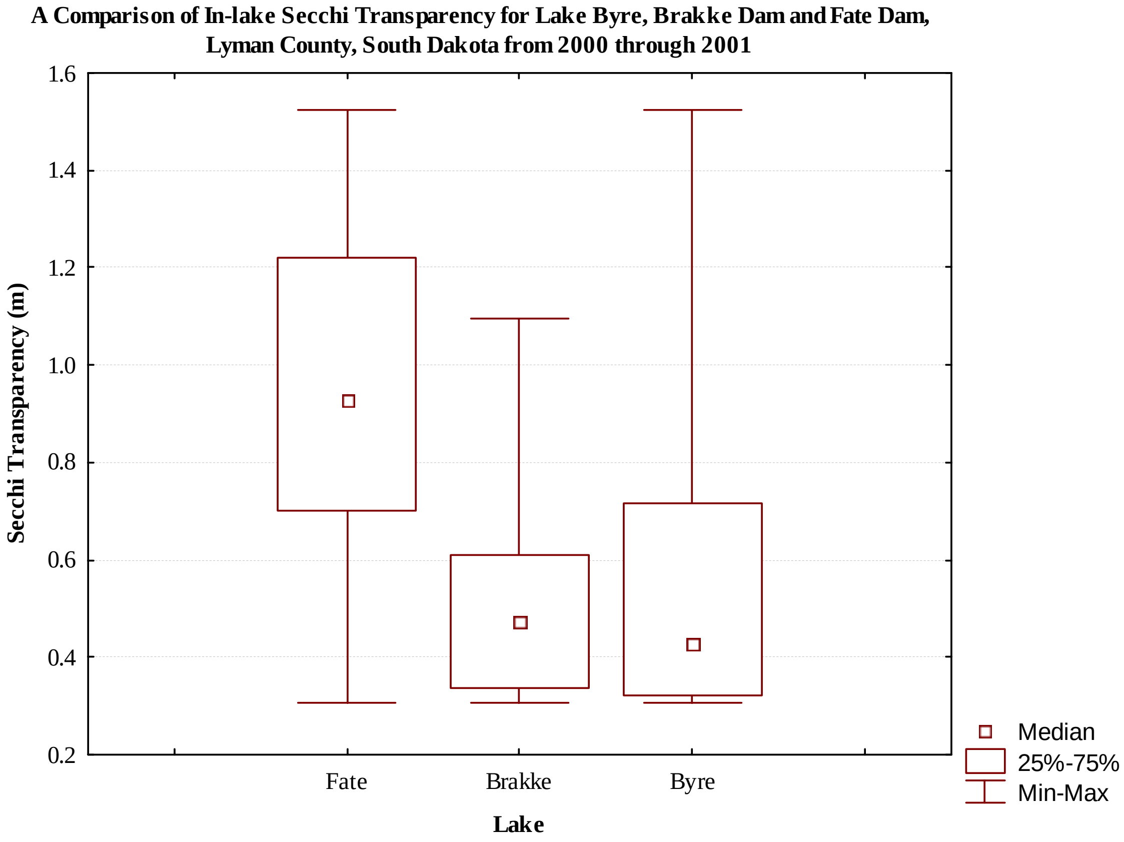


Figure 41. Comparing in-lake Secchi transparency depths between lakes in the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam), Lyman County, South Dakota from 2000 through 2001.

Statistical comparisons of Secchi transparency depths between lakes within the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam) indicated Fate Dam had significantly higher (deeper) Secchi depths than Byre Lake and Brakke Dam (H=11.128, (α = 0.05, N=52), p=0.0038) while Brakke Dam and Byre Lake were statistically similar (Figure 41).

Alkalinity

As discussed previously (tributary section), alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7.00 su). The median alkalinity in Fate Dam was 146.5 mg/L (average 150.7 mg/L). The maximum alkalinity concentration (199 mg/L) was collected at FD-1 in March of 2001 while the minimum alkalinity concentration (89 mg/L) was collected at FD-1 in February 2001.

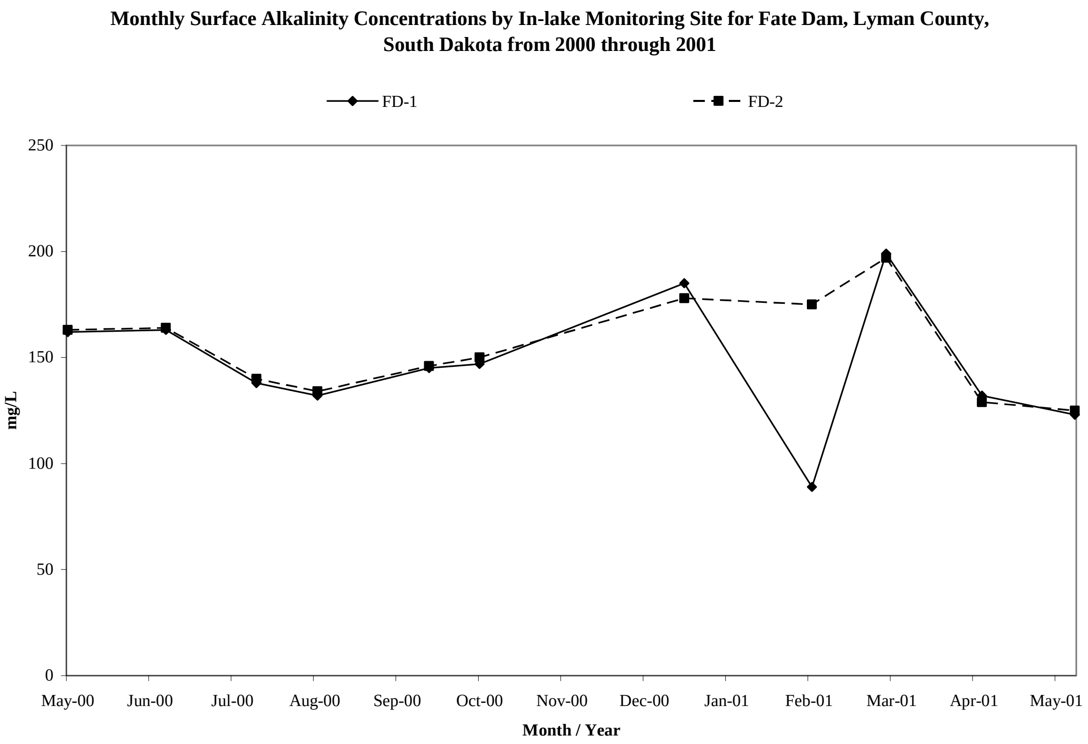


Figure 42. Monthly surface alkalinity concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Generally, alkalinity concentrations were consistent in the spring and summer and increased during the winter under ice cover (Figure 42) and were not significant different between in-lake sampling sites (Table 28). Seasonally, the highest average concentration of alkalinity occurred in the winter of 2001 (average 186 mg/L) at FD-2 (Table 32).

Concentrations in Fate Dam were statistically similar to both Byre Lake and Brakke Dam (Figure 28). Comparison of alkalinity concentrations between lakes within the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam) indicated Byre Lake had significantly higher alkalinity concentrations than Brakke Dam (H=11.701, (α = 0.05, N=52), p=0.0039) while Fate Dam and Brakke Dam were similar (Figure 43).

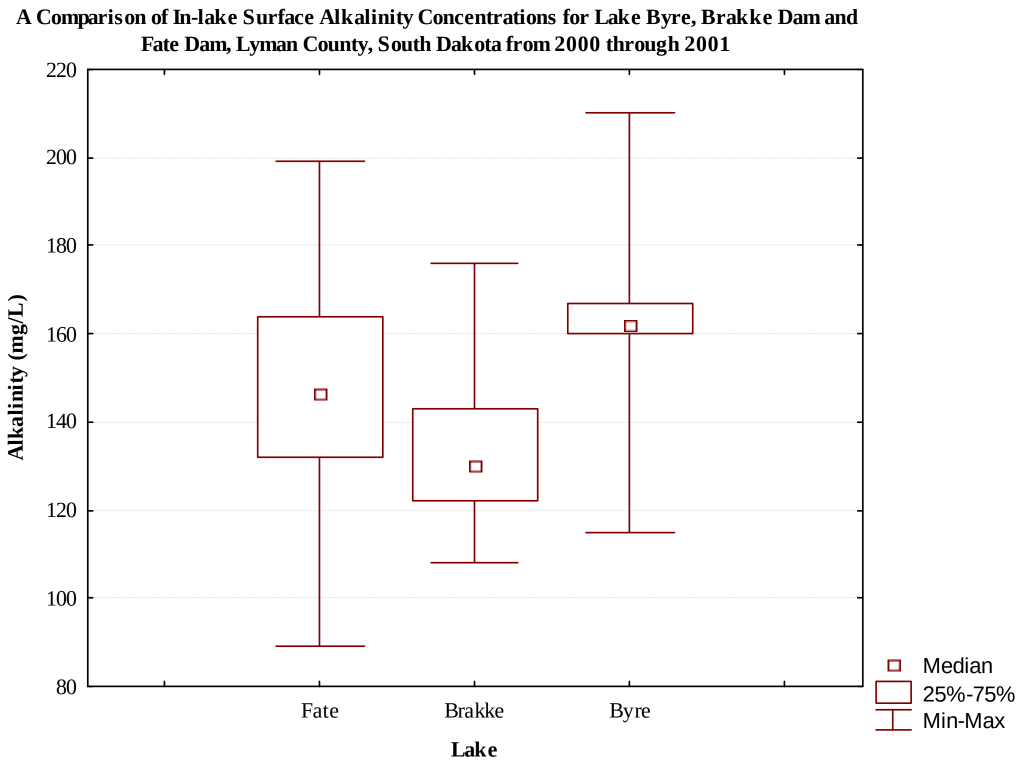


Figure 43. Comparing in-lake alkalinity concentrations between lakes in the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam), Lyman County, South Dakota from 2000 through 2001.

Total Solids

Total solids are the materials, suspended or dissolved, present in natural water. Dissolved solids include materials that pass through a filter. Suspended solids are the materials that do not pass through a filter, e.g. sediment and algae. Subtracting suspended solids from total solids derives total dissolved solids concentrations. Suspended volatile solids are that portion of suspended solids that are organic (organic matter that burns in a 500° C muffle furnace).

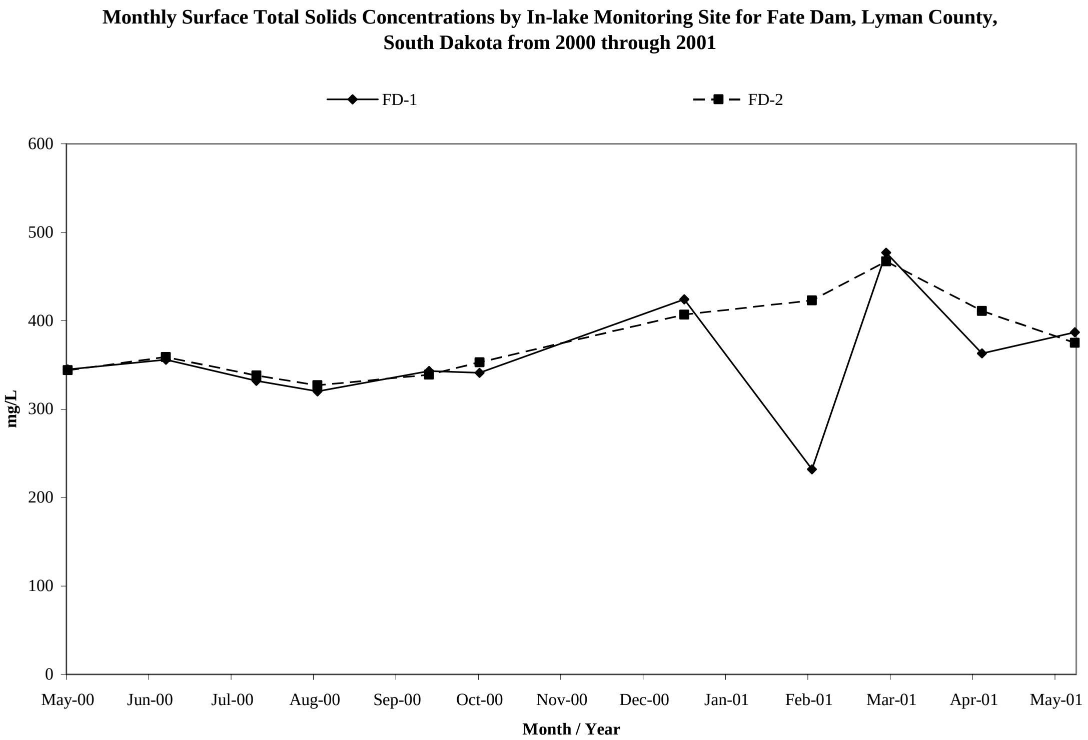


Figure 44. Monthly surface total solids concentration by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

The median total solids concentration in Fate Dam was 354.5 mg/L (average366.5 mg/L) with a maximum of 477 mg/L and a minimum of 232 mg/L. Generally, total solids concentrations were higher in the winter of 2001 and gradually peaked in March 2001 (Figure 44). Seasonal averages for total solids concentrations were highest in the winter of 2001 at FD-2 (Table 32). Total solids concentrations were not significantly different between in-lake sampling sites (Table 28).

Comparing total solids concentrations between lakes within the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam) indicated all lakes were significantly different from each other (H=50.988, $(\alpha = 0.05, N=65)$, p=0.0000). Data suggest Brakke Dam had the lowest total solids concentrations of all TMDL lakes in the Medicine Creek watershed (median concentration 242 mg/L) followed by Fate Dam (median concentration 354 mg/L) and Byre Lake (median 458 mg/L) total solids concentration (Figure 45).

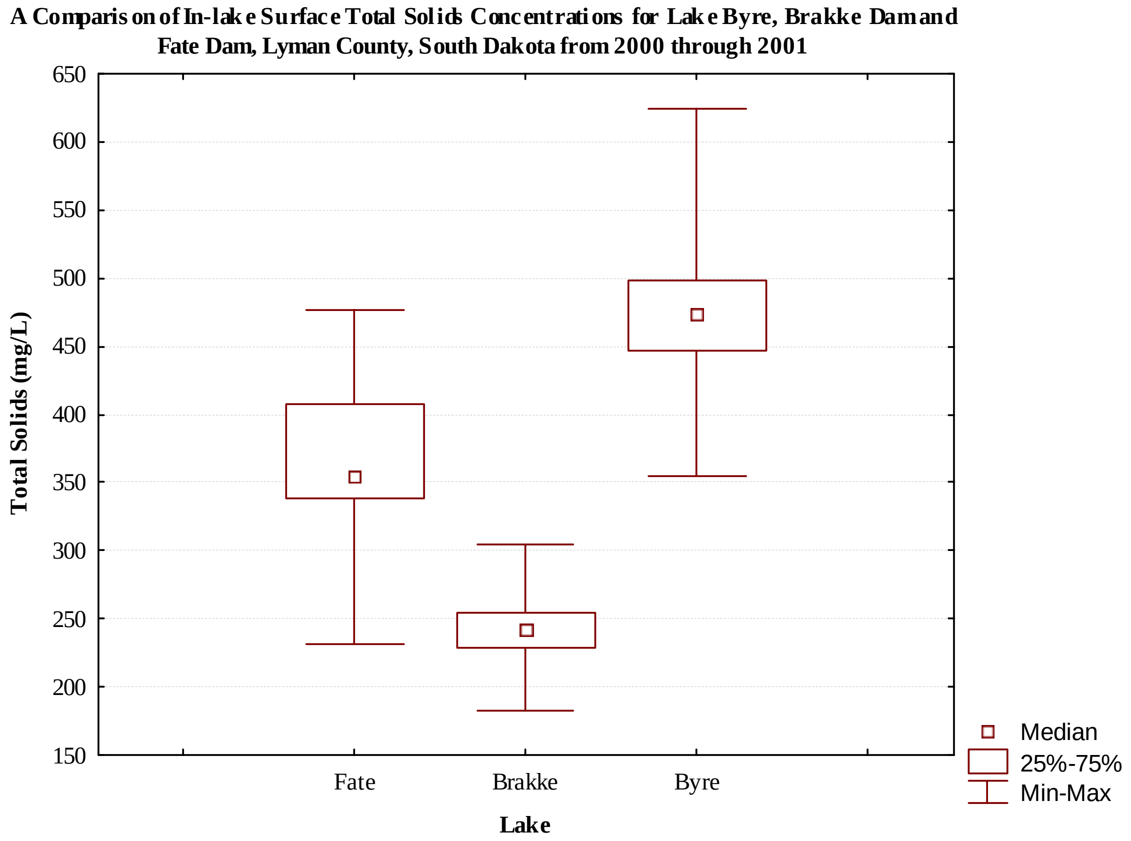


Figure 45. Comparing in-lake total solids concentrations between lakes in the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam), Lyman County, South Dakota from 2000 through 2001.

Total Dissolved Solids

Total dissolved solids is that portion of total solids that pass through a filter and are typically composed of earth compounds, particularly bicarbonates, carbonates, sulfates and chlorides which also determines salinity (Wetzel, 1983). Generally, total dissolved solids make up by far the larger percentage of total solids.

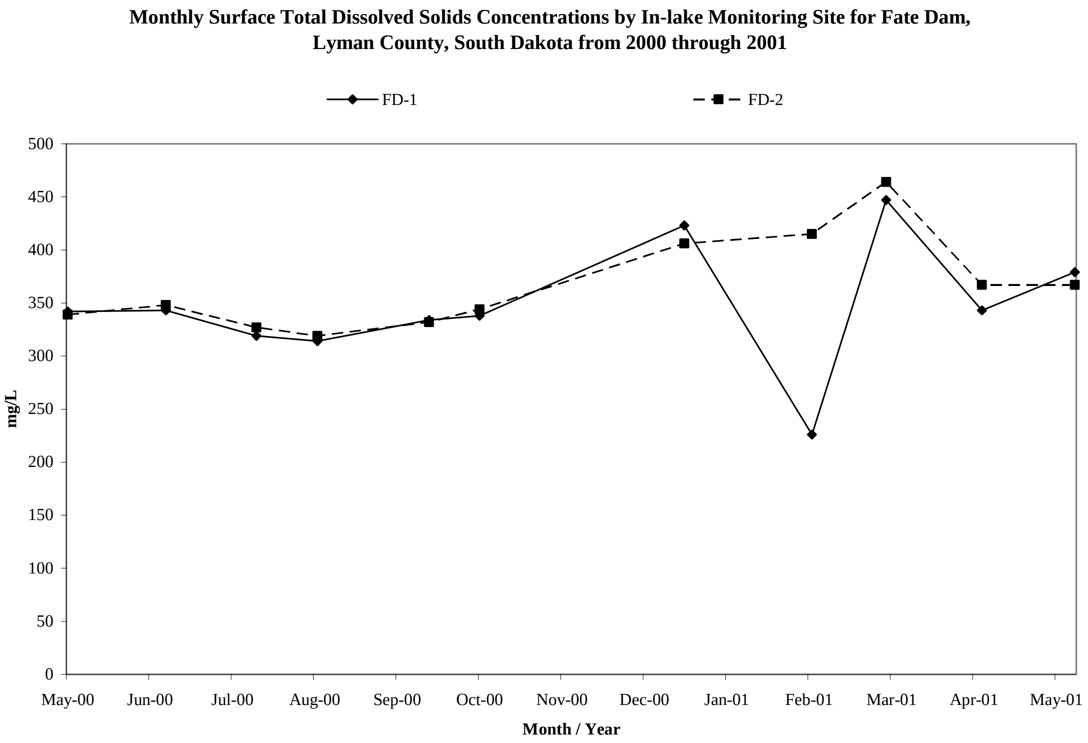


Figure 46. Monthly surface total dissolved solids concentration by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Similar to total solids, total dissolved solids concentrations were higher in the winter of 2001 and gradually peaked in March 2001 (Figure 46). The median total dissolved solids concentration in Fate Dam was 343.0 mg/L (average 366.5 mg/L) with a maximum of 464 mg/L and a minimum of 226 mg/L. Total dissolved solids concentrations comprised between 89.3 percent and 99.8 percent of total solids concentrations, thus Figure 44 and Figure 46 are similar. Total dissolved solids concentrations between FD-1 and FD-2 were statistically similar (Table 28). In-lake concentrations of TDS eventually pass through the outlet and influence concentrations in Medicine Creek. An extremely good statistical relationship was found between in-lake and especially tributary total dissolved solids and conductivity (Figure 7). Current data indicate that Fate Dam total dissolved solids concentrations appears not to contribute increased TDS concentrations and/or conductivity values to Medicine Creek.

Comparing TDS concentrations between lakes within the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam) indicated all lakes were significantly different between from each other (H=50.227, $_{(\alpha\ =\ 0.05,\ N=65)}$, p=0.0000). Data suggest Brakke Dam had the lowest total dissolved solids concentrations of all TMDL lakes in the Medicine Creek watershed followed by Fate Dam and Byre Lake (Figure 47).

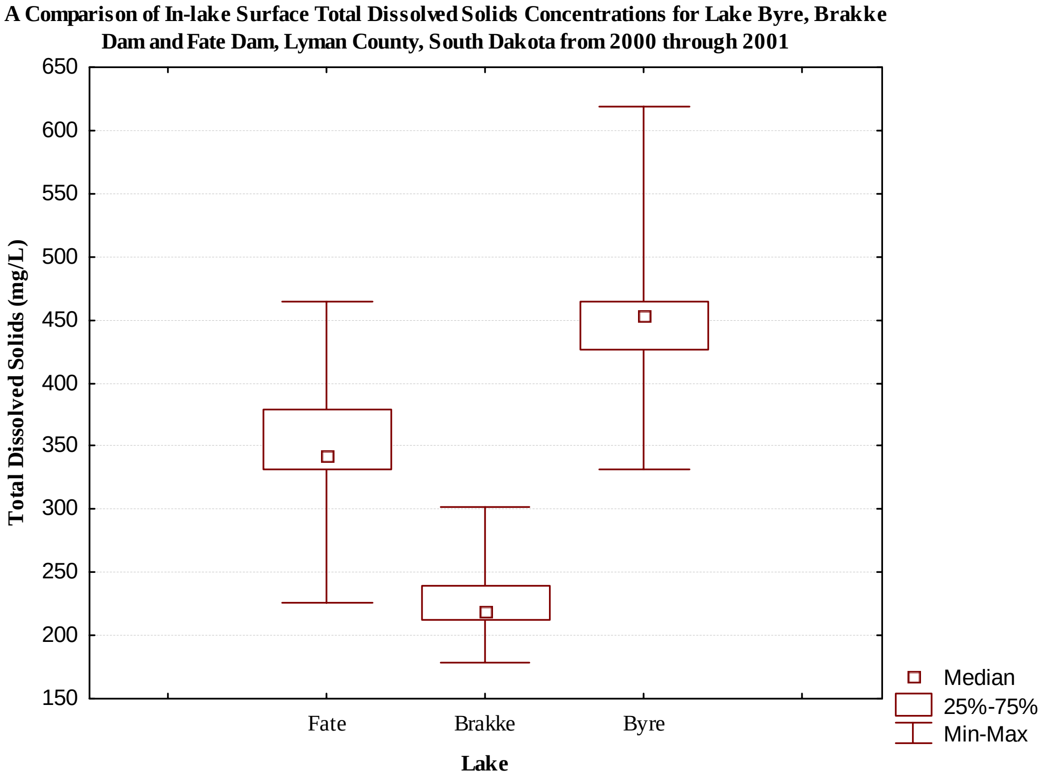


Figure 47. Comparing in-lake total dissolved solids concentrations between lakes in the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam), Lyman County, South Dakota from 2000 through 2001.

Total Suspended Solids

Total suspended solids are organic and inorganic particles that do not pass through a filter and based upon tributary loading and the sediment budget contribute to in-lake sedimentation rates.

The median total suspended solids concentrations in Fate Dam was 8.0 mg/L (average 9.1 mg/L) with a maximum of 44 mg/L and a minimum of 1 mg/L. Seasonal averages for total suspended solids concentrations were highest in the spring of 2001 at FD-2 (Table 32). The surface sample with the highest total suspended solids concentration was collected in April 10, 2001 at FD-2 (Appendix C) which appeared influenced by increased TSS loads from Nail Creek (Figure 48 and Figure 15).

Total suspended solids data supports the trend observed in Secchi disk depth, with a decrease in Secchi depth in June 2000, generally increased depths from July through the end of the year (2000) and a dramatic decrease in Secchi depth in late winter and early spring 2001 (Figure 40). Total suspended solids concentrations between in-lake sampling sites were not significantly different during this study (Table 28).

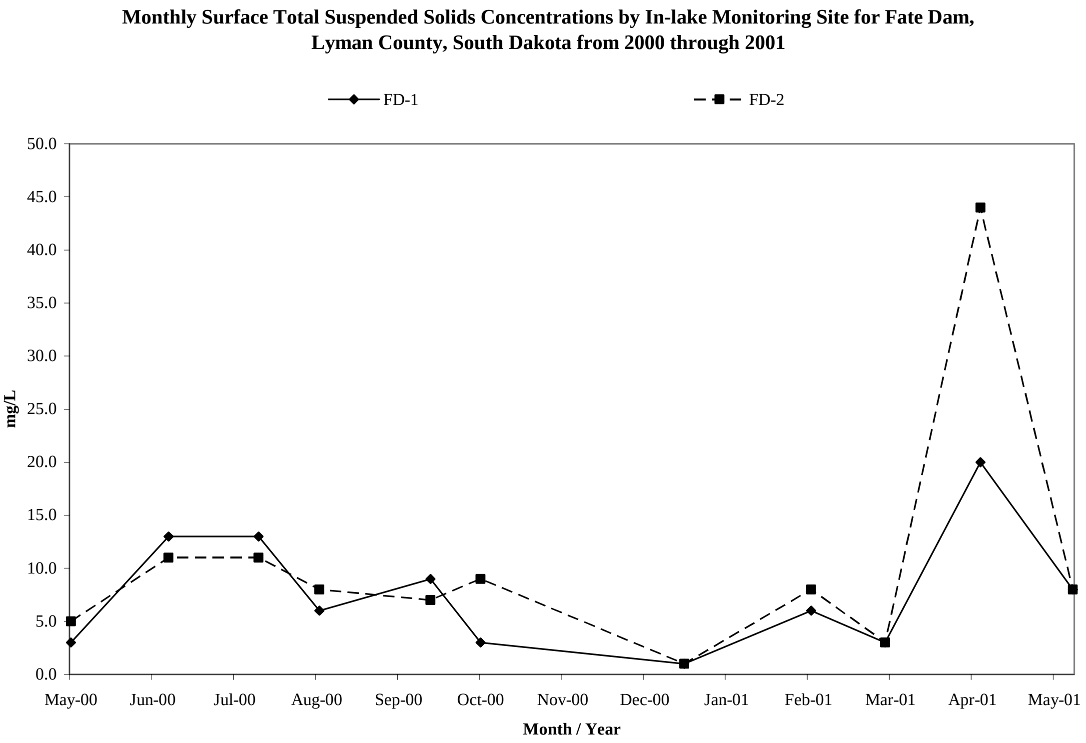


Figure 48. Monthly surface total suspended solids concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Comparing TDS concentrations between lakes within the Medicine Creek watershed (impaired for TDS and conductivity) indicated Fate Dam had significantly lower TDS concentrations than Byre Lake (H=13.955, $_{(\alpha = 0.05, N=65)}$, p=0.0009); however, Brakke Dam TDS concentrations were statistically similar to Byre Lake and Fate Dam (Figure 49). Current data suggest none of the lakes deliver significant total dissolved solids concentrations/loads to Medicine Creek.

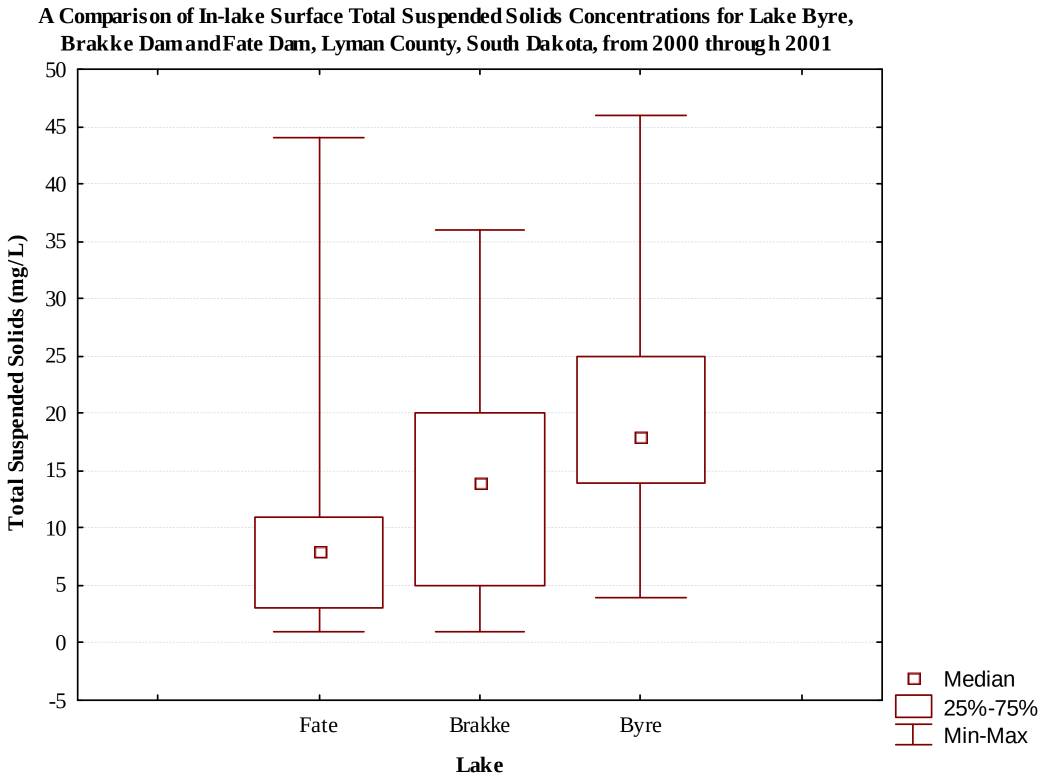


Figure 49. Comparing in-lake total suspended solids concentrations between lakes in the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam), Lyman County, South Dakota from 2000 through 2001.

Volatile Total Suspended Solids

Volatile total suspended solids are that portion of total suspended solids that volatilize at 500° Celsius. Volatile solids are composed of allochthonous (organic material produced and transported from the watershed (plants and organic debris)) and autochthonous (organic material produced within the lake (plants and algae)) matter.

Seasonal average volatile total suspended solids concentrations were highest in the summer of 2000 and the spring of 2001 (Table 32). Median volatile total suspended solids concentration in Fate Dam was 1.5 mg/L (average 2.2 mg/L) with a maximum of 7.0 mg/L and a minimum concentration of 0.5 mg/L. The maximum surface water concentration of volatile total suspended solids was collected in July 11, 2000 at FD-1 and April 10, 2001 at FD-2 (Figure 50). No significant differences were detected between in-lake sampling sites (Table 28).

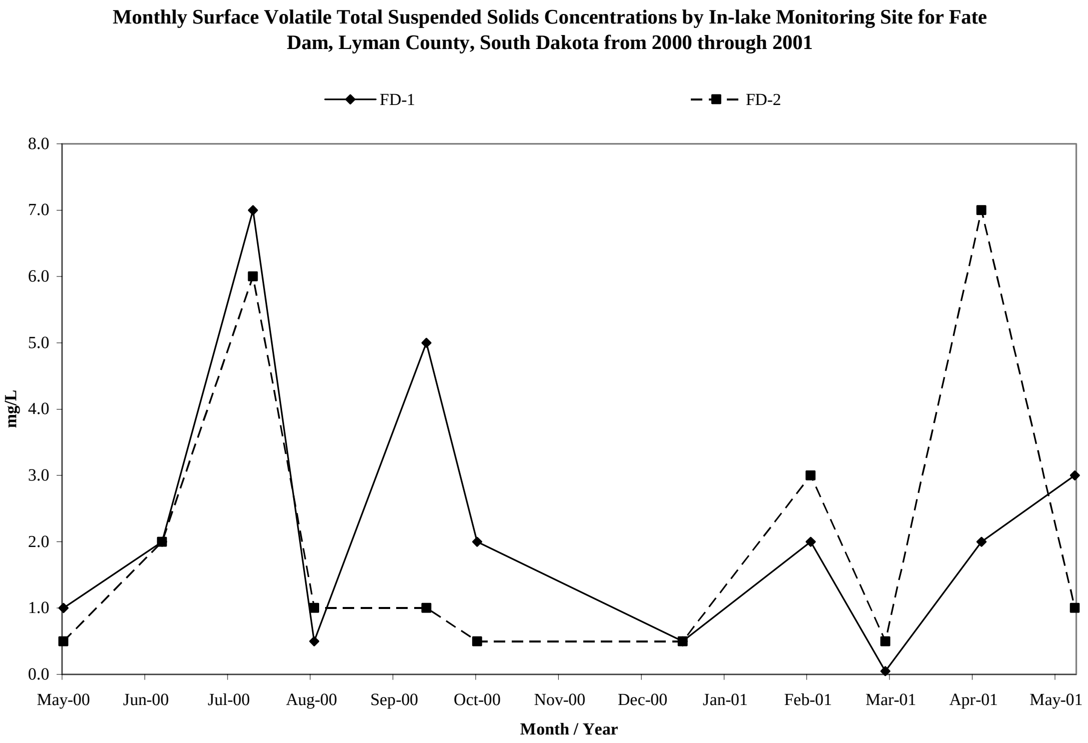


Figure 50. Monthly surface volatile total suspended solids concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

The percentage of volatile total suspended solids in total suspended solids by site ranged widely. FD-1 percent volatile suspended solids ranged from 1.7 percent to 66.7 percent and in-lake sampling site FD-2 ranged from 5.6 percent to 54.5 percent.

Total suspended solids and volatile total suspended solids affect Secchi transparency and chlorophyll-*a* concentrations, respectively. Fate Dam is currently listed on the 2004 Integrated Report (Integrated Report for Surface Water Quality Assessment, page 128), current assessment data indicate elevated TSI values above ecoregion 43 beneficial use categories (TSI (Trophic State Index) > 55.00) (SD DENR, 2002). A decrease in in-lake total suspended solids (both organic and inorganic) should improve (lower) all TSI values, and over time, improve in-lake clarity and overall water quality.

Comparing volatile total suspended solids concentrations between lakes within the Medicine Creek watershed (impaired for TDS and conductivity) indicated Fate Dam had significantly lower volatile total suspended solids concentrations than Byre Lake (H=7.390, (α = 0.05, N=65), p=0.0190); however, Brakke Dam volatile total suspended solids concentrations were statistically similar to Byre Lake and Fate Dam (Figure 51).

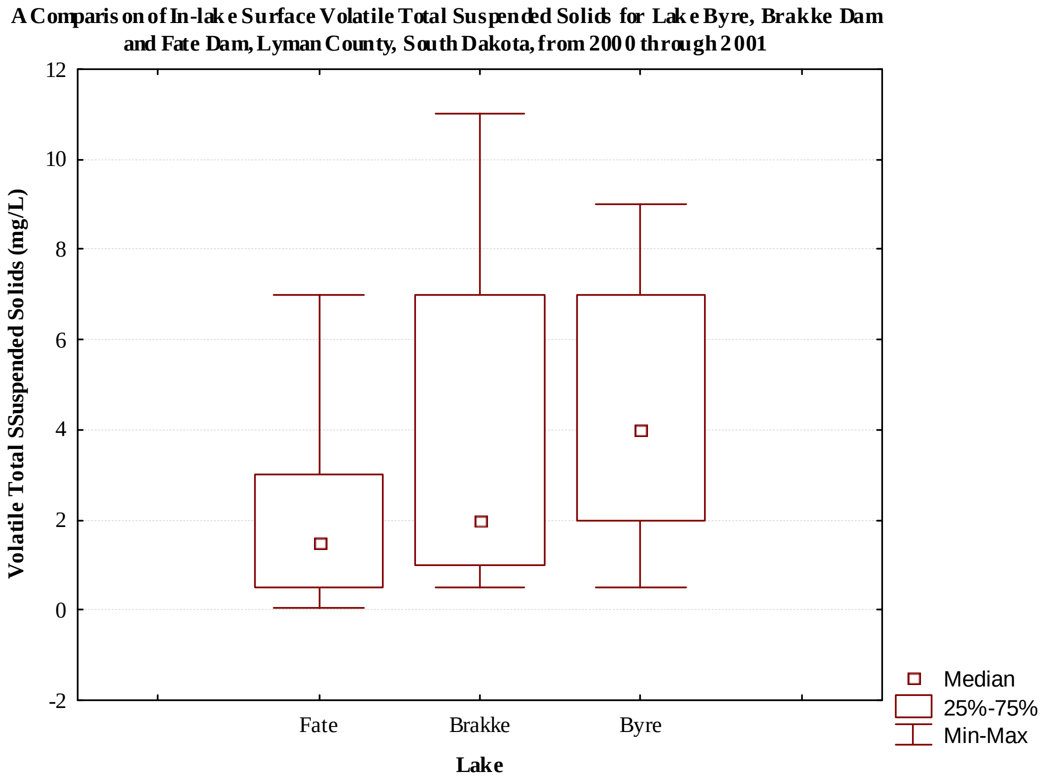


Figure 51. Comparing in-lake volatile total suspended solids concentrations between lakes in the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam), Lyman County, South Dakota from 2000 through 2001.

Ammonia

Ammonia (NH_3) is the nitrogen product of bacterial decomposition of organic matter and is the form of nitrogen most readily available to plants for uptake and growth. Ammonia in Fate Dam comes from Nail Creek loadings, runoff from ungauged areas of the watershed, wildlife with direct access to the lake, decaying organic matter and bacterial conversion of other nitrogen compounds.

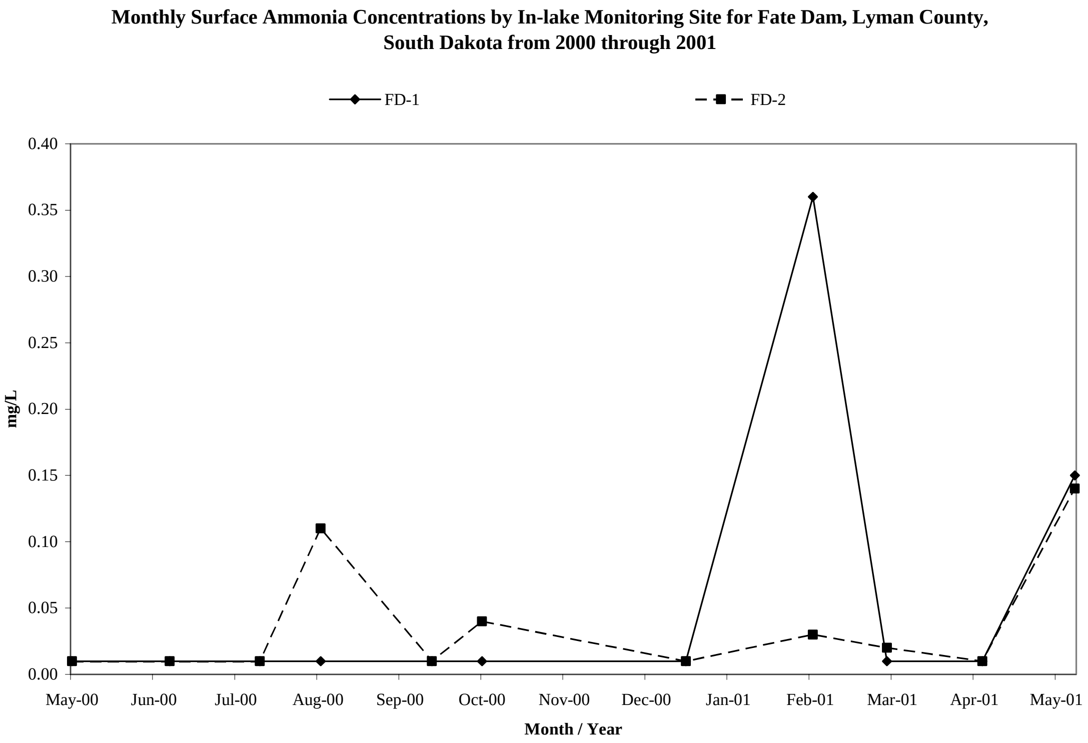


Figure 52. Monthly ammonia concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

The median concentration of ammonia in Fate Dam was 0.01 mg/L with an average of 0.05 mg/L. Maximum ammonia concentration in Fate Dam was 0.36 mg/L and the minimum was < 0.02 mg/L (Figure 52). The standard deviation was 0.08 mg/L which indicates a slight variation in sample concentrations during the project. Sixty-eight percent of all surface samples collected at Fate Dam were below laboratory detection limits (< 0.02 mg/L). Seasonal concentrations were highest in the winter of 2001 (average 0.19 mg/L) at FD-1 (Table 32). No significant differences in ammonia concentrations were detected between FD-1 and FD-2 during this study (Table 28).

Decomposing bacteria in the sediment and blue-green algae in the water column can convert free nitrogen (N_2) to ammonia. Blue-green algae can then use the ammonia for growth. Although algae use both nitrate-nitrite and ammonia, highest growth rates are found when ammonia is available (Wetzel, 1983).

Un-ionized Ammonia

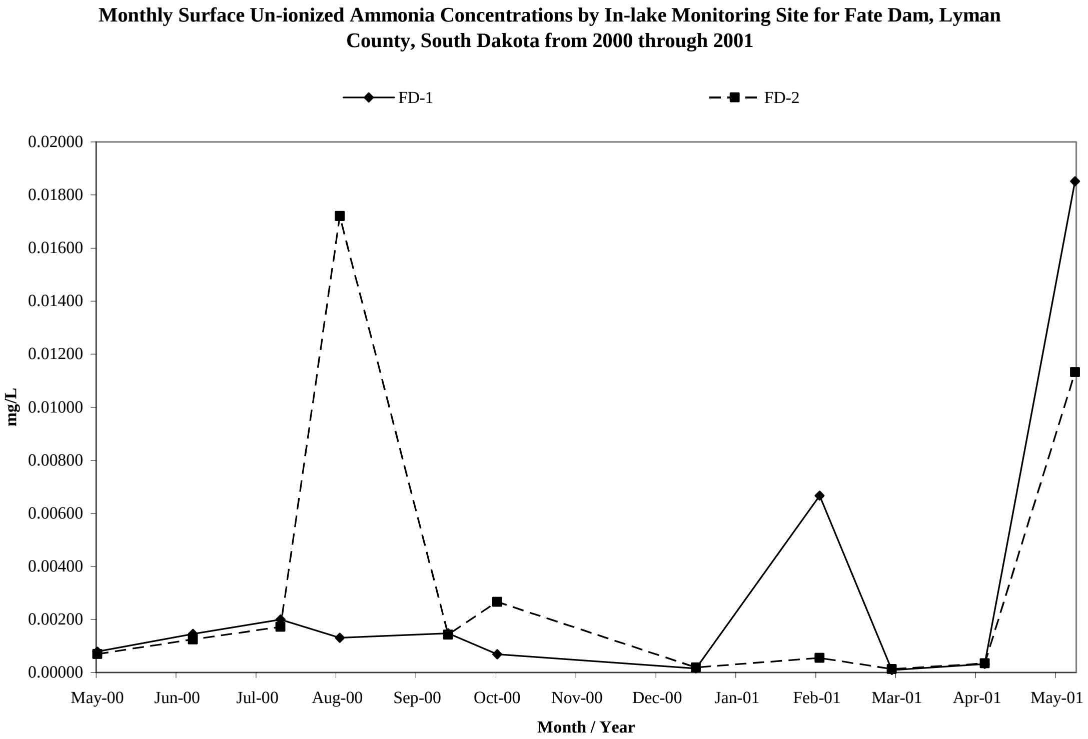


Figure 53. Monthly instantaneous un-ionized ammonia concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

As indicated in the tributary section of this report, un-ionized ammonia (NH_4-OH) is toxic to aquatic organisms and is calculated using temperature and pH. Un-ionized ammonia concentrations are calculated values, dependent on temperature, pH and ammonia, and are instantaneous concentrations and not a load. The median un-ionized ammonia concentration for Fate Dam was 0.00128 mg/L (average 0.00323 mg/L). The maximum concentration was 0.01852 mg/L and a minimum concentration of 0.00009 mg/L. Seasonal average un-ionized ammonia concentrations were highest at FD-1 in the spring of 2001 (0.00942 mg/L). Un-ionized ammonia concentrations (mg/L) peaked at FD-1 in the summer of 2001 and in the summer at FD-2 (Figure 53). The concentration of un-ionized ammonia between sampling sites at Fate Dam were not statistically different (Table 28) from 2000 through 2001.

Nitrate-Nitrite

Nitrate and nitrite (NO_3^- and NO_2^-) are inorganic forms of nitrogen easily assimilated by algae and macrophytes. Sources of nitrate and nitrite can be from agricultural practices and direct input from septic tanks, municipal and industrial discharges, precipitation, ground water, and from decaying organic matter. Nitrate-nitrite can also be converted from ammonia through denitrification by bacteria. This process increases with increasing temperature and decreasing pH.

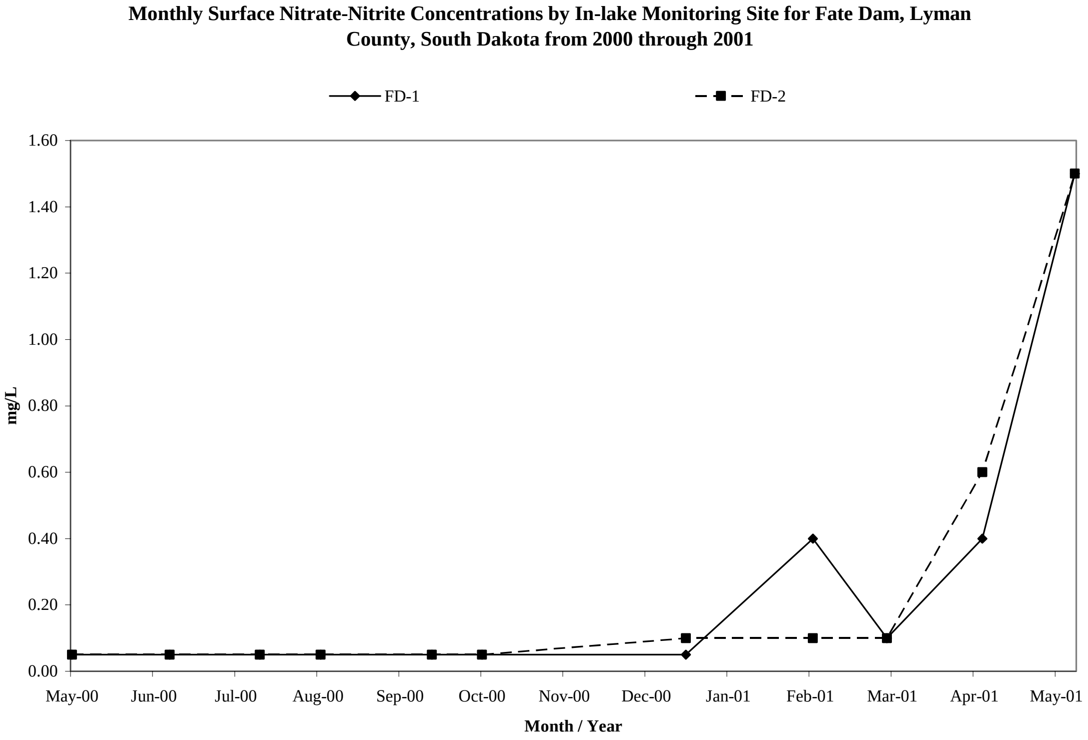


Figure 54. Monthly surface nitrate-nitrite concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

The median nitrate-nitrite concentration for Fate Dam was 0.05 mg/L (average 0.25 mg/L), with a maximum of 1.50 mg/L and a minimum concentration of 0.05 mg/L. Monthly average nitrate–nitrite concentrations were relatively steady during the 2000 sampling season with minimal input from Nail Creek and reduced lake levels (evaporative loss). Nitrate–nitrite concentrations peaked in the spring of 2001 at 1.50 mg/L at FD-1 in May (Figure 54). Seasonal concentrations were highest in the spring of 2001 (average 1.05 mg/L) at FD-2 (Table 32). Nitrogen and phosphorus concentrations in eutrophic lakes are frequently higher after ice out (spring) due to accumulation over the winter through decay and low algal numbers, however, with minimal input from Nail Creek in 2000 and inflow occurring during ice out, this situation may have been masked in Fate Dam during the study. Nitrate–nitrite concentrations between in-lake sampling sites were not significantly different (Table 28).

Inorganic Nitrogen

Inorganic nitrogen is calculated using ammonia plus nitrate-nitrite. Inorganic nitrogen is readily broken down to more usable (assimilated) ammonia by biological dissimilation.

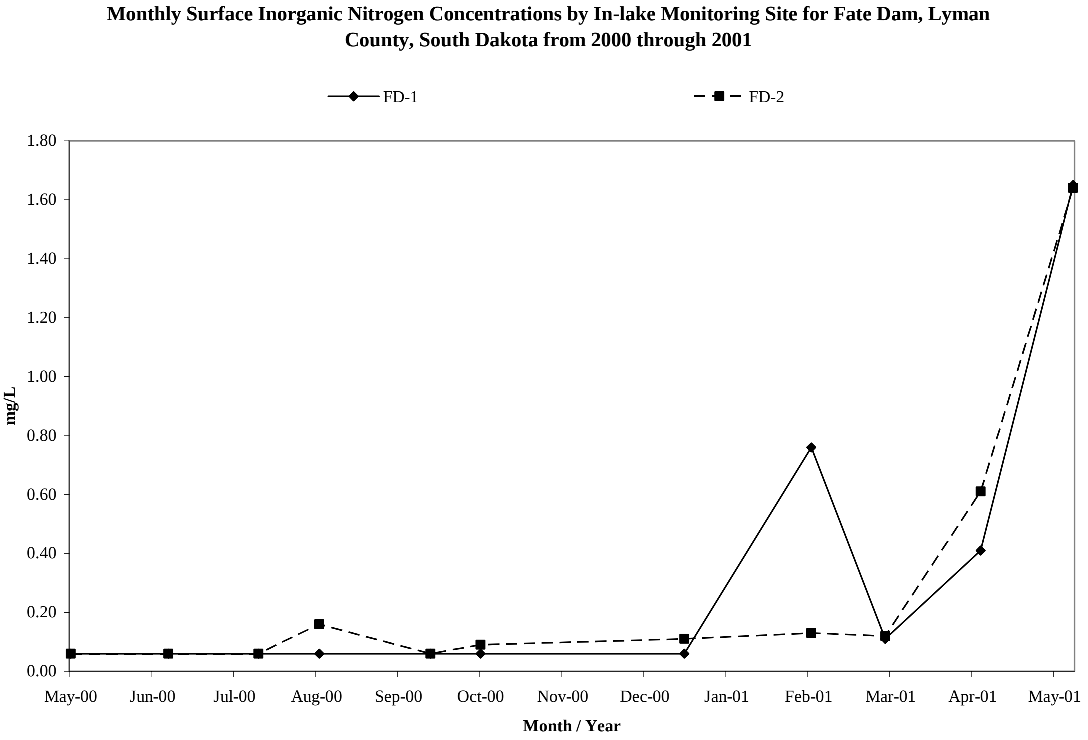


Figure 55. Monthly surface inorganic nitrogen concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Median inorganic nitrogen concentration in Fate Dam was 0.07 mg/L (average0.29 mg/L) with a maximum of 1.65 mg/L and a minimum concentration of 0.06 mg/L. Inorganic nitrogen concentrations peaked in the spring of 2001 and are similar to the nitrate-nitrite graph (Figure 55), because as mentioned above, inorganic nitrogen incorporates nitrate-nitrite in the calculation (Figure 54). Inorganic nitrogen concentrations between sampling sites were not statistically different (Table 28). Similar to nitrate-nitrite, seasonal averages for inorganic nitrogen concentrations were highest in the spring of 2001 at FD-2 (Table 32).

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is used to calculate organic and total nitrogen. TKN is composed mostly of organic nitrogen but also includes ammonia. Sources of organic nitrogen can include releases from dead or decaying organic matter, lakeside septic systems, or agricultural waste. Organic nitrogen is broken down to more usable ammonia and other forms of inorganic nitrogen.

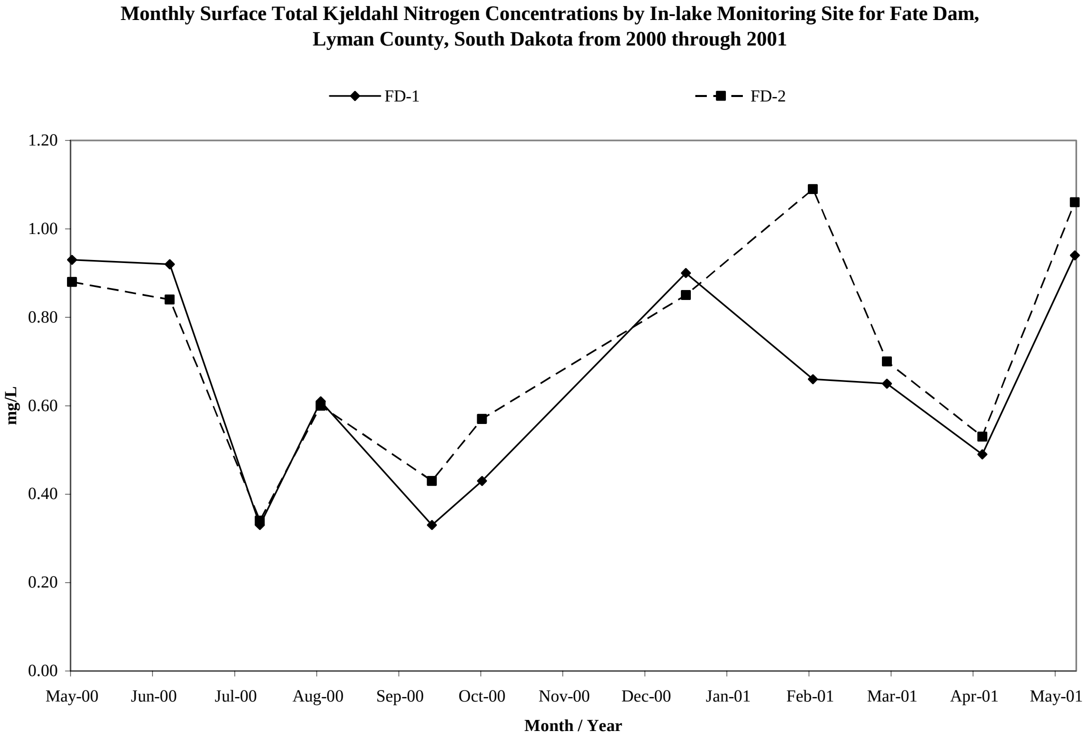


Figure 56. Monthly surface Total Kjeldahl Nitrogen (TKN) concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

The median and average TKN concentrations were 0.65 mg/L and 0.69 mg/L, respectively. Monthly average TKN concentrations fluctuated during throughout the project especially, during the 2000 sampling season with minimal input from Nail Creek (Figure 56). Seasonally, average TKN concentrations were highest in the spring of 2001 at BL-2 (Table 32). Monthly in-lake TKN concentrations were not significantly different between in-lake sampling sites (Table 28).

Organic Nitrogen

The organic portion of TKN (TKN minus ammonia) is graphed on Figure 56. Organic nitrogen percentages (percent organic nitrogen in TKN) ranged from 45.5 percent to 98.9 percent and averaged 86.8 percent. The lowest organic percentage was in February 2001 at FD-1 (45.5 percent).

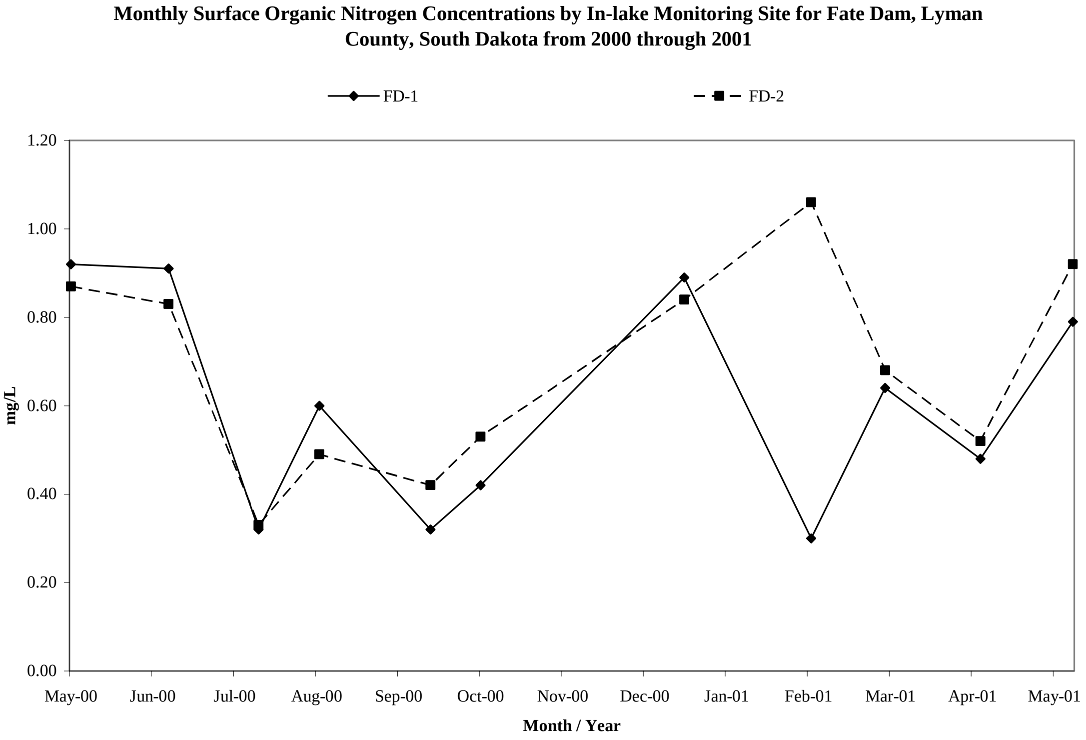


Figure 57. Monthly surface organic nitrogen concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

The median organic nitrogen concentration for Fate Dam was 0.62 mg/L (average 0.64 mg/L), with a maximum of 1.06 mg/L and a minimum concentration of 0.30 mg/L. Since organic nitrogen is a constituent of TKN, seasonal average organic nitrogen concentrations were similar (Table 32). Organic nitrogen concentrations peaked in the winter of 2001 at FD-2 and are similar to the TKN graph (Figure 56), because organic nitrogen incorporates TKN in the calculation (Figure 57). Organic nitrogen concentrations were not significantly different between in-lake sampling sites (Table 28).

Comparing organic nitrogen concentrations between lakes within the Medicine Creek watershed indicated Fate Dam had significantly lower organic nitrogen concentrations than Byre Lake (H=9.338, $_{(\alpha = 0.05,\ N=65)}$, p=0.0094); however, Brakke Dam organic nitrogen concentrations were statistically similar to both Byre Lake and Fate Dam (Figure 58).

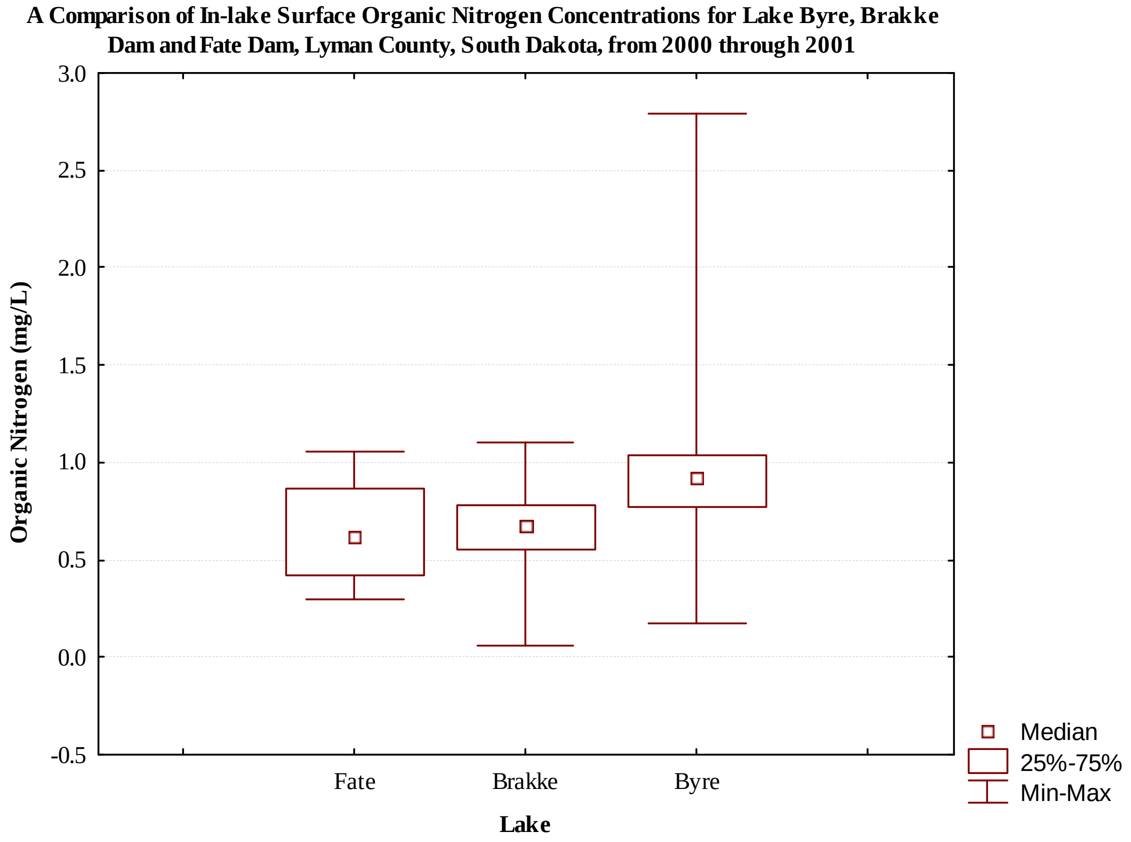


Figure 58. Comparing in-lake organic nitrogen concentrations between lakes in the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam), Lyman County, South Dakota from 2000 through 2001.

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used to determine total nitrogen to total phosphorus ratios (limiting nutrient), and are discussed in the tributary section (3.1) and later in the in-lake section (3.1.1) of this report. Seasonally, average total nitrogen concentrations for Fate Dam were highest in the spring of 2001 at FD-2 (Table 32 and Figure 59). The median total nitrogen concentration for Fate Dam was 0.89 mg/L (average 0.93 mg/L), with a maximum of 2.56 mg/L and a minimum concentration of 0.38 mg/L. Total nitrogen concentrations between in-lake sampling sites were not significantly different (Table 28).

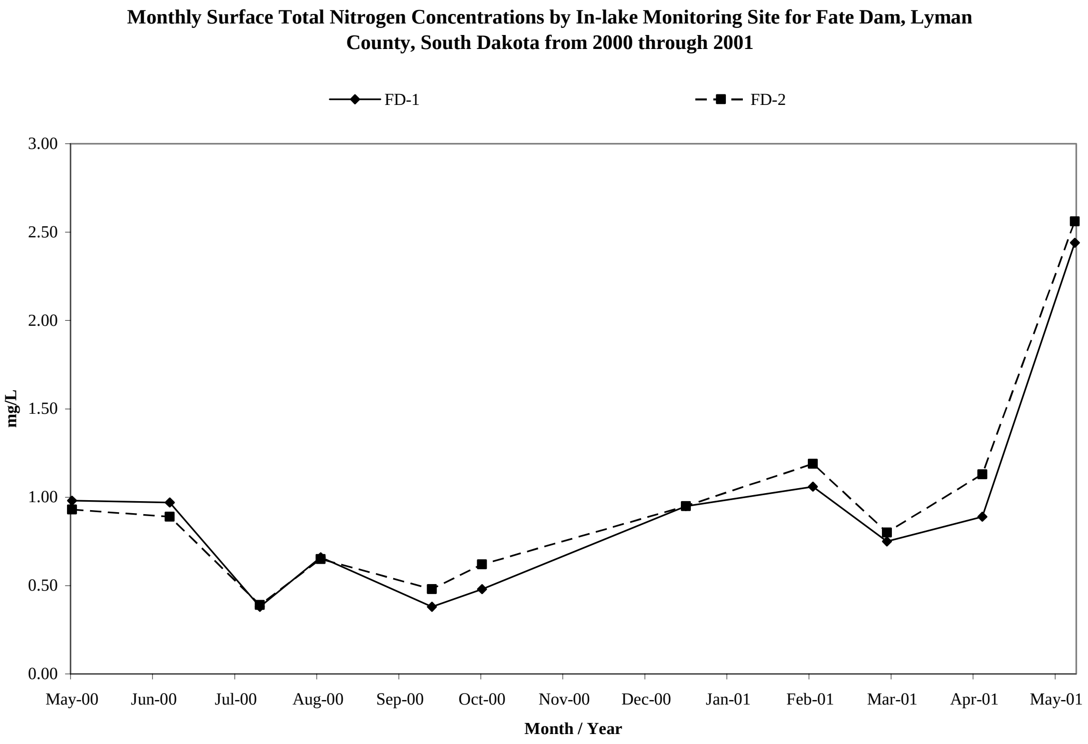


Figure 59. Monthly total nitrogen concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota in 1999 and 2000.

Total Phosphorus

Typically, phosphorus is the single best chemical indicator of the condition of a nutrient-rich lake. Algae need as little as 0.02 mg/L of phosphorus for blooms to occur (Wetzel, 1983). Phosphorus differs from nitrogen in that it is not as water-soluble and will sorb on to sediments and other substrates. Once phosphorus sorbs on to any substrate, it is not readily available for uptake by algae. Phosphorus sources can be natural from the geology and soil, from decaying organic matter, waste from septic tanks/systems or agricultural runoff. Once phosphorus enters a lake it may be used by the biota in the system or stored in lake sediment. Phosphorus will remain in the sediments unless released by wind and wave action suspending phosphorus into the water column, or by the loss of oxygen and the reduction of the redox potential in the microzone (sediment-water interface). As dissolved oxygen levels are reduced, the ability of the microzone to hold phosphorus in the sediments is also reduced. The re-suspension of phosphorus into a lake from the sediments is called internal loading and can be a large contributor of phosphorus available to algae (Zicker, 1956).

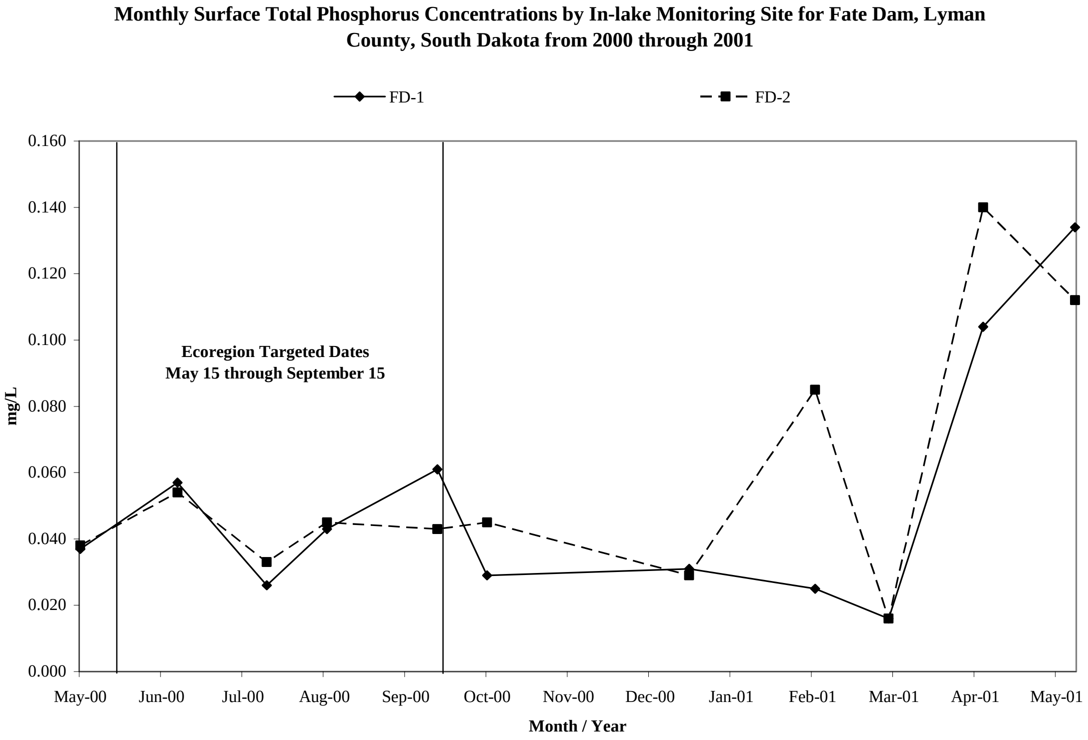


Figure 60. Monthly surface total phosphorus concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

The median concentration of total phosphorus throughout the study period was 0.043 mg/L (average 0. 055 mg/L). The maximum sample concentration was collected at FD-2 in April (0.140 mg/L) and the minimum concentration (0.016 mg/L) collected at FD-1 and FD-2 in March 2001 (Figure 60). Total phosphorus concentrations between in-lake sampling sites were not significantly different (Table 28). Total phosphorus concentrations during ecoregion targeting dates (May 15 through September 15) were relatively low (median 0.045, average 0.059 mg/L).

Seasonally, average total phosphorus concentrations were lower in the winter of 2001 (Figure 60 and Table 32). On average, Fate Dam had 2.75 times more total phosphorus than the amount needed to cause algal blooms ((0.02 mg/L) Wetzel, 1983). During this study, monthly in-lake total phosphorus was generally limited (Figure 59). The highest densities of algae occurred in the spring of 2001 (May) with flagellated algae blooms. Based on this information, algae appeared to utilize most of the available phosphorus. Since excess phosphorus can cause algal blooms, reducing phosphorus loads in periods increased tributary loading (including internal loads) over time should promote better water quality and lower total phosphorus TSI.

Significant total phosphorus loading from Nail Creek occurred from late March through May 2001 (Figure 27) and contributed to peak in-lake total phosphorus concentrations in May 2001. Increased in-lake concentrations were from tributary loading of total phosphorus to the lake. In-lake total phosphorus concentrations in May could have been much higher if it were not for submergent macrophyte and algal growth utilizing phosphorus and other nutrients during this time.

Data indicate that a reduction in total phosphorus is needed in the watershed to reduce/lower in-lake total phosphorus in Fate Dam to help meet designated beneficial uses based on reference lake criteria for ecoregion 43. Fate Dam, along with Brakke and Byre Lake appear not to fit current ecoregion-based beneficial use criteria based on current ecoregion 43 targets (mean TSI < 55.00).

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae. Dissolved phosphorus will sorb on to suspended materials (organic and inorganic) if present and not already saturated with phosphorus. In-lake total dissolved phosphorus and chlorophyll-*a* concentrations for each date were averaged because algae densities, which respond to available phosphorus concentrations, were also averaged for Fate Dam.

Generally, increased total suspended solids concentrations decrease concentrations of available total dissolved phosphorus; however, during this study total suspended solids showed a limited relationship to total dissolved phosphorus (R^2=0.02). The overall average percent phosphorus that was dissolved during the project was 80.4 percent. Percentages of total dissolved phosphorus ranged from 6.9 percent in the fall of 2000 to 100.0 percent in the winter of 2001. The median dissolved phosphorus concentration in Fate Dam was 0.020 mg/L (average 0.026 mg/L), with a maximum of 0.096 mg/L and a minimum concentration of 0.002 mg/L. Since algae only need 0.02 mg/L of phosphorus to produce an algal bloom (Wetzel, 1983), Fate Dam averages 1.3 times the available total dissolved phosphorus needed for algal blooms. Total dissolved phosphorus concentrations between in-lake sampling sites were not statistically different (Table 28). Total dissolved phosphorus concentrations during ecoregion targeting dates (May 15 through September 15) were relatively low (median 0.018, average 0.033 mg/L).

Seasonal average total dissolved phosphorus concentrations were low from May 2000 through the winter of 2001 and increased to the highest average concentration (0.063 mg/L) in the spring of 2001 at FD-2 (Figure 61 and Table 32).

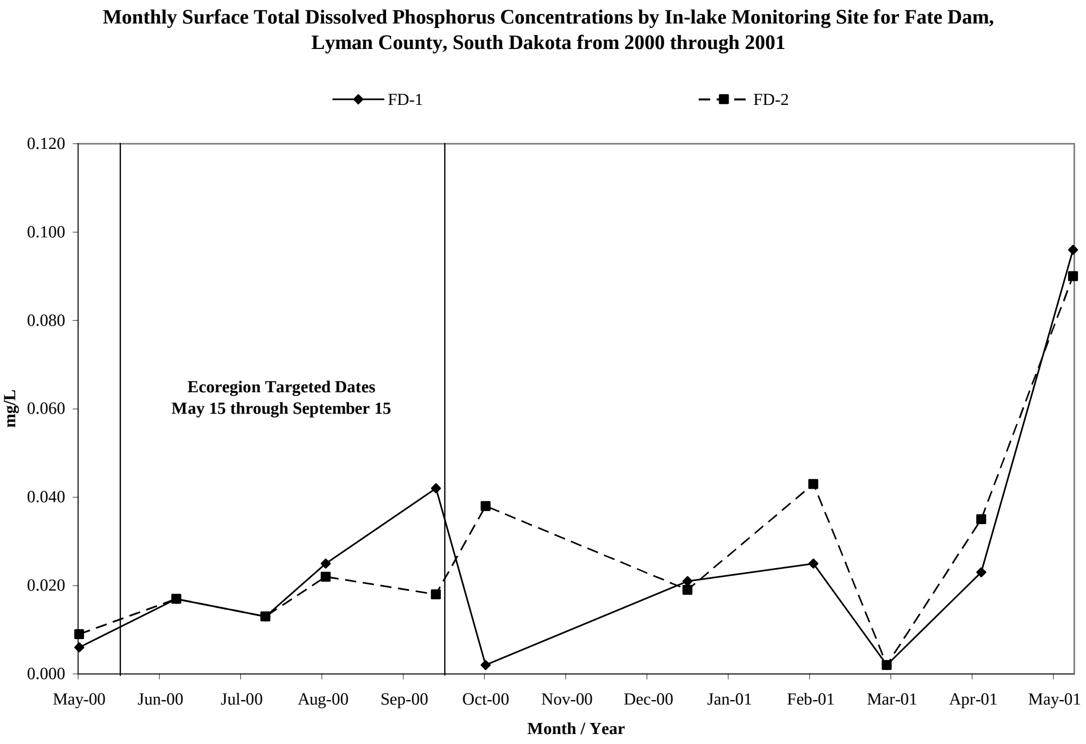


Figure 61. Monthly surface total dissolved phosphorus concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Data indicate that while, algal densities in Fate Dam were relatively high in fall of 2000 and the spring of 2001 those densities did not produce thick floating algal mats in Fate Dam. Since no algal blooms were reported by DENR personnel or the public during sampling, other conditions (light transparency, micronutrients, etc.) suppressed excessive productivity. Reducing tributary and in-lake total dissolved phosphorus concentrations will, over time, reduce Carlson TSI values and increase water quality.

Fecal Coliform Bacteria

As was mentioned in the tributary section of this report, fecal coliform bacteria are found in the intestinal tract of warm-blooded animals and are used as indicators of waste and the presence of pathogens in a waterbody. Fecal coliform bacteria standards are in effect from May 1 through September 30 each year.

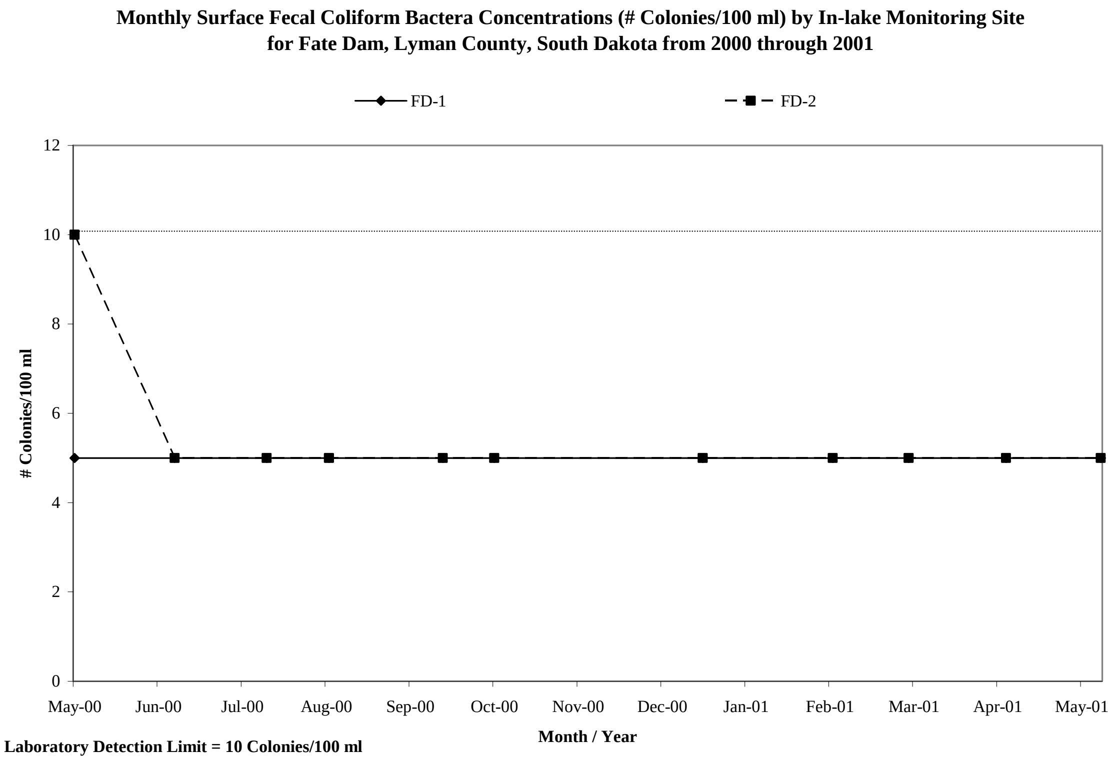


Figure 62. Surface fecal coliform bacteria colonies per 100 milliliters by date and sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

In-lake fecal coliform concentrations are typically low because of exposure to sunlight and dilution of bacteria in a larger body of water. Of the 12 individual samples collected, 100 percent of fecal coliform concentrations (Figure 62) were at or below detection limits (indicated by the arrow). The maximum concentrations (10 colonies/100 ml) were collected in May of 2000 at FD-2; all other fecal coliform counts were below laboratory detection limits. Using a value of 5 (½ the detection limit) for those samples below laboratory detection limits, the median fecal coliform bacteria count was approximately 5.0 colonies/100 ml (average 5.2 colonies/100 ml). No significant differences in fecal coliform counts were detected between in-lake sampling sites (Table 28).

Fecal coliform samples collected from Nail Creek water quality sites upstream of Fate Dam had one elevated fecal coliform counts in excess of 1,000 colonies/100 ml (Table 26). Typically, most high fecal coliform counts are collected during peak flow conditions in the early spring. The one elevated sample (1,400 colonies/100 ml) was collected in the spring during increased flows. Elevated fecal coliform values in April on Nail Creek did not translate to elevated in-lake fecal coliform bacteria (Table 26 and Figure 62). This is due in part to increased exposure to sunlight and dilution in Fate Dam. Fecal coliform concentrations in Fate Dam do not indicate animal waste is a problem.

Chlorophyll-*a*

Chlorophyll-*a* is a major pigment in algae that may be used to estimate the biomass of algae found in a water sample (Brower, 1984). Chlorophyll-*a* samples were collected at both in-lake sampling sites during the project. Overall, chlorophyll-*a* concentrations in Fate Dam were relatively moderate (Figure 62).

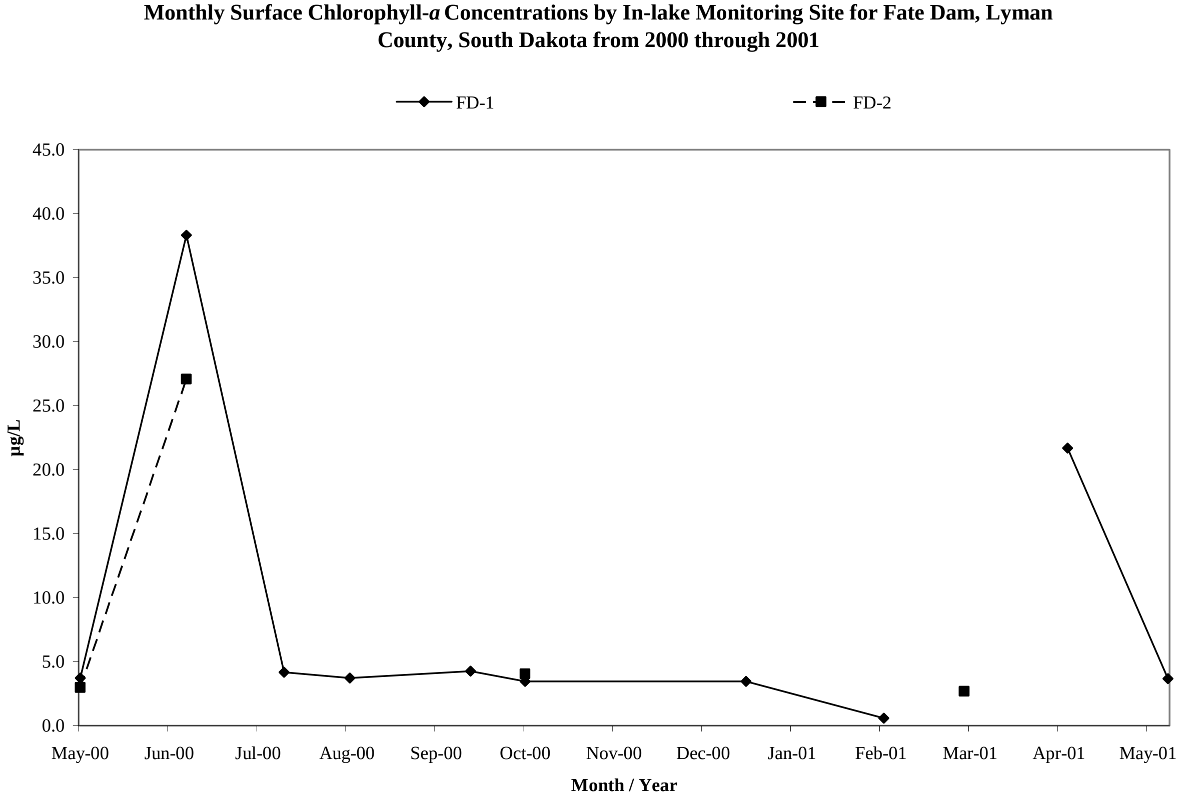


Figure 63. Monthly surface in-lake chlorophyll-*a* concentrations by date and sampling site for Fate Dam, Lyman County, South Dakota in 2000 and 2001.

The maximum in-lake chlorophyll-*a* concentration (38.3 µg/L) was collected on June 7, 2000 at FD-1 and minimum chlorophyll-*a* concentration of 0.58 µg/L collected on February 5, 2001 at FD-1 (Figure 63). The median chlorophyll-*a* concentration for the project was 3.71 µg/L (average 8.84 µg/L$^{)}$. Only four samples were collected on various dates at FD-2 (Appendix C). In-lake chlorophyll-a concentrations between sampling sites were not significantly different (Table 28).

Comparing chlorophyll-*a* concentrations between lakes within the Medicine Creek watershed indicated Fate Dam had significantly lower chlorophyll-*a* concentrations than Byre Lake and Brakke Dam (H=8.556, $_{(\alpha\,=\,0.05,\,N=45)}$, p=0.0139). Chlorophyll-*a* concentrations in Brakke Dam and Byre Lake were not statistically different (Figure 64).

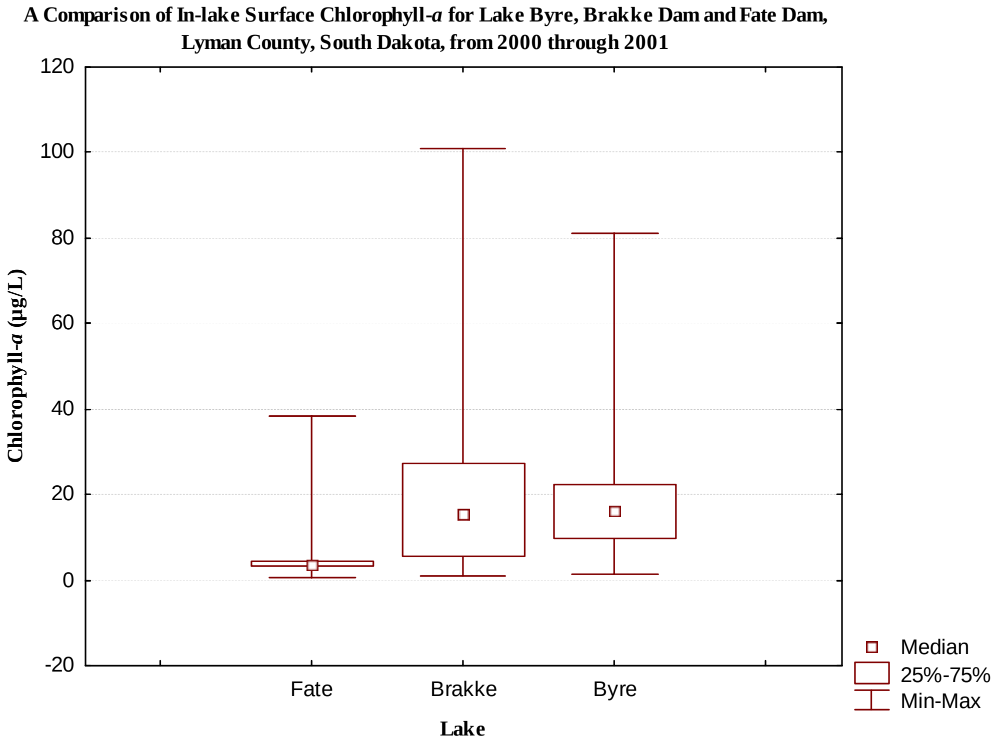


Figure 64. Comparing in-lake chlorophyll-*a* concentrations between lakes in the Medicine Creek watershed (Byre Lake, Brakke Dam and Fate Dam), Lyman County, South Dakota from 2000 through 2001.

Chlorophyll-*a* and total phosphorus can direct relationships. However, lakes usually show a different relationship because of factors including, but not limited to: nutrient ratios, temperature, light, suspended sediment, and hydrologic residence time. Generally, as total phosphorus concentrations increase, so do chlorophyll-*a* concentrations.

Chlorophyll-*a* and total phosphorus concentrations were transformed using $\mathrm{Log}_{(10)}$ to linearize the data. Chlorophyll-*a* samples for the two sites were plotted against total phosphorus concentrations to determine their relationship in Fate Dam. A regression calculation was run on all data points to determine a regression equation and R^2 value to predict chlorophyll-*a* values from total phosphorus concentrations. The R^2 is a value given for a group of points with a statistically calculated line running through them. The higher the R^2 value, the better the relationship, with a perfect relationship reached when $R^2 = 1.0$.

The statistical relationship of chlorophyll-*a* to total phosphorus was calculated as having a $R^2 = 0.2662$ (Figure 65). This indicates a relatively poor positive relationship between chlorophyll-*a* to total phosphorus. Generally, as availability of total phosphorus increases, chlorophyll-*a* concentrations also increase. Data indicate that total phosphorus is a moderate predictor of chlorophyll-a concentrations (algal populations) in Fate Dam.

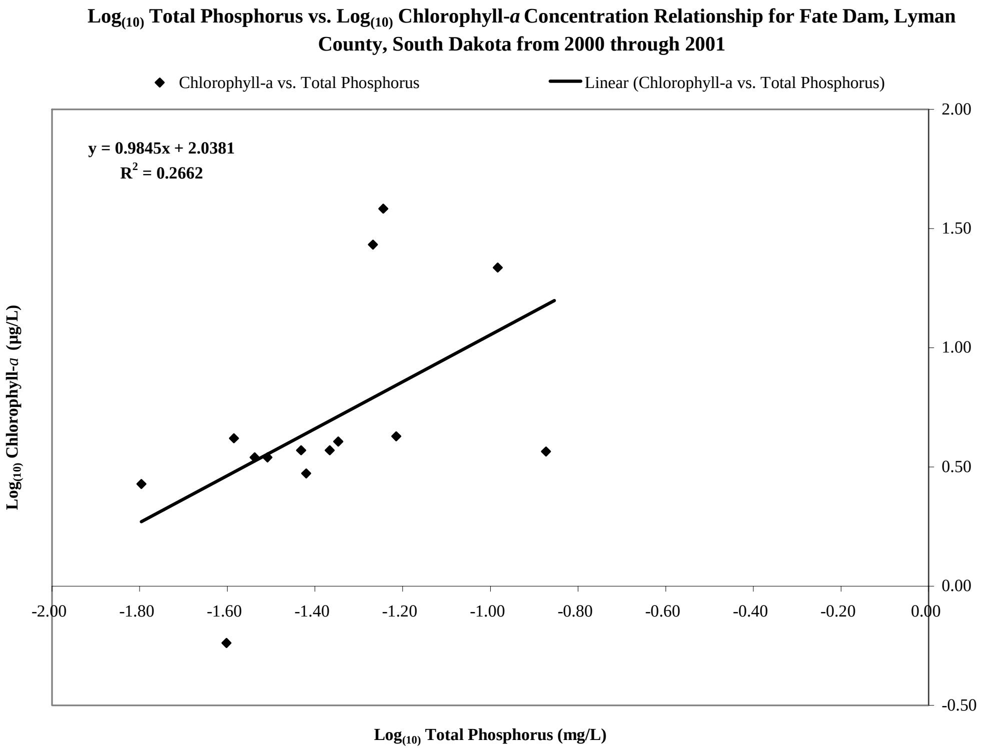


Figure 65. Log(10) chlorophyll-a concentrations vs. log (10) total phosphorus concentrations by date and in-lake sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

In-lake Total Nitrogen-to-Total Phosphorus Ratios (Limiting Nutrient)

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

In order to determine which nutrient is limiting in lakes, US EPA, (1990) has suggested an in-lake total nitrogen-to-total phosphorus ratio of 10:1. If the total nitrogen concentration divided by the total phosphorus concentration in a given sample is greater than 10, the lake is considered phosphorus-limited. If the ratio is less than 10, the waterbody is considered nitrogen-limited.

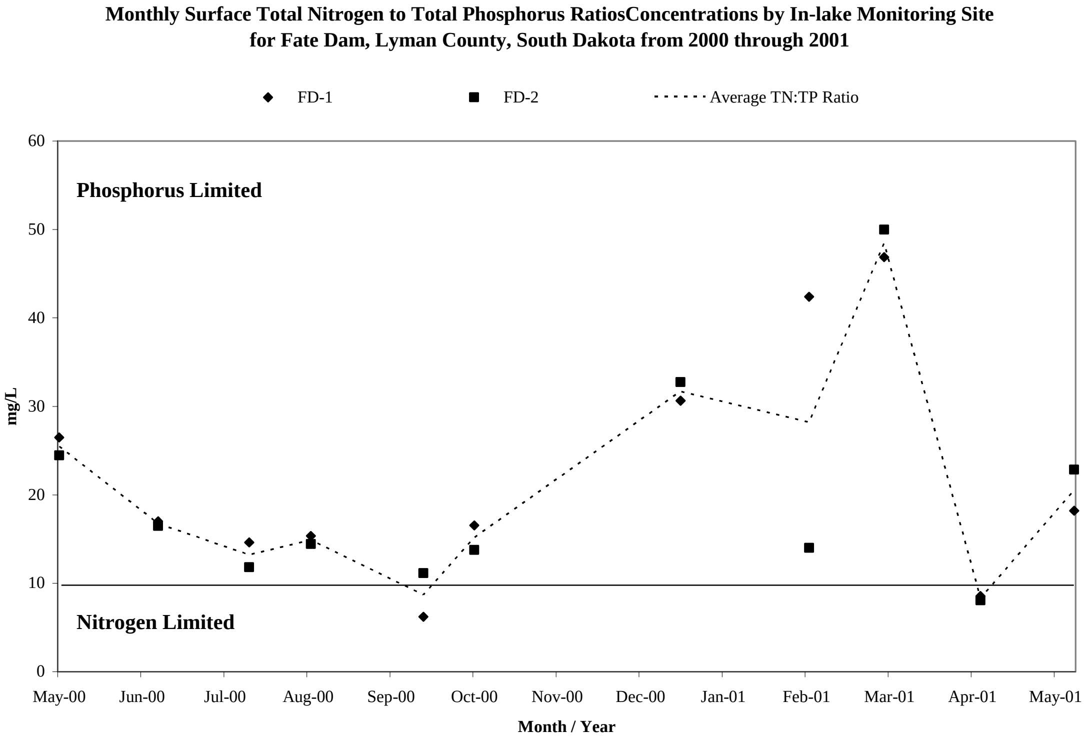


Figure 66. Surface total nitrogen-to-total phosphorus ratios by date and in-lake sampling site for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

During the project, Fate Dam was generally phosphorus-limited (Figure 66). The median in-lake total nitrogen-to-total phosphorus ratio was 16.5:1 (phosphorus-limited above 10) with an average of 21.0:1. Fate Dam was slightly nitrogen-limited in September 2000 at FD-1 and September 2000 and April of 2001 at FD-2. All total nitrogen to total phosphorus ratios between in-lake sampling sites (FD-1 and FD-2) were statistically similar (Table 28).

As stated earlier, limiting factors can be anything physical or chemical that limits the growth or production of organisms. Although phosphorus limitation was observed during most of the project, algal densities (cells/ml) increased from April through May 2001 for Fate Dam (Figure 66 and Figure 67). Algal production fluctuated (increased and decreased) at the same time total nitrogen-to-total phosphorus ratios varied only slightly (always nitrogen-limited), indicating nutrients may not be as limiting as other factors in determining algae population densities.

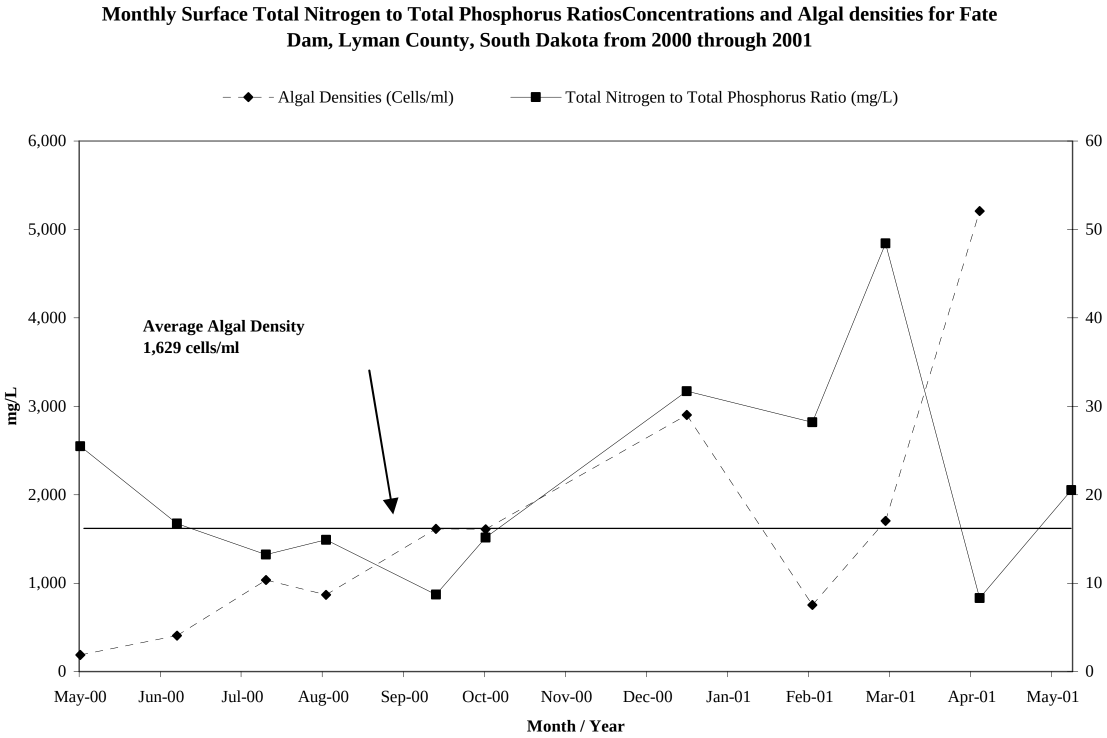


Figure 67. Average monthly surface total nitrogen-to-total phosphorus ratios and algal densities (cells/ml) for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Fate Dam Hydrologic, Sediment and Nutrient Budgets

Hydrologic Budget

The hydrologic budget estimates how much water entered the lake and how much water left the lake. The hydrologic, sediment and nutrient budgets will be based on 2000 through 2001 tributary sampling data. Sampling and gauging began in the spring of 2000 and continued until ice up and began again when ice left the stream and continuous discharge measurements could be collected.

Hydrologic inputs to Fate Dam included precipitation, tributary runoff, both gauged and ungauged areas of the watershed. Hydrologic output from Fate Dam included the water leaving the lake over the spillway from March through May 2001, evaporation and initial volume loss (initial lake level when project began). Precipitation data for Kennebec, South Dakota was acquired from the state climatologist in Brookings, South Dakota. Tributary sites were gauged when possible, and, ungauged discharge was estimated using gauged hydrologic export coefficients.

In many projects, the volume of water above or below the level of the spillway at the beginning or end of the project is calculated as an input or output. Fate Dam was 0.32 feet (48.35 acre-feet) below spillway height at the beginning of the study (Table 33). During the study period, water was below the level of the spillway 355 days out of 400 days of monitoring (88.7 percent).

Table 33. Hydrologic budget for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Tributary	Input (acre-feet)	Tributary	Output (acre-feet)
Nail Creek (MCT-6)	3,069.00	**Outlet Discharge (MCT-8)**	2,736.90
Rainfall on Fate Dam	191.25	**Evaporation**	475.00
		Initial Volume Loss	48.35
Total	**3,260.25**		**3,260.25**

The hydrologic budget for Fate Dam is provided in Table 33. Table 33 incorporates precipitation and evaporation in both the input and output calculations/estimations. The hydrologic budget was developed using output data from the FLUX model (Walker, 1999). One factor never directly measured in Fate Dam was the total volume of ground water that passed through the lake. Ground water in the area (based on alluvial wells (all are $\geq$ 30 feet)) is relatively deep and generally of poor drinking water quality. Generally, ground water usually has little effect on the overall water quality of the lake due to the reduced percentage contributed from this source. It was assumed that the same amount of ground water entered the lake as left the lake.

Major source of hydrologic input to Fate Dam was MCT-6 (Nail Creek Inlet to Fate Dam) at 94.1 percent of the total hydrologic load followed by rainfall directly on Fate Dam contributing 5.9 percent. The hydraulic residence is the time between when water enters a reactor (lake) and that same water leaves the reactor. The hydraulic residence time when Fate Dam is full was estimated at 0.42 years or 159days (calculated using BATHTUB (Walker, 1999)).

Total Dissolved Solids Budget

Total dissolved solids is that portion of total solids that pass through a filter and are typically composed of earth compounds, particularly bicarbonates, carbonates, sulfates and chlorides which also determines salinity (Wetzel, 1983). Fate Dam watershed is part of and drains directly into Medicine Creek. Medicine Creek is listed in the 1998 and 2002 303(d) list and the 2004 Integrated Report for total dissolved solids and conductivity (SD DENR 1998, SD DENR 2002 and SD DENR 2004). Discharge from Fate Dam directly affects total dissolved solids (dissolved ions) which in turn affect specific conductance (conductivity @ 25°C) in Medicine Creek (Figure 7).

Data indicate approximately 72 percent of the total dissolved solids load was discharged back into Nail Creek (via the Fate Dam outlet (MCT-8)) to load/effect Medicine Creek total dissolved solids concentrations (Figure 68). Total dissolved solids loading and concentrations in 2001 at MCT-8 (Fate Dam/Nail Creek watershed) were not a significant contributor to elevated total dissolved solids or conductivity values (based on tributary TDS-conductivity relationship (Figure 7)) in Medicine Creek over the project period.

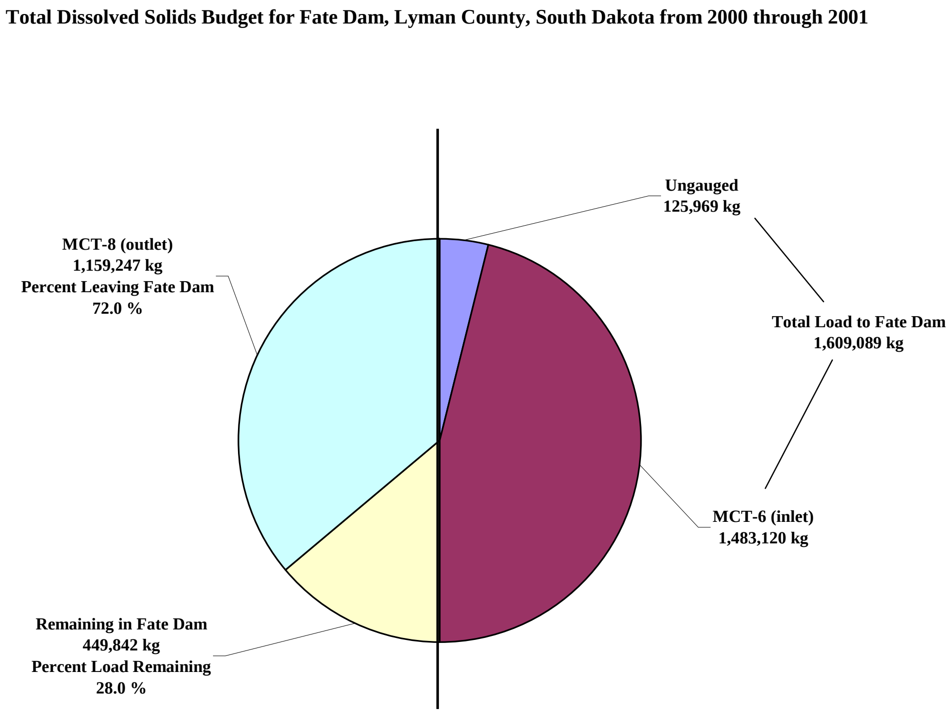


Figure 68. Percent total dissolved solids budget for Fate Dam, Lyman County, South Dakota by source from 2000 through 2001.

Suspended Solids Budget

As described in the tributary section of the report, overall suspended solids loads from the watershed did not appear to be significant during the sampling period. According to data collected from Nail Creek and the estimated amount from the ungauged portion of the watershed, Fate Dam received approximately 626.4 m^3 (0.51 acre-feet) of sediment, during this study. The volume of sediment was calculated by dividing the annual kilograms of sediment (1,354,603 kg) by 2,162.5 kg/m^3 (Stueven and Bren, 1999).

The calculation of total suspended solids at the outlet (MCT-8) found approximately 141,533 kg or 65.4 m^3 (0.05 acre-feet) or 10.4 percent of the total suspended solids load to Fate Dam. The amount of suspended solids retained in Fate Dam during this study was approximately 1,213,070 kg, which is 561.0 m^3 (0.45 acre-feet) or 89.6 percent of the total of suspended solids loading to the lake (Figure 69). This translates to an overall increase of 0.92 mm in sediment depth over the entire lake.

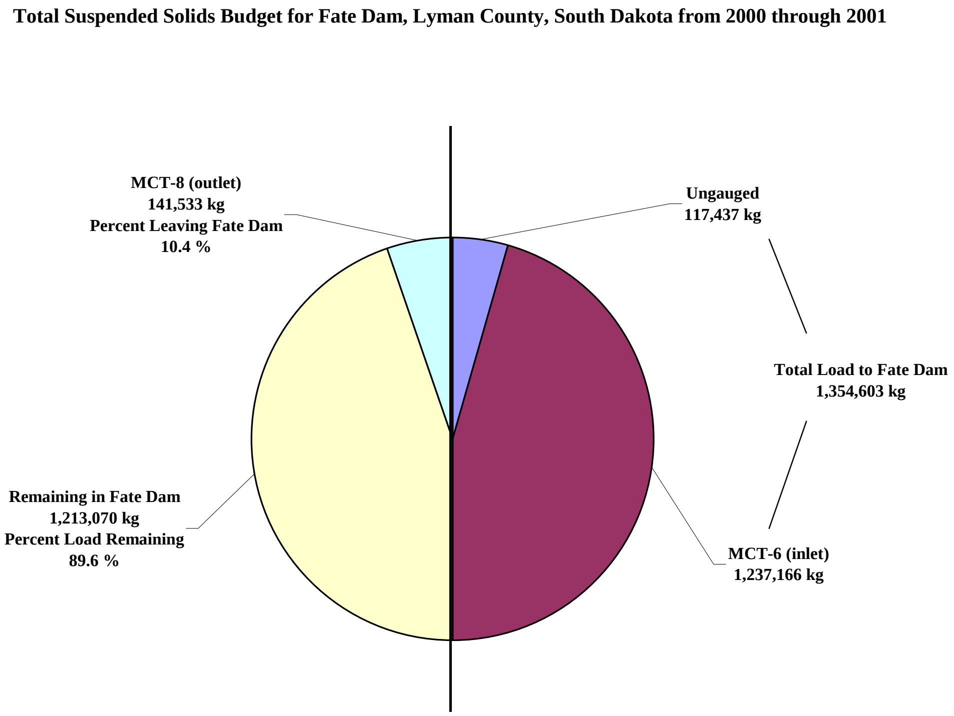

Total Suspended Solids Budget for Fate Dam, Lyman County, South Dakota from 2000 through 2001

Figure 69. Percent total suspended solids budget for Fate Dam, Lyman County, South Dakota by source from 2000 through 2001.

To estimate the average organic portion of total suspended solids leaving Fate Dam, the total kilograms per year of volatile total suspended solids (VTSS) were divided by the total suspended solids to predict the percentage of organic suspended solids. The organic percentage of suspended solids measured at MCT-6 (Fate Dam inlet) during the project was 10.5 percent. In comparison, the overall average in-lake percentage of volatile total suspended solids at FD-1 was

37.5 percent while the percentage of volatile total suspended solids at FD-2 was 12.5 percent (Fate Dam average 23.2 percent). An increase in organic composition of total suspended solids from tributary to in-lake percentages was observed in Fate Dam. A large portion of this increase may be attributed to in-lake algal populations and macrophyte decay. The estimated volatile total suspended solids percentage discharged from Fate Dam was 16.6 percent. Reducing suspended solids concentrations to Fate Dam should be beneficial in reducing trophic state indices and the partially supporting (eutrophic) condition of the lake.

Total Nitrogen Budget

Tributary loadings were taken from the water quality data collected at MCT-6 and the ungauged portion of the watershed (estimated based on gauged export coefficients). Ground water loading was not considered in the overall input budget because there was no way to measure the input or fate of ground water total nitrogen from the time it enters the lake until it leaves.

Atmospheric nitrogen can enter a waterbody in many forms: as nitrogen, nitric acid, ammonia, nitrite, and as organic compounds either dissolved or particulate (Wetzel, 1983). It was not possible to know what ratio of inorganic to organic nitrogen entered the lake from the atmosphere. Blue-green algae are able to fix atmospheric nitrogen; however, the rate and amount at which atmospheric nitrogen was incorporated could not be determined given the scope of this project. Because no water quality data from precipitation was collected, the inputs will be estimated as minimal and not considered in this report.

Total nitrogen concentrations are derived from adding TKN concentrations to nitrate–nitrite concentrations. Figure 70 indicates a total nitrogen load of 22,039 kg (24.3 tons) to Fate Dam, of which, approximately 12,438 kg (13.7 tons) or 56.4 percent of the total nitrogen load was retained in Fate Dam during the project. As was discussed previously, total nitrogen is used along with total phosphorus to determine limiting nutrients (ratio) which may affect algal metabolism for growth and chlorophyll-*a* production. Tributary total nitrogen-to-total phosphorus ratios indicated a nitrogen limited system (7.1**:**1) in 2001, while in-lake ratios indicated a mostly a phosphorus-limited system (14.8**:**1) from 2000 through 2001 (Figure 32 and Figure 66).

All forms of nitrogen can eventually be broken down and reused for algal growth. Reducing the influx of nitrogen will be beneficial for reducing the eutrophic (partially-supporting) condition found in Fate Dam.

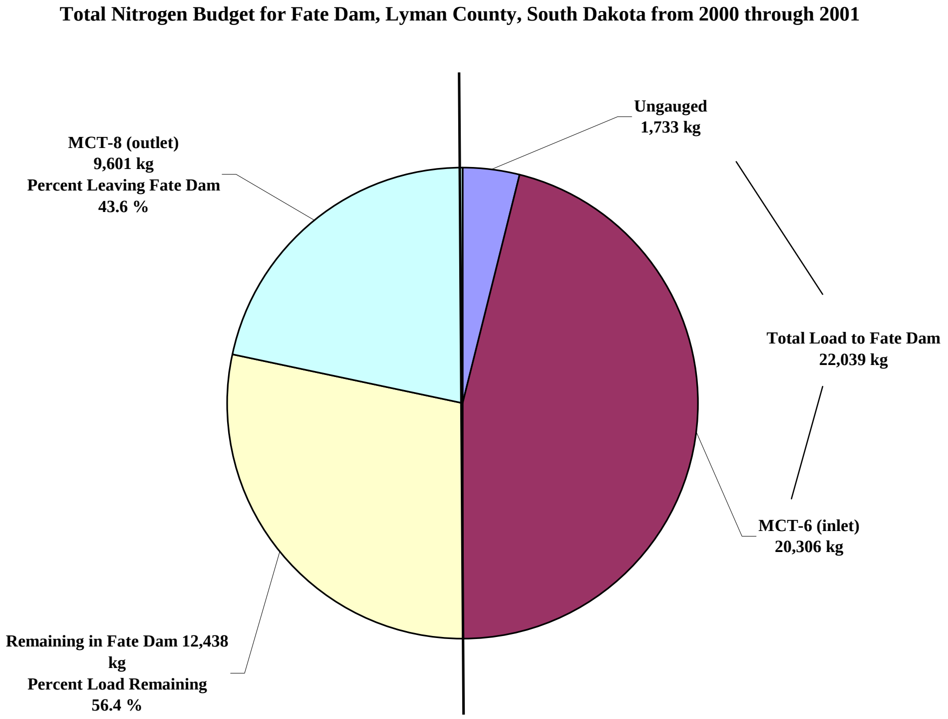


Figure 70. Percent total nitrogen budget for Fate Dam, Lyman County, South Dakota by source from 2000 through 2001.

Total Phosphorus Budget

Total phosphorus inputs during the 2000 through 2001 sampling season totaled approximately 3,440 kg (3.8 tons) to Fate Dam (Figure 71). The ground water portion of the phosphorus budget in most lakes is insignificant compared to tributary inputs. As with nitrogen, there is no way to know how much ground water entered the lake and how much left the lake. Phosphorus residence time for Fate Dam was calculated using BATHTUB (Walker, 1999) and was estimated to be 0.03 years or 12 days.

The total load out of Fate Dam via the spillway was approximately 749 kg (0.38 tons). During the 2000 through 2001 sampling season, there was an estimated 2,691 kg (2.9 tons), or 78.2 percent of the phosphorus entering Fate Dam stayed and was available or utilized in the lake. Increased in-lake concentrations of total phosphorus were observed during spring runoff in 2001. Variable total phosphorus and total nitrogen concentrations contributed to the nutrient limitations (especially phosphorus) observed in Fate Dam from 2000 through 2001.

Reducing the influx of total phosphorus will improve the overall trophic state of the lake and increase the beneficial use status of Fate Dam.

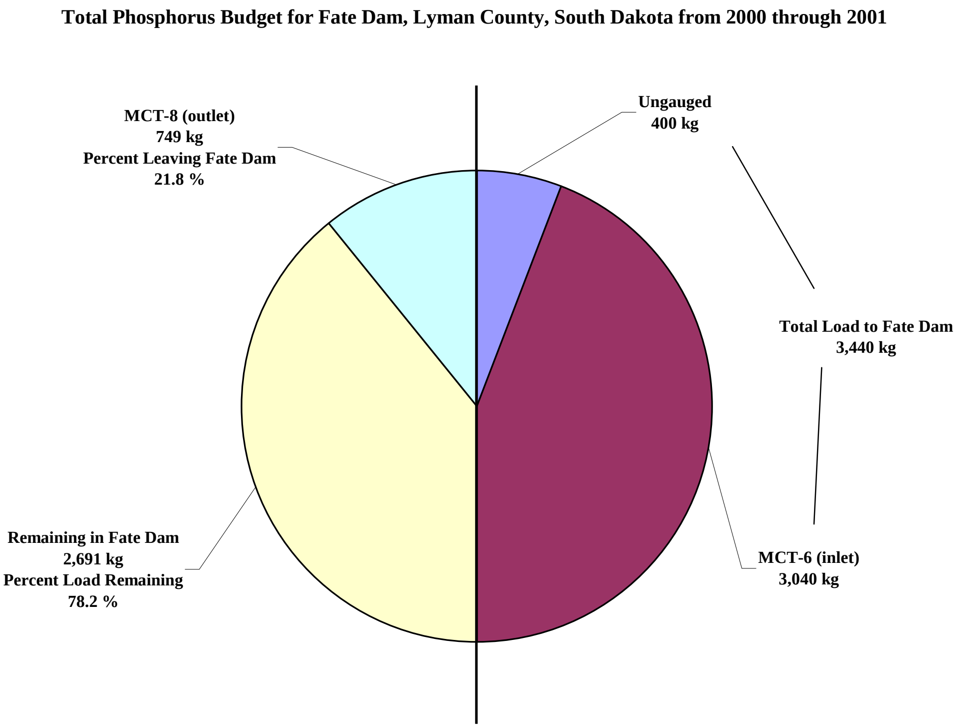


Figure 71. Percent total phosphorus budget for Fate Dam, Lyman County, South Dakota by source from 2000 through 2001.

Total Dissolved Phosphorus Budget

The inputs (loads) of total dissolved phosphorus (Figure 72) to Fate Dam were estimated at 1,263 kg (1.4 tons). Fate Dam retained approximately 67.4 percent or 852 kg (0.94 tons) of the total dissolved phosphorus load. Tributary loading percentage of total dissolved phosphorus to total phosphorus was 47.0 percent while the outlet percentage of total dissolved phosphorus increased to 57.5 percent. The 10.5 percent difference may imply in-lake internal processing (loading) of total dissolved phosphorus or may represent a higher percentage of dissolved organic phosphorus compounds, which are utilized at a slower rate than inorganic forms (Wetzel, 2001).

Reducing the influx of total dissolved phosphorus will improve the overall trophic state of Fate Dam.

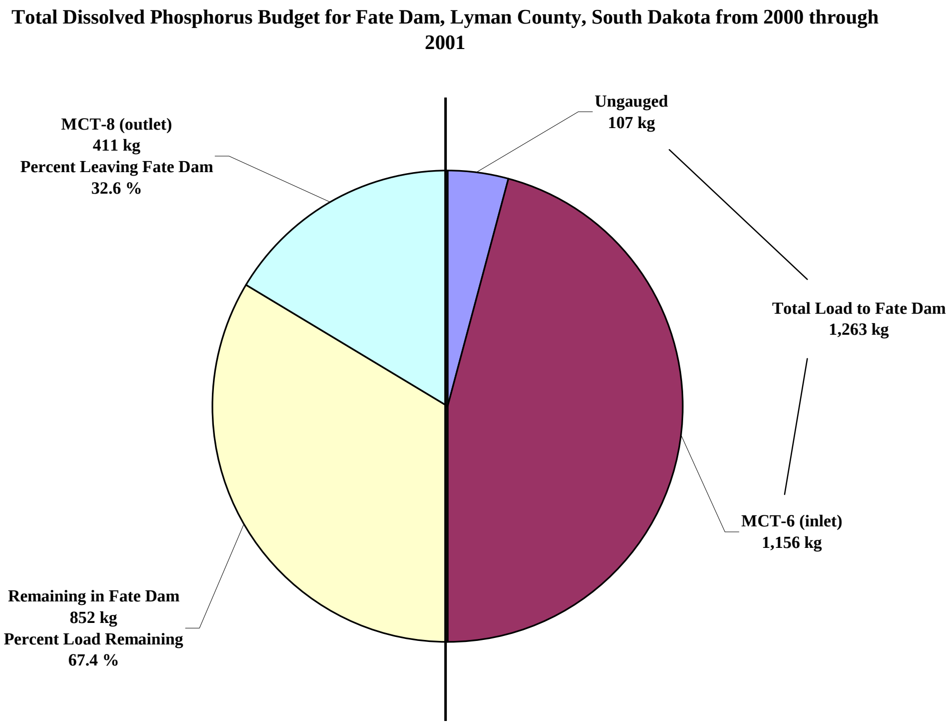


Figure 72. Percent total dissolved phosphorus budget for Fate Dam, Lyman County, South Dakota by source from 2000 through 2001.

Trophic State Index

Carlson's (1977) Trophic State Index (TSI) is one index that can be used to measure the relative trophic state of a waterbody. The trophic state estimates how much algal production occurs in lakes. The lower the nutrient concentrations are, the lower the trophic level (state), and the higher the nutrient concentrations, the more eutrophic (nutrient-rich) the lake. Trophic states range from oligotrophic (least productive) to hyper-eutrophic (excessive amounts of nutrients and production). Excessive or increased nutrient concentrations can impact aquatic communities, especially the algal community and can create excessive production. Overproduction creates algal blooms that adversely impact the structure and function of indigenous or intentionally introduced aquatic communities (ARSD § 74:51:01:12). Table 34 describes the different numeric limits applied to various levels of the Carlson Index.

Three different parameters are used to compare the trophic index of a lake: 1) total phosphorus, 2) Secchi disk, and 3) chlorophyll-*a*. The TSI trophic levels and numeric ranges applicable to Fate Dam are shown in Table 35 and a graph showing the monthly TSI parameters for 2000 and 2001 are plotted on Carlson's trophic levels are shown in Figure 73.

Table 34. Carlson trophic levels and numeric ranges by category

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

In May 2000, SD DENR published *Ecoregion Targeting for Impaired Lakes in South Dakota*. This document proposed ecoregion-specific targeted TSI values based on beneficial uses. October 2000, EPA approved the use of ecoregion-specific targets to evaluate lakes using beneficial use categories. Generally, TSI values are now evaluated based upon ecoregion-specific beneficial use categories. This was done to evaluate lakes based upon other lakes within each level III Ecoregion instead of a statewide comparison as was formerly done. Fate Dam is in Ecoregion 43 and is categorized as partially supporting based on the document above. There are three beneficial use categories: non-supporting, partially supporting and fully supporting. Numeric ranges for beneficial use categories are shown in Table 35.

Table 35. Ecoregion 43 beneficial use category and Carlson TSI numeric ranges by beneficial use category.

Ecoregion (43) Beneficial Use Category	TSI Numeric Range
Non-Supporting	71 – 100
Partially Supporting	56 – 70
Fully Supporting	0 – 55

Trophic State Index values are plotted using beneficial use categories in Figure 74. Generally, most of the TSI values (85.2 percent) were in the partially or fully supporting category. Based on ecoregion targeting, Fate Dam is categorized as partially supporting. The mean and median for observed ecoregion targeted total phosphorus, Secchi and chlorophyll-*a* TSI were partially supporting (eutrophic) category (Table 37), with an average rating of 60.81 TSI (median 60.64). After model calibration, the mean observed ecoregion targeted TSI value (60.81, median 60.64) was less than one TSI point (0.90 TSI) from the mean modeled TSI using BATHTUB (59.91).

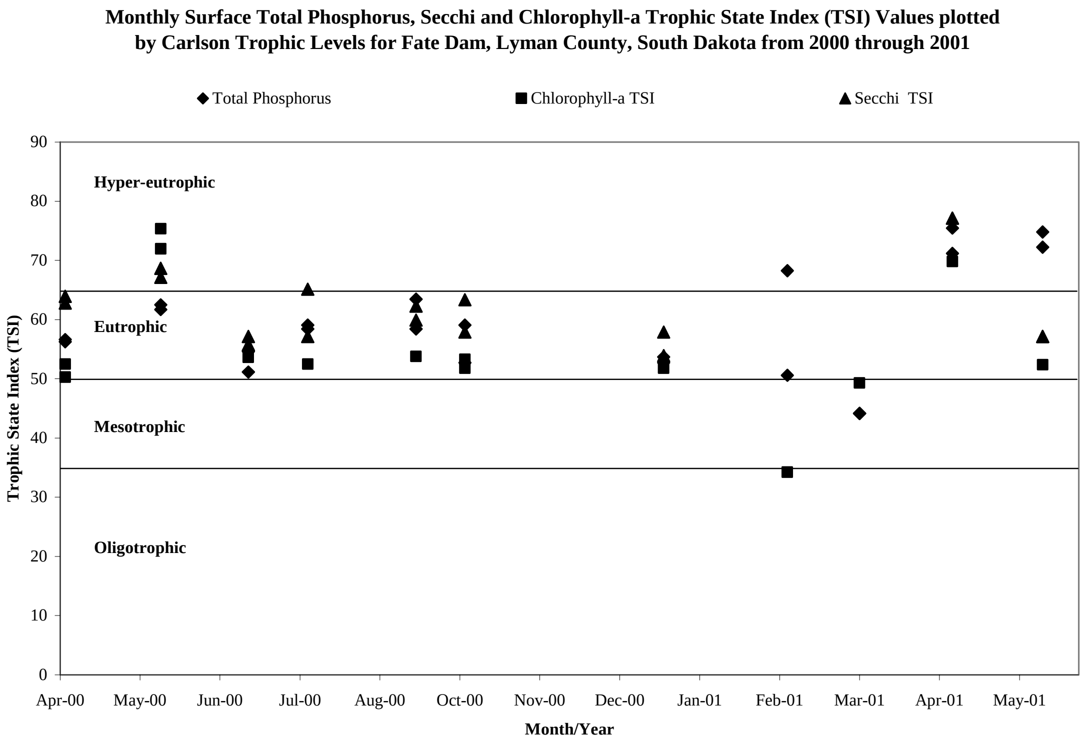


Figure 73. Monthly TSI values for total phosphorus, Secchi and chlorophyll-*a* TSI plotted by Carlson trophic level from Fate Dam, Lyman County, South Dakota by date from 2000 through 2001.

Excessive total phosphorus resulting in elevated TSI values are the result of elevated in-lake total phosphorus concentrations (Figure 73 and Figure 74). Based on current data Fate Dam will not meet ecoregional beneficial use criteria. Unrealistic reductions in total phosphorus loads (62 percent) are needed to achieve ecoregion 43 criteria. Realistic criteria/goals for Fate Dam should be based on modified/alternative site specific criteria resulting in watershed specific attainability (Table 36). Alternative attainable AnnAGNPS modeled criteria for Fate Dam attainability would require a 19.5 percent reduction in tributary loading to meet site specific TSI criteria. BMP reductions in total phosphorus will lower in-lake total phosphorus, Secchi and chlorophyll-*a* TSI values, improving water quality in Nail Creek and Fate Dam.

Table 36. Proposed Fate Dam alternative site specific beneficial use category

Fate Dam Alternative (Site Specific) Beneficial Use Category	TSI Numeric Range
Non-Supporting	71 – 100
Partially Supporting	60 – 70
Fully Supporting	0.0 – 59

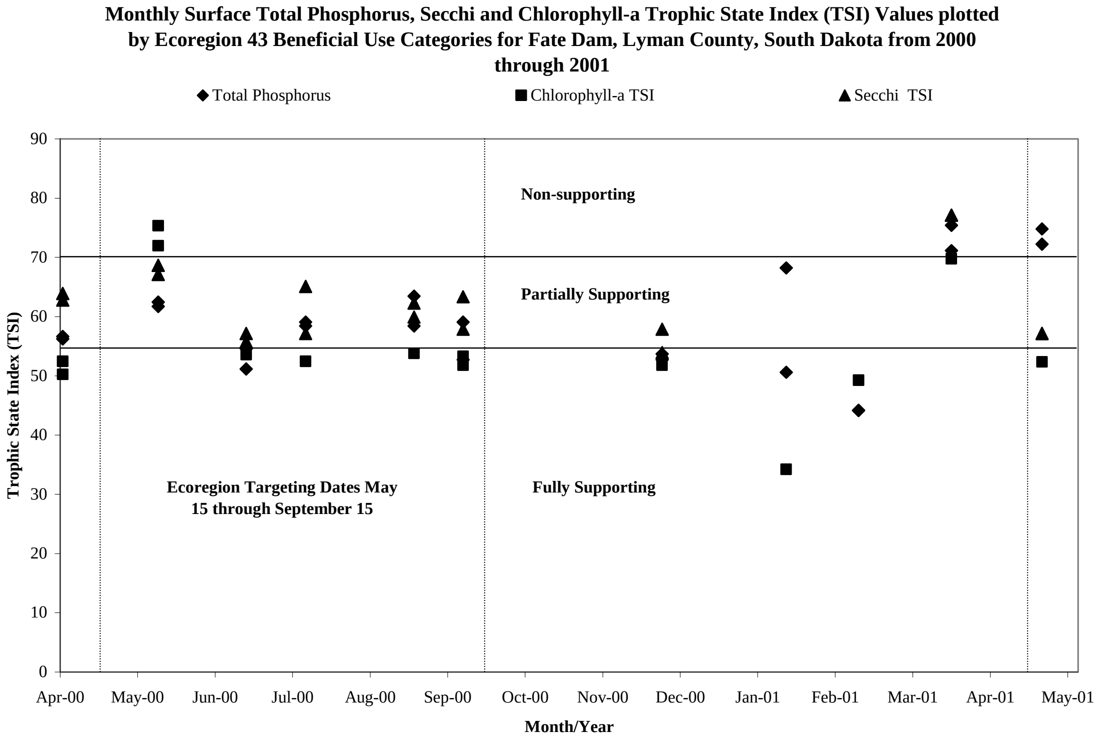


Figure 74. TSI values for phosphorus, chlorophyll-*a* and Secchi TSI plotted by Ecoregion 43 beneficial use categories for Fate Dam, Lyman County, South Dakota by date in 2000 and 2001.

Table 37. Descriptive statistics for observed and modeled Trophic State Index values and initial modeled values for Fate Dam, Lyman County, South Dakota in 2000 through 2001.

Parameter	Total Phosphorus	Chlorophyll-*a*	Secchi Depth	Parameters Combined
Ecoregion Targeted Dates (May 15 through September 15)				
Average TSI	61.63	60.75	59.92	60.81
Median TSI	60.38	58.53	53.70	60.64
Standard Deviation	7.28	4.74	10.71	4.99
BATHTUB Modeled TSI Values for Fate Dam				
Modeled Average TSI	63.44	56.12	60.18	59.91
All Dates (May 2000 through May 2001)				
Average TSI	59.14	62.31	55.18	58.78
Median TSI	58.41	61.10	52.47	58.06
Standard Deviation	8.95	6.78	10.58	8.62

Long-Term Trophic State Index Trend

Because there were a number of samples collected from this study and during the Statewide Lake Assessment surveys (Stueven and Stewart, 1996) it was possible to make some assumptions about water quality trends (TSI) in Fate Dam over time. Since samples taken in 1979, 1989, 1991 and 1994 and during this study were collected during the ecoregion targeted dates (May 15 through September 15) long-term trend analysis was evaluated. Long-term TSI values were plotted on current Ecoregion 43 beneficial use criteria and site specific criteria for comparison (Figure 75 and Figure 76).

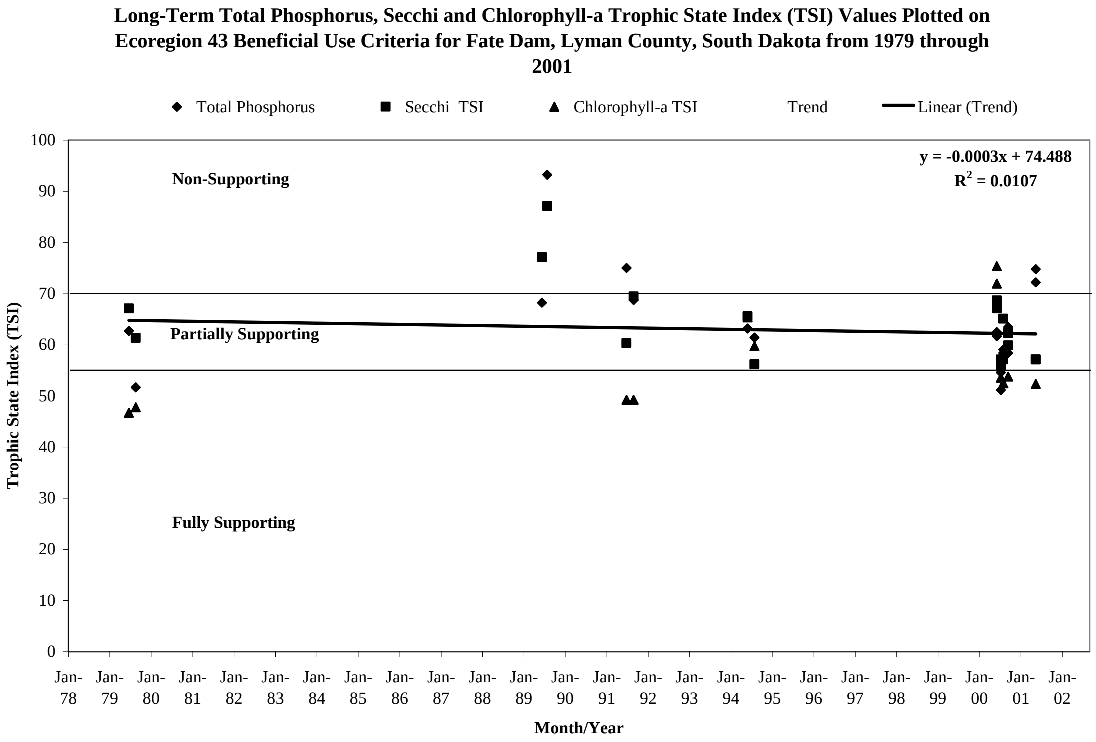


Figure 75. Long-term summer TSI trend for phosphorus, chlorophyll-*a* concentrations and Secchi depth plotted by Ecoregion 43 trophic level criteria for Fate Dam, Lyman County, South Dakota by year.

The general trend for all TSI values (Secchi, chlorophyll-*a* and total phosphorus) showed a very slight decrease from 1979 through 2001 (slope = -0.0003). However, the range of TSI values after 1991 varied similarly and was relatively stable (Figure 75). Higher TSI values in 1989, if removed, would show a slightly increasing trend line (slope = 0.0005). No in-lake water quality samples were collected from 1994 through 2000 in Fate Dam.

Four chlorophyll-*a*, fifteen total phosphorus and all Secchi, TSI values were in the partially supporting and non-supporting (eutrophic/hyper-eutrophic) categories (Figure 75) based on current ecoregion targeted beneficial use categories. Approximately 60.4 percent of all long-term TSI values in Fate Dam were in the partially supporting category. Long-term TSI trend values plotted on site specific criteria and were similar to current ecoregion 43 criteria which indicate a decreasing trend within the partially supporting category (Figure 75 and Figure 76). Mitigation projects (estimated BMP reductions) in the Fate Dam watershed should, over time, reduce nutrient TSI values, complementing the overall trend observed from 1989 to 2001.

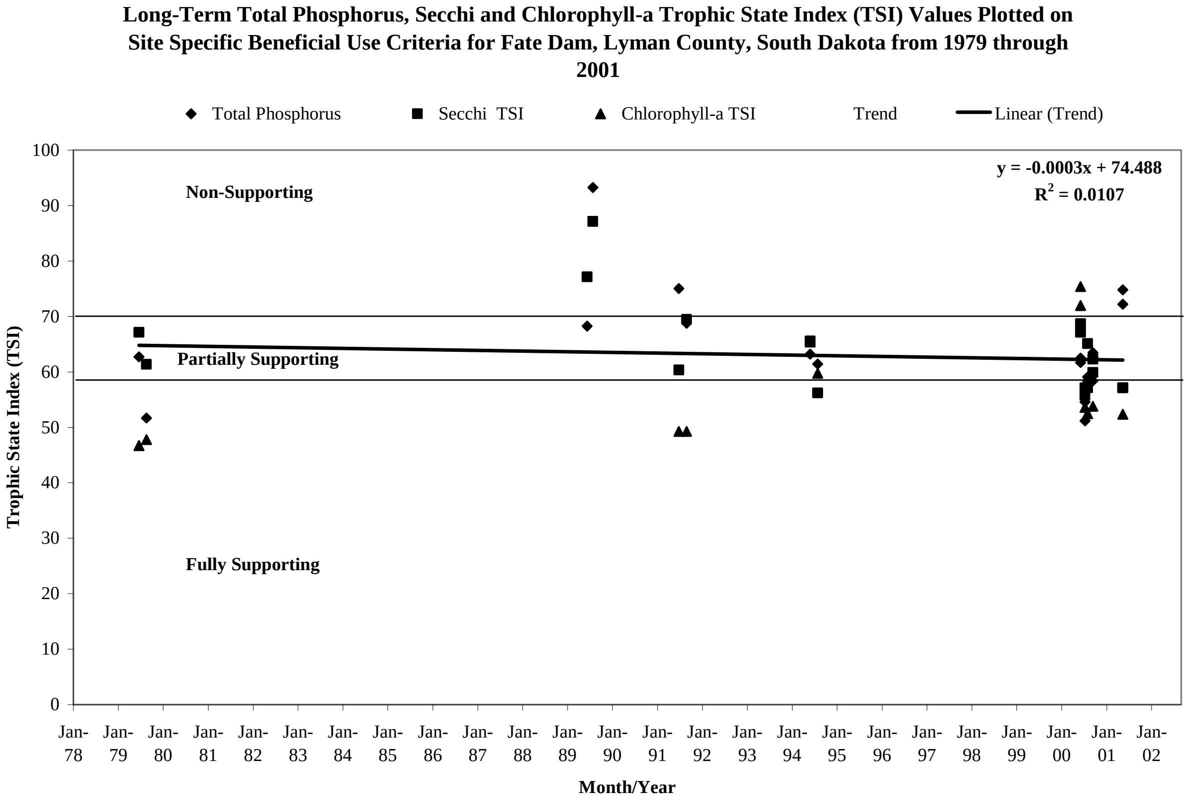


Figure 76. Long-term summer TSI trend for phosphorus, chlorophyll-*a* concentrations and Secchi depth plotted by site specific beneficial use criteria in Fate Dam, Lyman County, South Dakota by year.

Biomass Based Spatial Comparisons

Fate Dam TSI data from 2000 through 2001 indicate total phosphorus and Secchi depth were relatively balanced and were not limiting biomass (chlorophyll-a); based on spatial position. TSI data points oscillating around zero for both the X (phosphorus-limited above the X-axis and something other than phosphorus limitation below the X-axis) and Y-axis (transparency greater than predicted from chlorophyll-*a* index right of the Y-axis and transparency less than predicted suggesting nonalgal factors (organic matter or suspended sediment) left of the Y-axis ((Wetzel, 2001)). Observed oscillations (spread) maybe related to yearly or seasonal variations in hydrologic, nutrient and internal loading (Figure 77). This scenario related well with in-lake total phosphorus concentrations and algal densities. Data indicate that Fate Dam is relatively balanced and tends to be phosphorus limited most of the year (Figure 66).

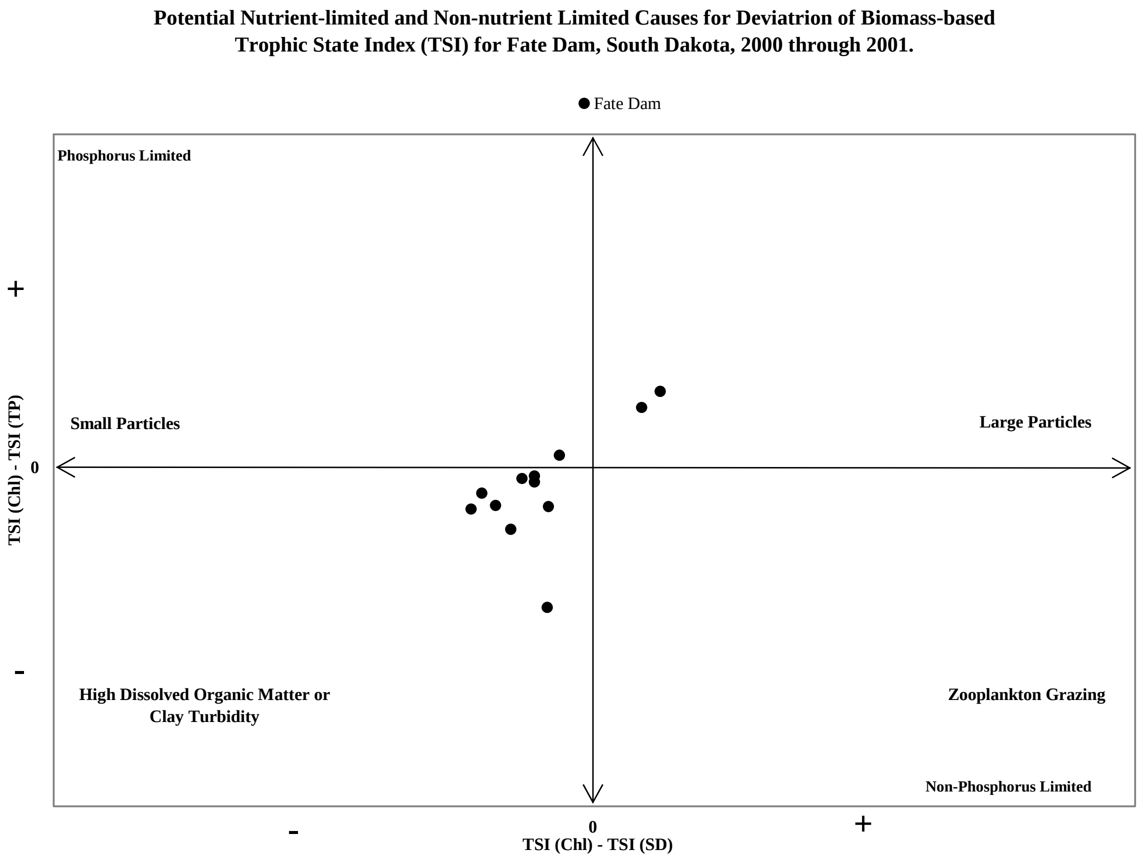


Figure 77. Potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) for Fate Dam, Lyman County, South Dakota in 2000 and 2001.

As part of the Medicine Creek watershed assessment (2000 through 2001), data was also collected on Byre Lake and Brakke Dam for separate evaluation and analysis. Brakke Dam, Fate Dam and Byre Lake TSI values adjusted using chlorophyll-*a* are provided in Figure 78 for evaluation and regional comparison.

Similar to Fate Dam, both Brakke Dam and Byre Lake, TSI data generally oscillated around zero (0), around both the X and Y-axis (Figure 78). All three lakes were relatively similar in seasonal phosphorus (generally oscillating around the X-axis) and seasonal variations in Secchi transparency (generally oscillating around the Y-axis) affecting biomass. Part of the seasonal similarity in biomass based TSI data is that all three lakes are in the same watershed (Medicine Creek) and county with similar agricultural disturbances.

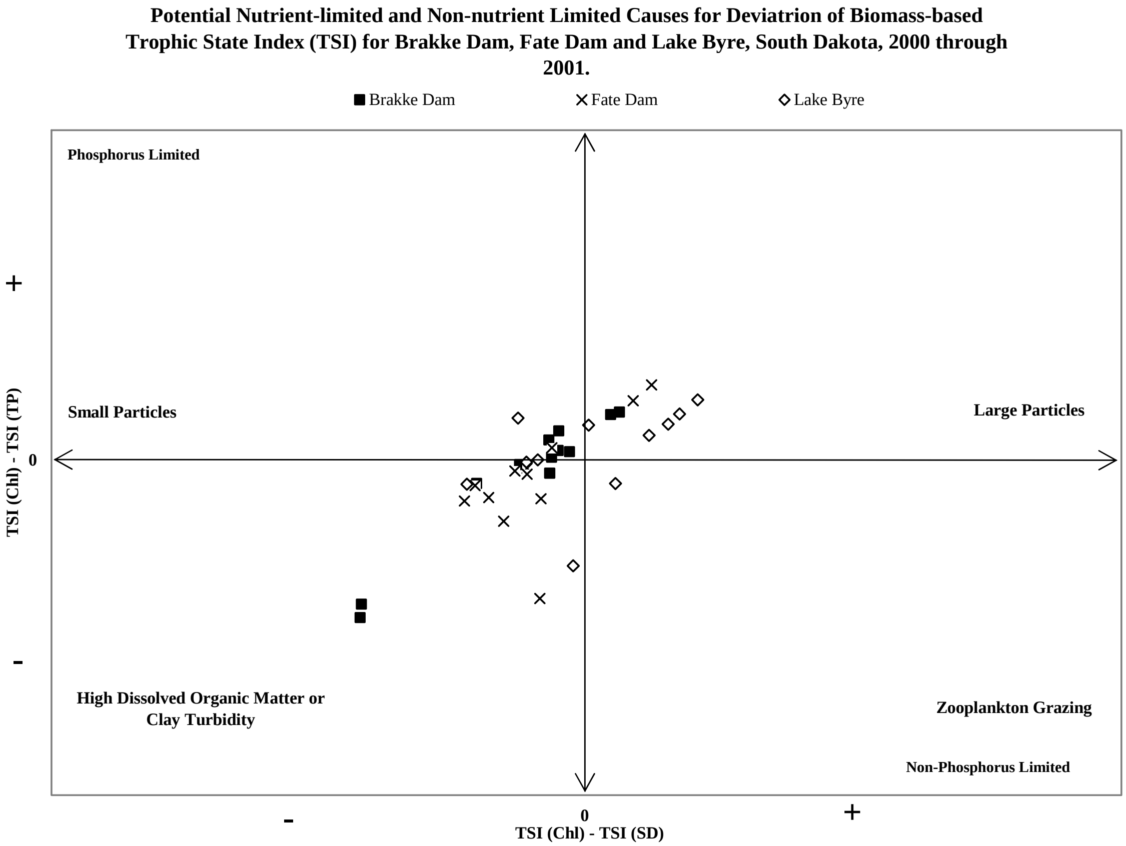


Figure 78. A comparison of potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) between Fate Dam, Fate Dam, and Fate Dam, Lyman County, South Dakota.

Long-term Biomass Based Spatial Trends

Long-term ecoregion targeted TSI data for Fate Dam was also graphed to determine causes in deviation from biomass-based TSI trends (Figure 79). Fate Dam TSI data from 1979 through 2001 (22-years) indicated neither phosphorus nor non-phosphorus limitation effected biomass (dashed diagonal line passing near the 0, 0 intercept). Transparency variations along the diagonal line represent yearly biomass changes in transparency and not nutrient limitations. Long-term yearly variations in biomass ranged from transparency greater than predicted, (dashed box, large algal particles) to transparency less than predicted (gray box, increased organic or clay turbidity). Based on Carlson's biomass plot, long-term data indicate variations in transparency in Fate Dam was less than predicted (gray box) due to increased dissolved organic matter or clay turbidity (Carlson 1991).

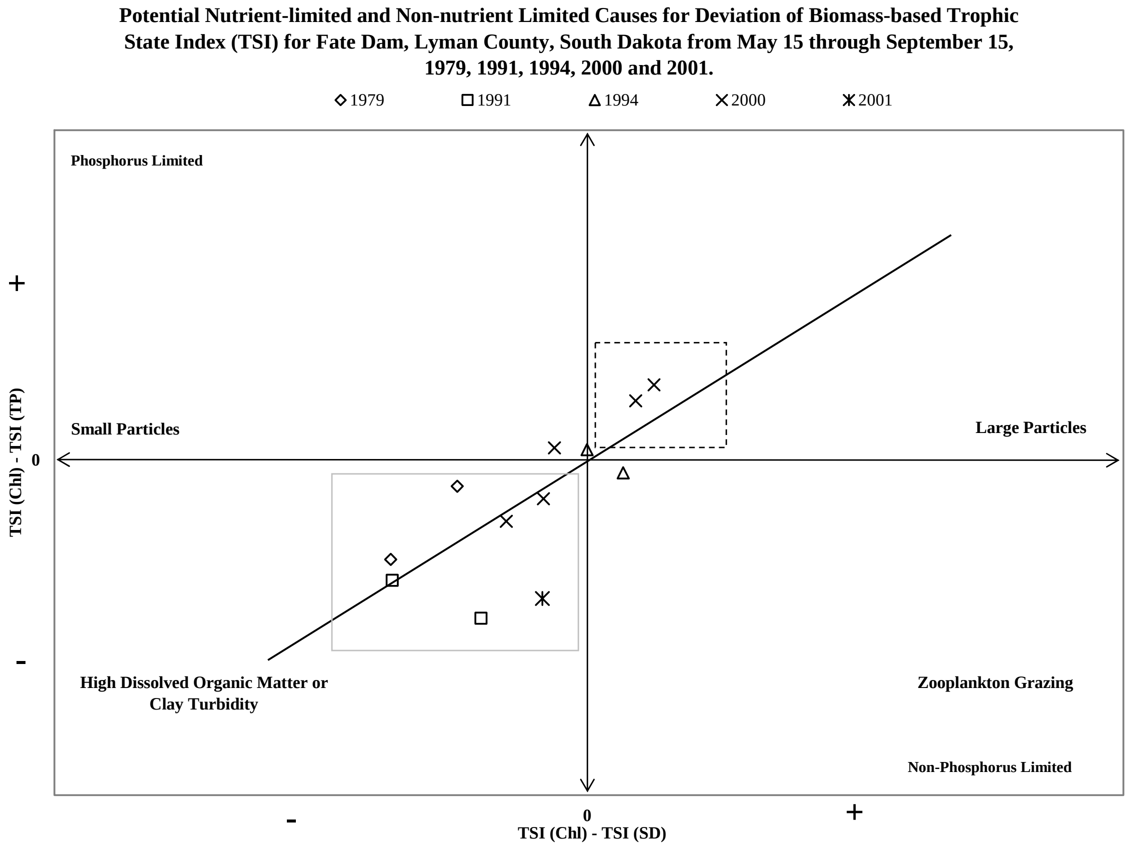


Figure 79. Long-term potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) for Fate Dam, Lyman County, South Dakota May 15 through September 15, 1979, 1991, 1994, 2000 and 2001.

Reduction Response Model (BATHTUB)

The reduction response model used to predict in-lake response to reductions in tributary input was BATHTUB (Walker, 1999). BATHTUB is predictive in that it will assess impacts of changes in water and/or nutrient loadings, and estimate nutrient loadings consistent with given water quality management objectives. In-lake and tributary data collected from this project was used to calculate existing conditions and to predict parameter-specific and mean TSI values based on general reductions in loadings from the Fate Dam watershed for 2000 and 2001 (Table 38).

Table 38. Existing and predicted tributary reductions in nitrogen and phosphorus concentrations and predicted in-lake mean TSI values using the BATHTUB model.

	Percent Nutrient Reduction										
Parameter	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**95%**
Total Phosphorus (mg/m^3)	61.04	57.78	54.37	50.7	46.82	42.59	37.87	32.59	26.36	18.22	12.77
Total Nitrogen (mg/m^3)	980	980	980	980	980	980	980	980	980	980	980
Composite Nutrient (mg/m^3)	45.77	44.34	42.75	40.89	38.77	36.27	33.22	29.48	24.63	17.62	12.56
Chlorophyll-*a* (mg/m^3)	13.48	13.07	12.6	11.96	11.24	10.4	9.38	8.1	6.52	4.32	2.83
Secchi (Meters)	0.99	1.01	1.04	1.08	1.13	1.19	1.27	1.4	1.61	2.1	2.74
Organic Nitrogen (mg/m^3)	514.69	505.24	494.53	479.98	463.65	444.46	421.14	392.07	356.02	305.82	271.9
Total Phosphorus-Total Dissolved Phosphorus (mg/m^3)	35.72	34.99	34.15	33.01	31.74	30.24	28.42	26.15	23.34	19.42	16.77
Antilog PC-1 (Principle Components)	371.54	351.92	330.42	304.42	276.09	244.35	208.04	166.82	120.3	65.8	36.11
Antilog PC-2 (Principle Components)	7.48	7.47	7.45	7.4	7.33	7.25	7.14	6.97	6.75	6.35	5.98
(Total Nitrogen - 150) / Total Phosphorus	13.6	14.37	15.26	16.37	17.73	19.49	21.92	25.47	31.49	45.55	64.98
Inorganic Nitrogen / Phosphorus	18.38	20.83	24.01	28.27	34.25	43.35	59.15	91.33	206.35	674.18	708.1
Turbidity 1/M (1/Secchi – 0.025* Chlorophyll-*a*)	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Mixed layer Depth * Turbidity	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Mixed layer Depth / Secchi	2.57	2.51	2.44	2.35	2.25	2.14	2	1.82	1.58	1.21	0.93
Chlorophyll-*a* * Secchi	13.32	13.23	13.13	12.91	12.66	12.35	11.93	11.33	10.51	9.07	7.77
Mean Chlorophyll-*a* / Total Phosphorus	0.22	0.23	0.23	0.24	0.24	0.24	0.25	0.25	0.25	0.24	0.22
Frequency (Chlorophyll-*a* >10) %	56.84	54.85	52.5	49.15	45.18	40.26	33.97	25.82	15.89	4.81	0.96
Frequency (Chlorophyll-*a* >20) %	17.2	15.95	14.56	12.73	10.77	8.62	6.28	3.86	1.71	0.27	0.03
Frequency (Chlorophyll-*a* >30) %	5.48	4.94	4.37	3.65	2.92	2.18	1.44	0.78	0.28	0.03	0
Frequency (Chlorophyll-*a* >40) %	1.95	1.73	1.49	1.2	0.92	0.65	0.4	0.2	0.06	0	0
Frequency (Chlorophyll-*a* >50) %	0.77	0.67	0.57	0.44	0.33	0.22	0.13	0.06	0.02	0	0
Frequency (Chlorophyll-*a* >60) %	0.33	0.28	0.24	0.18	0.13	0.09	0.05	0.02	0.01	0	0
Carlson TSI-(Phosphorus)	63.44	62.65	61.77	60.76	59.61	58.25	56.55	54.39	51.33	46.01	40.88
Carlson TSI-(Chlorophyll-*a*)	56.12	55.81	55.45	54.94	54.34	53.58	52.56	51.13	49	44.96	40.82
Carlson TSI-(Secchi)	60.18	59.82	59.4	58.9	58.29	57.53	56.53	55.17	53.13	49.31	45.46
Mean TSI	59.91	59.43	58.87	58.20	57.41	56.45	55.21	53.56	51.15	46.76	42.39

Existing average tributary phosphorus concentrations (0.438 mg/L) were reduced by 10 percent successively (10 percent increments) and modeled to create an in-lake reduction curve. Reductions in each TSI category (Secchi, total phosphorus and chlorophyll-*a*) are plotted by Ecoregion 43 beneficial use categories separately in Figure 80.

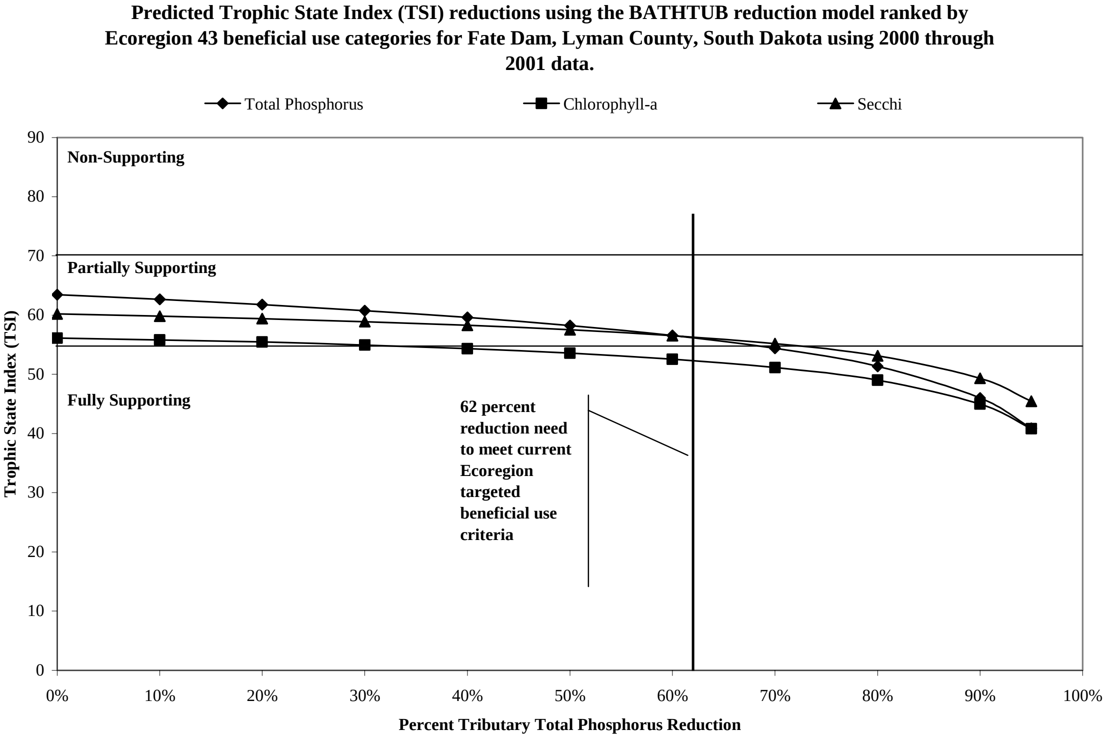


Figure 80. Predicted Trophic State Index (TSI) reductions using the BATHTUB reduction model ranked by Ecoregion 43 beneficial use categories for Fate Dam, Lyman County, South Dakota using 2000 through 2001 data.

Initial Secchi, chlorophyll-*a* and total phosphorus Trophic State Index (TSI) reduction values begin in the partially supporting category based on ecoregion 43 beneficial use categories (Figure 80). Secchi and Chlorophyll-*a* TSI reduction values declined at a similar rate within the partially supporting category; however, predicted total phosphorus TSI values declined faster in the partially supporting category than did Secchi and chlorophyll-*a* TSI reduction values. Predicted TSI began to significantly trend downward only after a 62 percent load reduction (Figure 80). This suggests that tributary total phosphorus concentrations and overall loading must be reduced 62 percent before they significantly affect changes in Secchi and chlorophyll-*a* TSI values.

Mean TSI values were calculated for each reduction and plotted by beneficial use categories (Figure 81). Current mean TSI values for 2000 and 2001 were calculated using “BATHTUB” and found to be partially supporting. Again, using predicted TSI reductions based on 2000 through 2001 tributary water quality data, a 62 percent reduction in total phosphorus loading will bring mean TSI values the lake into fully supporting status based on current ecoregion 43 beneficial use criteria (Figure 80 and Figure 81).

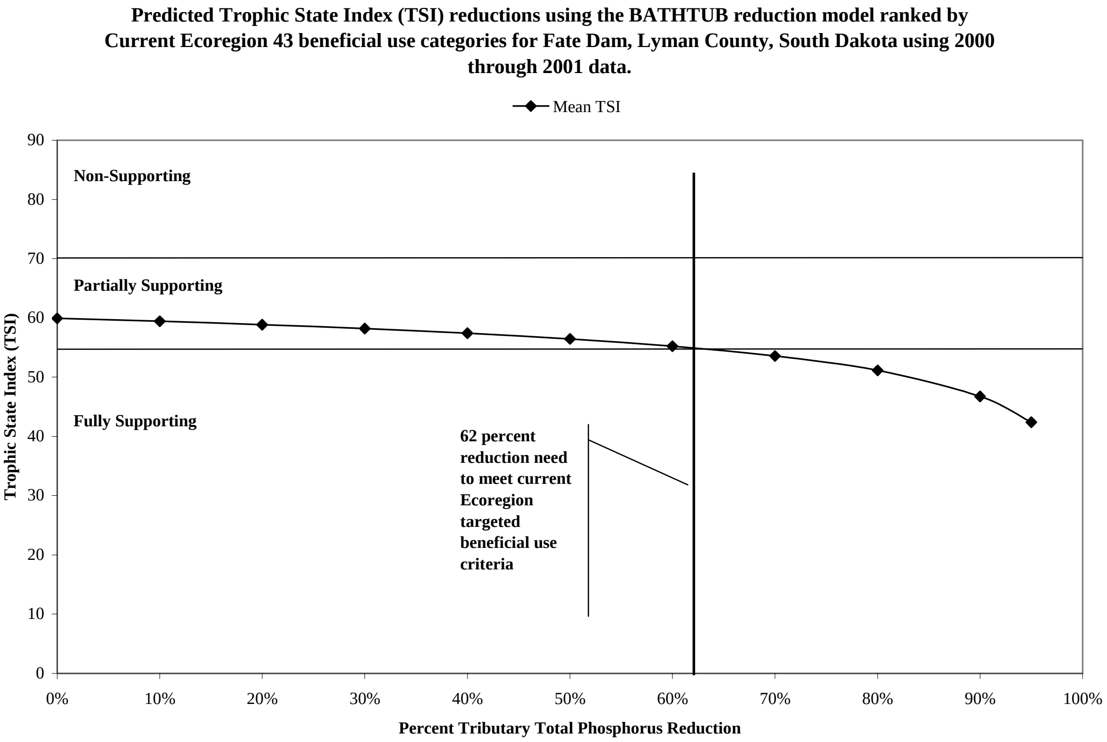


Figure 81. Predicted mean Trophic State Index (TSI) reductions using the BATHTUB reduction model ranked by Ecoregion 43 beneficial use categories for Fate Dam, Lyman County, South Dakota using 1999 loading data.

The current phosphorus load to Fate Dam based on 2000 through 2001 data is 3,440 kg/yr (total phosphorus budget, pages 113 trough 114). Current phosphorus loading on average would have to be reduced by 2,132 kg/yr (62 percent) to fully support beneficial uses based on phosphorus TSI values. Reduction in in-lake phosphorus may also be realized by reducing internal loading in Fate Dam. To fully support beneficial uses based on phosphorus TSI the TMDL would be 1,308 kg/yr.

However, excessive tributary total phosphorus loading and elevated in-lake total phosphorus concentrations resulted in increased phosphorus TSI values (Figure 75). Based on current data, Fate Dam will not meet ecoregional based beneficial use criteria. A 62 percent reduction in total phosphorus loads to Fate Dam is needed to meet current criteria; however, based on AnnAGNPS modeling, this is unrealistic and unachievable. Realistic criteria/goals for Fate Dam should be based BMP reductions within the Fate Dam watershed resulting in watershed specific criteria. Based on AnnAGNPS current modeling, a 19.5 percent reduction in total phosphorus loading can be attained with an estimated annual total phosphorus loading of 2,769 kg/yr. This translates to a mean TSI of 58.91 fully supporting Fate Dam site specific beneficial use criteria (mean TSI ≤ 59.00).

Modeled reductions using BATHTUB assumes chlorophyll-*a* concentrations, Secchi transparency and associated TSI values are indirectly related to total phosphorus concentrations. Thus, reductions in total phosphorus loading are crucial to any long-term watershed improvement scenario. Realistic criteria/goals for Fate Dam should be based on BMP reductions within the Fate Dam watershed resulting in watershed specific criteria.

3.2 Groundwater Monitoring

Groundwater was not monitored during the Fate Dam watershed assessment, part of the Medicine Creek Watershed Assessment Project.

3.3 Biological Monitoring (In-lake)

Fate Dam Phytoplankton

Composited surface algae samples were collected monthly at two in-lake water quality monitoring sites from May 1, 2000 to December 19, 2000, and February 5, 2001 to April 10, 2001. Algae samples were not taken in November 2000 or January 2001. A total of 85 taxa (algae genera or species) including two ‘unidentified’ categories were collected in 18 samples from this small 150-acre reservoir during this survey (Table 39). Algae species richness (the number of taxa observed) was rated as ‘above average’ compared to 13 other recently monitored small (< 200 ac.) eutrophic state lakes (mean: 74 taxa). However, the relative abundance of those taxa was uneven. Seven species made up 71 percent of total algae density and 71 taxa (83 percent) each contributed less than 1 percent to total algae abundance during this project (Table 39).

Table 39. Algae species collected from Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Taxa	Type	Density (Cells/ml)	Density (Percent)	Biovolume (μm3/ml)	Biovolume (Percent)
Achnanthes minutissima	Non-Motile Green Algae	5	0.03%	250	0.01%
Anabaena planctonica	Blue-Green Algae	99	0.61%	74,646	2.70%
Ankistrodesmus falcatus	Non-Motile Green Algae	110	0.68%	2,750	0.10%
Ankistrodesmus sp.	Non-Motile Green Algae	7	0.04%	175	0.01%
Aphanizomenon flos-aquae	Blue-Green Algae	505	3.10%	59,085	2.14%
Aphanocapsa sp.	Blue-Green Algae	515	3.16%	2,060	0.07%
Asterionella formosa	Diatom	2,021	12.41%	444,620	16.09%
Chlamydomonas sp.	Flagellated Algae (Green Algae)	834	5.12%	125,100	4.53%
Chromulina sp.	Flagellated Algae (Yellow-Brown Algae)	62	0.38%	4,030	0.15%
Chrysochromulina parva	Flagellated Algae (Yellow-Brown Algae)	100	0.61%	8,400	0.30%
Cocconeis placentula	Diatom	10	0.06%	4,600	0.17%
Coelastrum microporum	Non-Motile Green Algae	123	0.76%	100,368	3.63%
Cosmarium sp.	Non-Motile Green Algae (Desmid)	5	0.03%	1,050	0.04%
Crucigenia tetrapedia	Non-Motile Green Algae	1	0.01%	85	0.00%
Cryptomonas erosa	Flagellated Algae (cryptophyte)	994	6.10%	498,988	18.06%
Cryptomonas ovata	Flagellated Algae (cryptophyte)	10	0.06%	17,270	0.63%
Cryptomonas sp.	Flagellated Algae (cryptophyte)	613	3.76%	245,200	8.88%
Cyclotella pseudostelligera	Diatom	4	0.02%	660	0.02%
Cyclotella stelligera	Diatom	34	0.21%	5,270	0.19%
Cymbella affinis	Diatom	5	0.03%	9,000	0.33%
Dinobryon sertularia	Flagellated Algae (Yellow-Brown Algae)	5	0.03%	4,000	0.14%
Diploneis puella	Diatom	5	0.03%	1,300	0.05%
Diplostauron sp.	Flagellated Algae (Green Algae)	1	0.01%	300	0.01%
Entomoneis ornata (Amphiprora)	Diatom	1	0.01%	4,000	0.14%
Eudorina sp.	Flagellated Algae (Green colonial)	10	0.06%	5,230	0.19%
Euglena sp.	Flagellated Algae (euglenoid)	6	0.04%	3,480	0.13%
Eunotia sp.	Diatom	3	0.02%	1,350	0.05%
Fragilaria crotonensis	Diatom (filamentous)	2	0.01%	1,680	0.06%
Fragilaria vaucheriae	Diatom (filamentous)	12	0.07%	3,456	0.13%
Glenodinium sp.	Flagellated Algae (Dinoflagellate)	33	0.20%	23,100	0.84%
Gomphonema gracile	Diatom	3	0.02%	735	0.03%
Gymnodinium sp.	Flagellated Algae (Dinoflagellate)	3	0.02%	8,100	0.29%
Gyrosigma sp.	Diatom	10	0.06%	5,000	0.18%
Gyrosigma spenceri	Diatom	1	0.01%	450	0.02%
Kephyrion littorale	Flagellated Algae (Yellow-Brown Algae)	3	0.02%	285	0.01%
Kephyrion sp.	Flagellated Algae (Yellow-Brown Algae)	2	0.01%	126	0.00%
Mallomonas pseudocoronata	Flagellated Algae (Yellow-Brown Algae)	63	0.39%	110,250	3.99%
Mallomonas sp.	Flagellated Algae (Yellow-Brown Algae)	46	0.28%	23,000	0.83%
Mallomonas tonsurata	Flagellated Algae (Yellow-Brown Algae)	23	0.14%	34,500	1.25%
Melosira varians	Diatom	7	0.04%	4,550	0.16%
Navicula cryptocephala	Diatom	9	0.06%	1,665	0.06%
Navicula cryptocephala v. veneta	Diatom	7	0.04%	665	0.02%
Navicula minuscula	Diatom	3	0.02%	135	0.00%

Table 39 (continued). Algae species collected from Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Taxa	Type	Density (Cells/ml)	Density (Percent)	Biovolume (µm3/ml)	Biovolume (Percent)
Navicula sp.	Diatom	14	0.09%	3,500	0.13%
Nitzschia acicularis	Diatom	87	0.53%	24,360	0.88%
Nitzschia amphibia	Diatom	1	0.01%	96	0.00%
Nitzschia capitellata	Diatom	1	0.01%	360	0.01%
Nitzschia frustulum	Diatom	4	0.02%	480	0.02%
Nitzschia lorenziana v. subtilis	Diatom	1	0.01%	160	0.01%
Nitzschia palea	Diatom	5	0.03%	2,625	0.10%
Nitzschia paleacea	Diatom	28	0.17%	2,744	0.10%
Nitzschia sp.	Diatom	59	0.36%	7,080	0.26%
Nitzschia vermicularis	Diatom	56	0.34%	6,720	0.24%
Ochromonas sp.	Non-Motile Green Algae	14	0.09%	1,190	0.04%
Oocystis lacustris	Non-Motile Green Algae (colonial)	6	0.04%	1,848	0.07%
Oocystis pusilla	Non-Motile Green Algae (colonial)	90	0.55%	4,860	0.18%
Oocystis sp.	Non-Motile Green Algae (colonial)	2	0.01%	300	0.01%
Oscillatoria agardhii	Blue-Green Algae	60	0.37%	2,880	0.10%
Oscillatoria sp.	Blue-Green Algae	308	1.89%	6,468	0.23%
Pandorina morum	Flagellated Algae (Green Algae)	8	0.05%	1,400	0.05%
Pascheriella tetras	Flagellated Algae (Green Algae)	1,080	6.63%	108,000	3.91%
Pediastrum duplex	Non-Motile Green Algae (colonial)	229	1.41%	114,500	4.14%
Rhodomonas minuta	Flagellated Algae (cryptophyte)	4,620	28.36%	121,380	4.39%
Rhoicosphenia curvata	Diatom	9	0.06%	1,053	0.04%
Scenedesmus quadricauda	Non-Motile Green Algae	25	0.15%	3,925	0.14%
Sphaerocystis schroeteri	Non-Motile Green Algae	91	0.56%	24,388	0.88%
Spirogyra sp.	Non-Motile Green Algae (filamentous)	18	0.11%	18,000	0.65%
Stephanodiscus hantzschii	Diatom	16	0.10%	3,200	0.12%
Stephanodiscus minutus	Diatom	350	2.15%	125,571	4.55%
Stephanodiscus sp.	Diatom	35	0.21%	3,500	0.13%
Surirella ovata	Diatom	15	0.09%	4,350	0.16%
Surirella sp.	Diatom	3	0.02%	1,500	0.05%
Syncrypta volvox	Flagellated Algae (Yellow-Brown Algae)	843	5.18%	169,443	6.13%
Synedra rumpens	Diatom	3	0.02%	420	0.02%
Synedra sp.	Diatom	2	0.01%	560	0.02%
Synura uvella	Diatom	4	0.02%	5,232	0.19%
Tabellaria fenestrata	Diatom	1	0.01%	2,400	0.09%
Trachelomonas hispida	Flagellated Algae (euglenoid)	34	0.21%	71,400	2.58%
Trachelomonas scabra	Flagellated Algae (euglenoid)	2	0.01%	3,200	0.12%
Trachelomonas sp.	Flagellated Algae (euglenoid)	6	0.04%	12,000	0.43%
Trachelomonas volvocina	Flagellated Algae (euglenoid)	1	0.01%	1,885	0.07%
Unidentified algae	Algae	640	3.93%	19,200	0.69%
Unidentified flagellates	Flagellated Algae	1,130	6.94%	34,350	1.24%
Unidentified pennate diatoms	Diatom (pennate)	24	0.15%	2,400	0.09%
Uroglenopsis americana	Flagellated Algae (Yellow-Brown, colonial)	50	0.31%	3,000	0.11%
Total Species	**85**				

Diatoms(Bacillariophyceae) represented the most diverse group of algae in Fate Dam with 39 taxa, or 46 percent of all algae species collected, followed by five phyla of motile (flagellated) algae with 28 taxa, including an ‘unidentified flagellates’ category. The other algal divisions were less diverse in this lake with non-motile green algae (Chlorophyta) comprising 12 taxa and blue-green algae (Cyanophyta) only 5 taxa. In other monitored eutrophic lakes, blue-green algae were also the least diverse but often the most abundant algae group collected. However, in Fate Dam, blue-greens composed only 9 percent of total algae abundance (density) and slightly more than 5% of total biovolume during this survey. *Aphanizomenon* sp. was the only blue-green species collected during 2000. It was collected only in September and early October at low mean densities of 165 cells/ml and 340 cells/ml, respectively.

Yellow-brown (or, golden-brown) flagellates (Chrysophyta) were clearly the most diverse phylum of motile algae in Fate Dam comprising 12 taxa followed distantly by green (Chlorophyta) and euglenoid (Euglenophyta) flagellates with 5 species each. The remaining two phyla had even fewer representatives. Dinoflagellates (Pyrrhophyta) and cryptomonads (Cryptophyta) accounted for only 2 and 3 species, respectively.

Fate Dam algal density and biovolume (a relative expression of biomass) showed considerable seasonal variability over the study period. Algal density (abundance) ranged from 188 cells/ml on May 1, 2000 to 5,207 cells/ml on April 10, 2001. Algal biovolume ranged from 86,198 um^3/ml on June 7, 2000 to 946,460 um^3/ml on April 10, 2001. The algae population recorded on May 1, 2000, is unusually small even for a moderately eutrophic lake in mid-spring. This low density may be a sampling artifact and/or the result of a heavy runoff event in the watershed that may have diluted lake algae populations. Similarly minimal algae densities were also observed in two nearby small lakes, Byre Lake and Brakke Dam, for the same date. Understandably, small waterbodies are more rapidly affected by the same amount of rainfall and other weather conditions than large lakes.

The average monthly algae density for this assessment amounted to only 1,629 cells/ml that had an average biovolume of 276,273 um^3/ml. These are the smallest values recorded for 14 small eutrophic lakes recently monitored in eastern South Dakota. Rated solely on these criteria (the size of the lake algae population during 2000 through 2001) would place Fate Dam in the mesotrophic category according to an algal biovolume index, $TSI_{(B)}$, developed by *Aquatic Analysts* (Sweet 1986) that is based on the widely-used Carlson (1977) Trophic State Index (TSI). They derived a $TSI_{(B)}$ value of 36.3 for Fate Dam which falls in the lower mesotrophic range (35 – 50).

The Fate Dam phytoplankton during this survey consisted primarily of flagellated (motile) algae which made up 65 percent of algae density and nearly 60 percent of biovolume (Figures 83 and 84). However, seasonal populations of motile algae were small to moderate (Table 40). Diatoms were next in importance, contributing 17% and 25% to total algae numbers and volume, respectively. Blue-green algae and non-motile green algae represented the least common groups in Fate Dam, the latter algal division accounting for only slightly more than 4 percent of total algae and 10 percent of annual biovolume.

Table 40. **Fate Dam algal density (cells/ml), biovolume ($\mu m^3/ml$) and percentage by algal group from 2000 through 2001.**

Date	Group	Density	Density %	Biovolume	Biovolume %
1-May-00	Diatom	154	81.9%	64,262	67.7%
	Flagellated Algae	33	17.6%	30,320	32.0%
	Non-Motile Green Algae	1	0.5%	308	0.3%
	Blue Green Algae	0	0.0%	0	0.0%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**188**		**94,890**	
7-Jun-00	Diatom	15	3.7%	4,620	5.4%
	Flagellated Algae	269	66.3%	12,994	15.1%
	Non-Motile Green Algae	122	30.0%	68,584	79.6%
	Blue Green Algae	0	0.0%	0	0.0%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**406**		**86,198**	
11-Jul-00	Diatom	49	4.7%	20,840	13.5%
	Flagellated Algae	878	84.7%	111,816	72.2%
	Non-Motile Green Algae	109	10.5%	22,212	14.3%
	Blue Green Algae	0	0.0%	0	0.0%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**1,036**		**154,868**	
3-Aug-00	Diatom	146	16.8%	34,995	20.9%
	Flagellated Algae	633	72.9%	113,481	67.7%
	Non-Motile Green Algae	89	10.3%	19,195	11.4%
	Blue Green Algae	0	0.0%	0	0.0%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**868**		**167,671**	
14-Sep-00	Diatom	192	11.9%	53,435	15.1%
	Flagellated Algae	858	53.1%	59,224	16.8%
	Non-Motile Green Algae	301	18.6%	146,944	41.6%
	Blue Green Algae	264	16.3%	93,951	26.6%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**1,615**		**353,554**	
3-Oct-00	Diatom	49	3.0%	12,803	4.7%
	Flagellated Algae	1,170	72.7%	217,862	80.0%
	Non-Motile Green Algae	50	3.1%	1,946	0.7%
	Blue Green Algae	340	21.1%	39,780	14.6%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**1,609**		**272,391**	

Table 40 (continued). Fate Dam algal density (cells/ml), biovolume (μm^3/ml) and percentage by algal group from 2000 through 2001.

Date	Group	Density	Density %	Biovolume	Biovolume %
19-Dec-00	Diatom	1,469	50.6%	326,720	69.4%
	Flagellated Algae	1,434	49.4%	144,112	30.6%
	Non-Motile Green Algae	0	0.0%	0	0.0%
	Blue Green Algae	0	0.0%	0	0.0%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**2,903**		**470,832**	
5-Feb-01	Diatom	173	22.9%	35,280	37.9%
	Flagellated Algae	165	21.9%	51,225	55.0%
	Non-Motile Green Algae	3	0.4%	385	0.4%
	Blue Green Algae	243	32.2%	1,108	1.2%
	Unidentified Algae	170	22.5%	5,100	5.5%
Total		**754**		**93,098**	
5-Mar-01	Diatom	136	8.0%	29,850	24.3%
	Flagellated Algae	767	45.0%	78,900	64.3%
	Non-Motile Green Algae	0	0.0%	0	0.0%
	Blue Green Algae	580	34.1%	7,420	6.0%
	Unidentified Algae	220	12.9%	6,600	5.4%
Total		**1,703**		**122,770**	
10-Apr-01	Diatom	472	9.1%	99,500	10.5%
	Flagellated Algae	4,393	84.4%	823,905	87.1%
	Non-Motile Green Algae	32	0.6%	12,675	1.3%
	Blue Green Algae	60	1.2%	2,880	0.3%
	Unidentified Algae	250	4.8%	7,500	0.8%
Total		**5,207**		**946,460**	

The seasonal pattern of algal abundance in Fate Dam during year 2000 consisted of no clearly defined peaks in algae density or biovolume. Instead, algae populations displayed a steady increase, with minor fluctuations, from May to late December (Figure 82). The December maximum consisted mainly of a moderate bloom of the diatom *Asterionella formosa* and a flagellate, *Rhodomonas minuta*. The next sampling dates in February and early March 2001 disclosed small winter algae populations comprised mostly of flagellated algae, blue-greens, and remnants of the December *Asterionella* sp. bloom.

The last sampling date of this project on April 10, 2001, indicated a sharp increase in the spring algae population (Figure 82) which consisted mostly (84 percent) of flagellated algae including cryptomonads *Rhodomonas* sp. and *Cryptomonas* sp. and green flagellates *Chlamydomonas* sp. and *Pascheriella tetras*. However, the total algae population at this time (5,207 cells/ml) is still reflective of only moderately productive waterbodies.

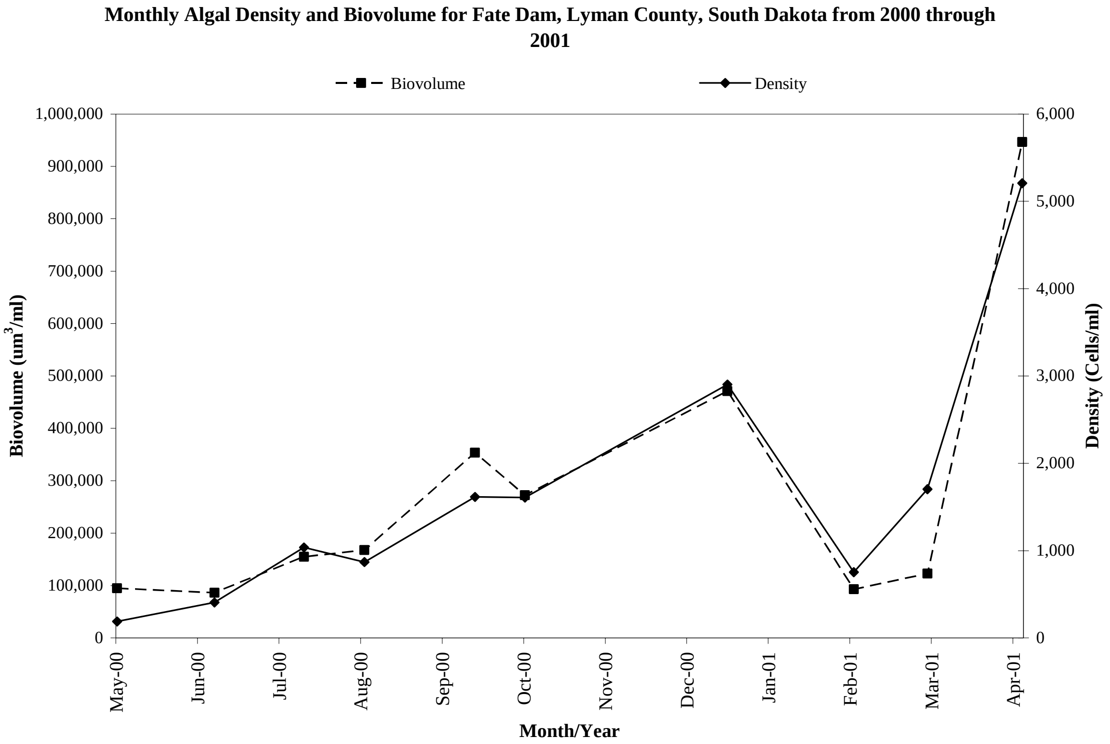


Figure 82. Total algal density (cells/ml) and biovolume (µm^3/ml) for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

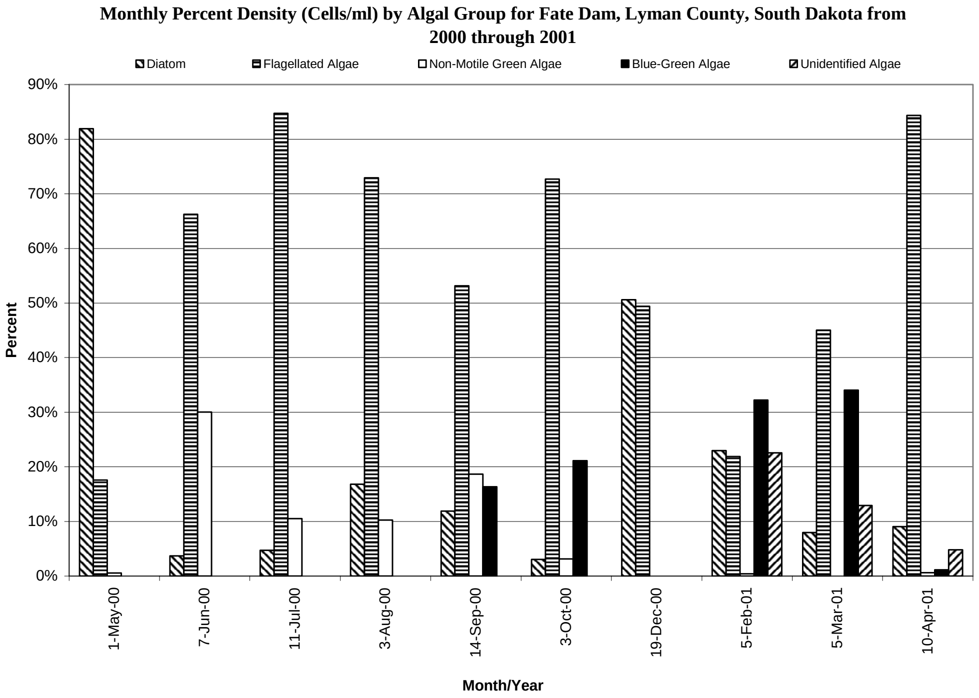


Figure 83. Relative percent density by algal group for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

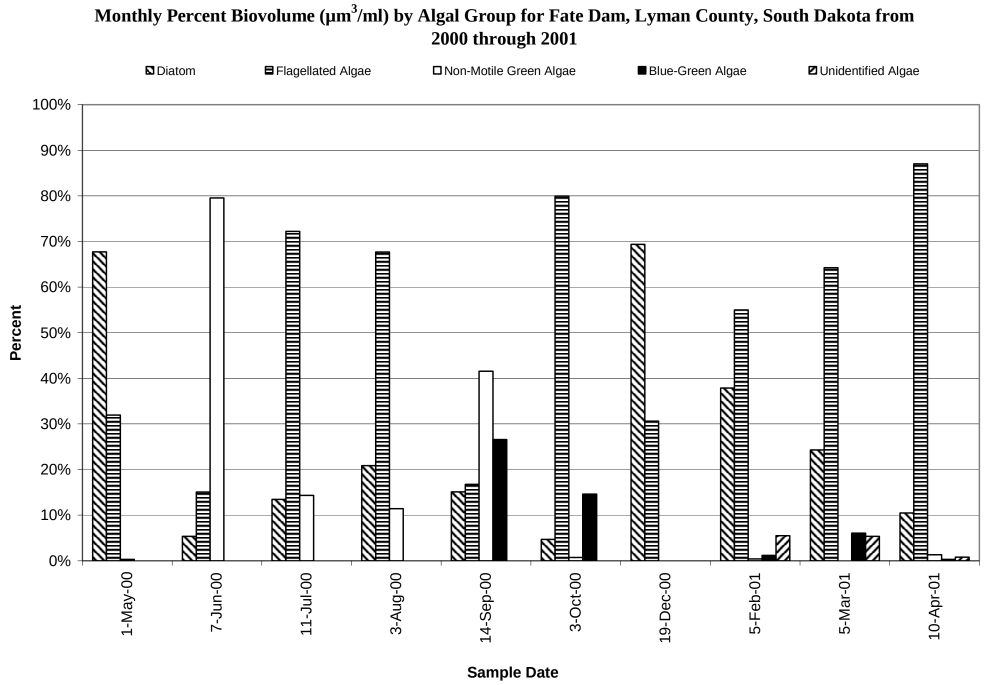


Figure 84. Relative percent biovolume by algal group for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Aquatic Macrophyte Survey

An aquatic macrophyte survey of Fate Dam was conducted on July 31, 2001. The survey consisted of surveying 15 transects, quantify and identifying the submergent plant community (Figure 85). Each transect had two survey point to evaluate the macrophyte community (approximately ten meters and 30 meters from shore). Sampling at each survey point consisted of casting a plant grapple approximately six meters in four separate directions (north, south, east and west), slowly retrieving the grapple and identifying plant species retained on the grapple. Submergent and emergent aquatic plant species were identified using Fassett (1957) and Crow and Hellquist (2000 and 2000a) and are listed in Table 41 and Table 42. Emergent shoreline plants were identified near each transect as a general survey of species present in Fate Dam. The survey also identified bank stability to identify potential erosional areas around Fate Dam.

Table 41. Submergent plant species identified in Fate Dam, Lyman County, South Dakota in 2001.

	Scientific Name
Transect Submerged Species	
Floating-leaved Pondweed	*Potamogeton natans*
Sago Pondweed	*Stuckenia pectinata*
Bushy Pondweed	*Najas* sp.
Flat-stemmed Pondweed	*Potamogeton zosteriformis*
Pondweed species	*Potamogeton* sp.
Coontail	*Ceratophyllum demersum*
Horned Pondweed	*Zannichellia* sp.
Curly-leaved Pondweed	*Potamogeton crispus*
Moss	Moss

Submergent macrophyte species were sampled using 15 transects (Figure 85) with 27 survey points throughout the lake. Nine separate transect species were identified during the survey and are listed on Table 41. Five shoreline emergent species were identified near transects in Fate Dam (Table 42). All identified macrophyte species, especially; sago pondweed (*Stuckenia pectinata*), floating leaf pondweed (*Potamogeton natans*), bushy pondweed (*Najas* sp.) and flat-stemmed pondweed (*Potamogeton zosteriformis*) are relatively ubiquitous and commonly found in other lakes in South Dakota. One species, curly-leaved pondweed, is considered an exotic species which was introduced from Europe. Eleven of the fifteen (73.3 percent) transects yielded submerged vegetation (Table 43).

Table 42. Shoreline emergent plant species identified in Fate Dam, Lyman County, South Dakota in 2001.

Shoreline Emergent Species	**Scientific Name**
Narrow-leaf Cattail	*Typha augustifolia*
River Bulrush	*Scirpus fluviatilis*
Bulrush	*Scirpus* sp.
Milkweed	*Asclepias* sp.
Cottonwood Trees	*Populus* sp.

Upstream of transects T-4 and T-5 (gray shaded lines) were extensive beds of sago pondweed (*Stuckenia pectinata*), coontail (*Ceratophyllum demersum*), *Potamogeton* species and moss. The majority of the shoreline in this area was composed of narrow-leaved cattail (*Typha augustifolia*).

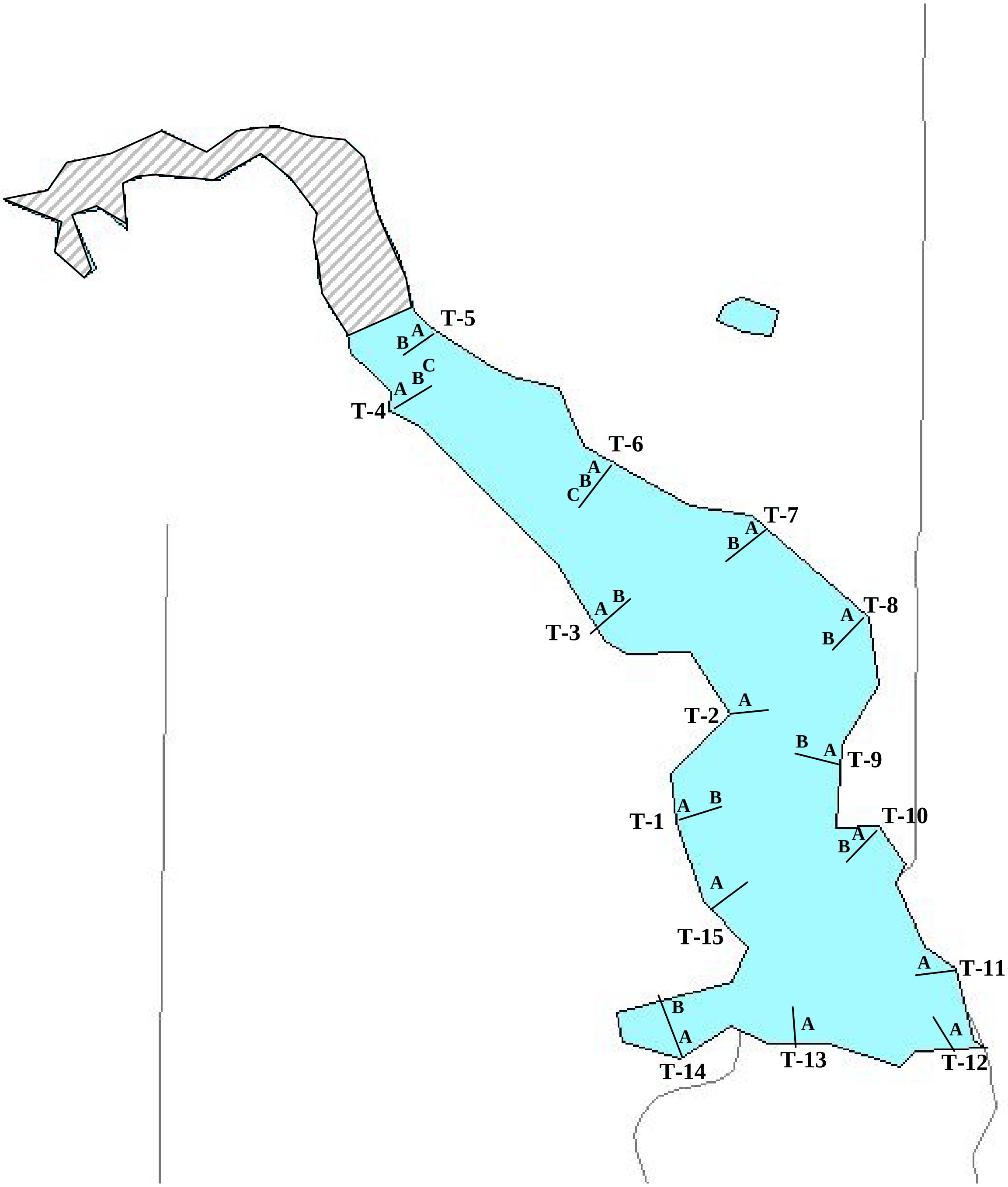


Figure 85. Submergent macrophyte transects at Fate Dam, Lyman County, South Dakota in July 2001.

Table 43. Shoreline and transect submergent plant species sampled from Fate Dam, Lyman County, South Dakota in July 2001.

Transect and Station	Total Depth (m)	Secchi Depth (m)	Transect Submergent Species	Transect Density	Shoreline Emergent Species
1A	0.91	0.61	*Ceratophyllum demersum*	1	*Typha augustifolia*
			Potamogeton sp	3	*Scripus* sp.
			Potamogeton natans	1	
1B	1.22	0.61	*Potamogeton* sp	2	
2A	2.13	0.61	*Potamogeton crispus*	2	*Typha augustifolia*
					Scripus sp.
					Scirpus fluviatilis
3A	1.37	0.67	Moss	3	*Scripus* sp.
			Potamogeton natans	2	*Scirpus fluviatilis*
			Potamogeton crispus	1	
			Potamogeton sp	1	
3B	2.44	0.61	None	-	
4A	0.61	0.55	Moss	2	*Typha augustifolia*
			Potamogeton crispus	4	
			Ceratophyllum demersum	2	
4B	1.22	0.67	Moss	2	
			Ceratophyllum demersum	1	
			Stuckenia pectinata	2	
4C	1.22	0.67	*Ceratophyllum demersum*	3	
			Stuckenia pectinata	1	
5A	1.83	0.61	*Ceratophyllum demersum*	3	*Typha augustifolia*
			Potamogeton sp	2	
			Stuckenia pectinata	1	
5B	1.98	0.61	*Stuckenia pectinata*	2	
			Ceratophyllum demersum	3	
6A	0.91	0.64	*Potamogeton* sp	3	*Typha augustifolia*
			Najas sp.	3	
6B	1.52	0.70	*Potamogeton* sp	4	
			Ceratophyllum demersum	4	
6C	1.83	0.64	*Stuckenia pectinata*	2	
			Potamogeton sp	1	
			Ceratophyllum demersum	1	
7A	1.07	0.61	*Potamogeton zosteriformis*	4	*Typha augustifolia*
			Ceratophyllum demersum	4	
			Moss	1	
			Stuckenia pectinata	2	
7B	1.22	0.52	Moss	3	
			Stuckenia pectinata	2	
			Ceratophyllum demersum	3	
			Najas sp.	2	
			Potamogeton zosteriformis	2	
8A	1.07	0.55	*Potamogeton natans*	1	*Scripus* sp.
			Moss	1	*Typha augustifolia*
			Ceratophyllum demersum	1	
			Stuckenia pectinata	2	
8B	1.52	0.64	*Potamogeton* sp	2	

Table 43 (continued). Shoreline and transect submergent plant species sampled from Fate Dam, Lyman County, South Dakota in July 2001.

Transect and Station	Total Depth (m)	Secchi Depth (m)	Transect Submergent Species	Transect Density	Shoreline Emergent Species
9A	0.67	0.49	*Potamogeton zosteriformis*	1	None (cutbank)
			Moss	3	
			Potamogeton crispus	2	
9B	2.13	0.67	Moss	1	
10A	1.22	0.46	*Zannichellia* sp.	4	*Typha augustifolia*
			Potamogeton sp.	1	*Scripus* sp.
			Potamogeton zosteriformis	2	
			Ceratophyllum demersum	2	
			Potamogeton crispus	1	
10B	1.68	0.55	*Zannichellia* sp.	2	
			Potamogeton sp.	1	
			Potamogeton zosteriformis	1	
11A	1.52	0.55	None	-	*Asclepias* sp.
12A	1.07	0.58	None	-	*Typha augustifolia*
13A	0.55	0.55	None		None (cutbank)
14A	0.76	0.58	*Potamogeton zosteriformis*	1	*Typha augustifolia*
			Stuckenia pectinata	1	*Scirpus fluviatilis*
			Ceratophyllum demersum	2	*Asclepias* sp.
			Potamogeton sp.	2	
14B	0.76	0.58	*Potamogeton zosteriformis*	3	
			Ceratophyllum demersum	3	
			Potamogeton natans	1	
			Potamogeton sp.	1	
			Stuckenia pectinata	2	
			Moss	1	
15A	0.76	0.55	None		*Typha augustifolia* *Populus* sp.

Canfield et al. (1985) proposed a model to determine maximum depth of colonization (MDC) for submerged macrophytes. The model is influenced by regional differences in plant response, changes in available light and seasonal characteristics. The model equation is as follows:

Equation 4. Maximum depth of colonization equation

$$\text{Log MDC} = 0.61(\log \text{SD}) + 0.26$$

MDC = Maximum depth of colonization
SD = Secchi depth (m)

The calculated maximum depth of colonization in Fate Dam was 1.32 meters (4.33 feet). Calculations were based upon the average measured Secchi depth in meters during the aquatic macrophyte survey (Table 43). The increase in submerged vegetation in the upper end of Fate Dam appears to be the result of long-term sedimentation from Nail Creek decreasing depth conducive to macrophyte colonization.

3.4 Other Monitoring

Fate Dam Sediment Survey

A sediment survey was completed on Fate Dam in the winter of 2002. Sampling entailed drilling holes through the ice and recording the depth of the water column. A long steel probe was then pushed into the sediment until solid substrate was encountered and the depth of the sediment recorded. Two hundred three survey sites were recorded by GPS (Global Positioning System) (Figure 86).

Figure 86. Sediment survey sediment depth for Fate Dam, Lyman County, South Dakota for January 2002.

Figure 86 indicate sediment depths ranged from 0 to 1.22 meters (0 to 4 feet). At the time of this survey, the average depth of sediment in Fate Dam was approximately 0.30 meters (1.0 foot). Total sediment volume accumulated within Fate Dam was estimated at approximately 153,675 m^3 (201,000 yd^3). The total loss in water volume due to sedimentation was estimated at approximately 150 acre-feet.

The estimated load (Nail Creek) to Fate Dam from 2000 through 2001 was 1,354,603 kg or 626.4 m^3 (0.51 acre/feet). Adjusting the load for sediment leaving the lake, based on FLUX loading, via the outlet (MCT-8) was approximately 141,533 kg or 65.4 m^3 (0.053 acre-feet). The corrected amount of suspended solids retained in Fate Dam during this study was approximately 4,213,070 kg, which is 561.0 m^3 (0.454 acre-feet) or 89.6 percent of the total of suspended solids loading to the lake. This translates to an overall increase of 0.92 mm of sediment depth over the entire lake. During this study, very little runoff was recorded in the watershed and loading should be considered below average.

Fate Dam Elutriate Analysis (Sediment Analysis)

Elutriate samples are used to determine chemical substances (contaminates) in sediment samples. In general, contaminates are composed of various metals, pesticides and herbicides (Table 44). A typical sample set is composed of sediment and receiving water (overlying water). Receiving water is typically analyzed before being mixed with the sediment to detect existing contamination. The sediment and receiving water are mixed for a predetermined amount of time at the laboratory and then the homogenous sample is separated again using a centrifuge. The overlying water is collected from the centrifuge bottles, extracted and analyzed for contaminates.

All water quality standards for toxic pollutants for human health and aquatic life values in South Dakota are based on beneficial use categories (ARSD § 74:51:01). Elutriate samples were collected from Fate Dam on July 24, 2001. Sediment and receiving water samples were collected from both in-lake sampling sites and composited. All sediment samples were collected using a stainless steel petite Ponar dredge and receiving water samples were collected using a Van Dorn type sampler. All samples were preserved (4° C) and transported to the laboratory.

Composite receiving water and elutriate samples collected at Fate Dam were analyzed at the South Dakota State Health Laboratory in Pierre. Data indicate both receiving water and elutriate samples were below laboratory detection limits for PCBs, herbicide and pesticide parameters and were relatively low or below laboratory detection limits for metals and nutrient parameters. Based on these data, there does not appear to be a contaminate problem in Fate Dam.

Table 44. Fate Dam receiving water and elutriate chemical concentrations collected in August 2001.

Parameter	Receiving Water Fate Dam	Elutriate Sample Fate Dam	Actual in Elutriate Fate Dam	Unit
COD	24.7	44.3	19.6	mg/L
Phosphorus, total	0.021	0.048	0.027	mg/L
TKN	0.91	3.43	2.52	mg/L
Hardness	190	140	140	mg/L
Nitrate	0.1	0.1	0	mg/L
Nitrite	<0.02	<0.02	<0.02	mg/L
Aluminum	9	21.3	12.3	µg/L
Zinc	3.1	11.3	8.2	µg/L
Silver	<0.2	<0.2	<0.2	µg/L
Selenium	6.4	1.6	-4.8	µg/L
Nickel	6.8	7	0.2	µg/L
Mercury, total	<0.2	<0.2	<0.2	µg/L
Lead	<0.1	0.2	>0.1	µg/L
Copper	5.8	14.4	8.6	µg/L
Cadmium	<0.2	<0.2	<0.2	µg/L
Arsenic	5.6	15.2	9.6	µg/L
Ammonia	0.02	2.14	2.12	mg/L
Endosulfan II	< 0.500	< 0.500	< 0.500	µg/L
Atrazine	< 0.500	< 0.500	< 0.500	µg/L
Endrin	< 0.500	< 0.500	< 0.500	µg/L
Heptachlor	< 0.400	< 0.400	< 0.400	µg/L
Heptachlor Epoxide	< 0.500	< 0.500	< 0.500	µg/L
Methoxychlor	< 0.500	< 0.500	< 0.500	µg/L
Toxaphene	ND	ND	ND	-
Aldrin	< 0.500	< 0.500	< 0.500	µg/L
Dieldrin	< 0.500	< 0.500	< 0.500	µg/L
Aroclor 1016	< 0.100	< 0.100	< 0.100	µg/L
Aroclor 1221	< 0.100	< 0.100	< 0.100	µg/L
Aroclor 1232	< 0.100	< 0.100	< 0.100	µg/L
Aroclor 1242	< 0.100	< 0.100	< 0.100	µg/L
Aroclor 1248	< 0.100	< 0.100	< 0.100	µg/L
Aroclor 1254	< 0.100	< 0.100	< 0.100	µg/L
Aroclor 1260	< 0.100	< 0.100	< 0.100	µg/L
Diazinon	< 0.500	< 0.500	< 0.500	µg/L
DDD	< 0.500	< 0.500	< 0.500	µg/L
DDT	< 0.500	< 0.500	< 0.500	µg/L
DDE	< 0.500	< 0.500	< 0.500	µg/L
BETA BHC	< 0.500	< 0.500	< 0.500	µg/L
GAMMA BHC	< 0.500	< 0.500	< 0.500	µg/L
ALPHA BHC	< 0.500	< 0.500	< 0.500	µg/L

Fisheries Data

The most recent fisheries survey data was collected by South Dakota Game, Fish and Parks from July 24 through July 27, 2000. That report is summarized below and is presented in Appendix E. Fate Dam is being managed using the latest management plan (F-21-R-30) 1997. The management classification of Fate Dam is a warm-water semi-permanent fishery and supports fifteen species of fish.

Fish collection consisted of setting eight 19 mm (¾ inch) three 24-hour periods from July 24 through July 26, 2000 and six 10-minute electrofishing transects on October 18, 2000. All fish captured by net and electrofishing methods were measured (total length in millimeters), weighed (grams) and identified to species. Six 10-minute electrofishing transects yielded 14 largemouth bass and 3 walleye and eight 24-hour frame nets yielded 38 black bullhead, 189 bluegill, 36 bluegill, 12 northern pike, 5 pumpkinseed sunfish, 9 yellow perch and 1 walleye (Appendix E).

South Dakota Game, Fish and Parks (SD GF&P) recommendations for Fate Dam indicate the lake should be resampled in 2003 to check all fish populations and to discontinue walleye stocking due to low returns.

Endangered Species

The South Dakota Natural Heritage Database identified one species, the whooping crane, as being endangered in the Medicine Creek watershed of which Fate Dam/Nail Creek is apart. This database contains documented identifications of rare, threatened or endangered species across the state and is listed in Appendix F. The whooping crane (*Grus americana*), a federally-listed endangered species, has been recorded in the Fate Dam/Nail Creek watershed. Two observations were recorded in the watershed, the first observation (October 29, 1997) indicated 3 cranes flying over and another on May 7, 1998 where on crane was on the ground for five days. The State of South Dakota lists the whooping crane as SZN, nonbreeding, no definable occurrences for conservation purposes, a category usually assigned to migrants. There are no other threatened or endangered species documented in the Nail Creek/Fate Dam watershed; however, six species are identified as being rare. Species identified as rare in the Fate Dam watershed were five bird species, Swainson’s hawk (*Buteo swainsoni*), Ferruginous hawk (*Buteo regalis*), Burrowing owl (*Athene cunicularia*), Baird’s sparrow (*Ammodramus* bairdii) and Sprague’s pipit (*Anthus spragueii*). The Baird’s sparrow (*Ammodramus* bairdii) and Sprague’s pipit (*Anthus spragueii*) are state listed as S2B as imperiled because of rarity or because of some other factor(s) making it very vulnerable to extinction throughout its range. One mammal species was also listed as rare, Plains spotted skunk (*Spilogale putorius interrupt).* The US Fish and Wildlife Service lists the bald eagle, and western prairie fringed orchid as species that could potentially be found in the area. None of these species were encountered during this study; however, care should be taken when conducting mitigation projects in the Fate Dam/Nail Creek watershed.

3.5 Quality Assurance Reporting

Thirteen quality assurance and quality control (QA/QC) samples were collected throughout the 2000 and 2001 sampling periods for both tributary and in-lake sampling sites (7 blank and 6 replicate). Standard chemical analysis was performed on all blank and replicate samples collected. Analyses followed both the tributary and in-lake standard routine chemical parameters for analysis and are listed in Table 2 for tributary samples and Table 27 for in-lake samples.

Replicate samples were compared to the original samples using the industrial statistic (%I). The value given is the absolute difference between the original and the duplicate sample in percent. The equation used was:

Equation 5. Industrial statistic equation.

$$\%I = (A-B) / (A+B)*100$$

%I = Industrial Statistic
(A-B) = Absolute difference
(A+B) = Absolute sum

Blank samples were evaluated by calculating the mean and standard deviation of all blank samples for both tributary and in-lake samples. The criterion for compliance was that the standard deviation be less than the mean of all blank samples.

Three tributary quality assurance / quality control samples were collected for watershed tributary monitoring samples (2 blank and 1 replicate). One tributary replicate sample was collected at MCT-6 for an overall quality assurance/quality control percentage of 8.3 percent. Three tributary replicate sample parameters (TKN, ammonia and organic nitrogen (related parameters)) had an industrial statistic (%I) greater than 10 percent (absolute percent). All industrial statistics greater than 10 percent (TKN, ammonia and organic nitrogen) are related parameters in that TKN concentrations contain ammonia and organic nitrogen concentration is calculated (TKN minus ammonia) using these (TKN and ammonia) parameters. All other replicate parameter samples were within 10 percent from the original samples. Variations in field sampling techniques, preparation and that the samples are replicate and not duplicate may be some reasons for differences. Over all, 80 percent (12 of 15 parameters) of all tributary industrial statistics values were less than 10 percent different (Table 45).

All blank quality assurance/quality control tributary samples were in compliance with criterion proposed above with the standard deviation being less than the mean for each chemical parameter.

Table 45. Tributary quality assurance/quality control samples collected in Nail Creek, Lyman County, South Dakota from 2000 and 2001.

Sample	Site	Date	Depth	Water Temp (° C)	Fecal Coliform (#/100 ml)	Alkalinity (mg/L)	Total Solid (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Organic Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)
Blank	BL	5/15/2001	-	-	10	6	8	8	1	1	0.36	0.01	0.1	0.35	0.11	0.46	0.002	0.002
Blank	BL	5/16/2001	-	-	10	6	14	14	1	1	0.36	0.01	0.2	0.35	0.21	0.56	0.002	0.002
	Mean				10.0	6.0	11.0	11.0	1.0	1.0	0.4	0.0	0.2	0.4	0.2	0.5	0.0	0.0
	Standard Deviation				0.00	0.00	4.24	4.24	0.00	0.00	0.00	0.00	0.07	0.00	0.07	0.07	0.00	0.00
Routine	MCT-6	04/26/01	Surface	14.7	200	113	576	380	196.0	24.0	1.76	0.06	3.40	1.70	3.46	5.16	0.621	0.306
Replicate	MCT-6	04/26/01	Surface	14.7	170	112	563	383	180.0	20.0	1.17	0.04	3.50	1.13	3.54	4.67	0.624	0.327
	Industrial Statistic (I%)			0.00%	8.11%	0.44%	1.14%	0.39%	4.26%	9.09%	**20.14%**	**20.00%**	1.45%	**20.14%**	1.14%	4.98%	0.24%	3.32%

Table 46. In-lake quality assurance/quality control samples collected in Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Sample	Site	Date	Time	Depth	Fecal Coliform (#/100 ml)	Alkalinity (mg/L)	Total Solid (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Organic Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)
Blank	BL	4/12/2000	13:00	-	10	6	7	6	1	1	0.21	0.01	0.1	0.2	0.11	0.31	0.002	0.002
Blank	BL	5/1/2001	17:00	-	10	19	67	66	1	1	0.21	0.01	0.6	0.2	0.61	0.81	0.002	0.002
Blank	BL	5/13/2001	17:00	-	10	6	7	6	1	1	0.36	0.01	0.1	0.35	0.11	0.46	0.002	0.002
Blank	BL	5/15/2001	12:00	-	10	6	8	8	1	1	0.36	0.01	0.1	0.35	0.11	0.46	0.002	0.002
Blank	BL	5/16/2001	10:00	-	10	6	14	13	1	1	0.36	0.01	0.2	0.35	0.21	0.56	0.002	0.002
	Mean				10.0	8.6	20.6	19.8	1.0	1.0	0.3	0.0	0.2	0.3	0.2	0.5	0.0	0.0
	Standard Deviation				0.00	5.81	**26.10**	**25.98**	0.00	0.00	0.08	0.00	0.22	0.08	0.22	0.19	0.00	0.00
Routine	FD-2	05/01/00	17:00	Surface	5	162	346	340	6.0	2.0	0.85	0.01	0.05	0.84	0.06	0.90	0.039	0.007
Replicate	FD-2	05/01/00	17:00	Surface	5	163	344	339	5.0	2.0	0.88	0.01	0.05	0.87	0.06	0.93	0.038	0.009
	Industrial Statistic (I%)				0.00%	0.31%	0.29%	0.15%	9.09%	0.00%	1.73%	0.00%	0.00%	1.75%	0.00%	1.64%	1.30%	**12.50%**
Routine	FD-2	09/14/00	10:00	Surface	5	146	339	332	7.0	1.0	0.43	0.01	0.05	0.42	0.06	0.48	0.043	0.018
Replicate	FD-2	09/14/00	10:00	Surface	5	145	335	331	4.0	1.0	0.42	0.01	0.05	0.41	0.06	0.47	0.040	0.016
	Industrial Statistic (I%)				0.00%	0.34%	0.59%	0.15%	**27.27%**	0.00%	1.18%	0.00%	0.00%	1.20%	0.00%	1.05%	3.61%	5.88%
Routine	FD-1	04/10/01	12:00	Surface	5	130	368	341	27.0	9.0	0.47	0.01	0.40	0.46	0.41	0.87	0.098	0.022
Replicate	FD-1	04/10/01	12:00	Surface	5	132	363	343	20.0	2.0	0.49	0.01	0.40	0.48	0.41	0.89	0.104	0.023
	Industrial Statistic (I%)				0.00%	0.76%	0.68%	0.29%	**14.89%**	**63.64%**	2.08%	0.00%	0.00%	2.13%	0.00%	1.14%	2.97%	2.22%
Routine	FD-2	05/15/01	10:30	Surface	5	124	366	360	6.0	0.5	1.73	0.15	1.40	1.58	1.55	3.13	0.133	0.089
Replicate	FD-2	05/15/01	10:30	Surface	5	125	375	367	8.0	1.0	1.06	0.14	1.50	0.92	1.64	2.56	0.112	0.090
	Industrial Statistic (I%)				0.00%	0.40%	1.21%	0.96%	**14.29%**	**33.33%**	**24.01%**	3.45%	3.45%	**26.40%**	2.82%	10.02%	8.57%	0.56%
Routine	FD-1	05/15/01	10:00	Surface	5	123	383	374	9.0	2.0	0.95	0.15	1.50	0.80	1.65	2.45	0.122	0.102
Replicate	FD-1	05/15/01	10:00	Surface	5	123	387	379	8.0	3.0	0.94	0.15	1.50	0.79	1.65	2.44	0.134	0.096
	Industrial Statistic (I%)				0.00%	0.00%	0.52%	0.66%	5.88%	**20.00%**	0.53%	0.00%	0.00%	0.63%	0.00%	0.20%	4.69%	3.03%

Ten quality assurance / quality control samples (5 blank and 5 replicate) were collected for in-lake monitoring samples. Twenty nine in-lake samples were collected in Fate Dam for an overall quality assurance/quality control percentage of 17.2 percent. Nine tributary replicate sample parameters (total suspended solids (three samples), volatile total suspended solids (three samples), TKN (one sample), organic nitrogen (one sample) and total dissolved phosphorus (one sample) had at least one industrial statistic (%I) greater than 10 percent (absolute percent). Sampling parameters total suspended solids (three of five samples) and volatile total suspended solids (three of five samples) had the most instances of exceeding the 10 percent threshold. Variations in field sampling techniques, preparation and that the samples are replicate and not duplicate may be some reasons for differences. All other replicate parameter samples were within 10 percent from the original samples. Over all, 64.2 percent of sampling parameters had all in-lake industrial statistics values less than 10 percent different (Table 46).

Two parameters (total solids and total dissolved solids) exceeded the criterion of the standard deviation being less than the mean. One in-lake blank sample collected on May 1, 2001 had elevated total solids concentration. The actual parameter caused the exceedance in total solids was total dissolved solids with 66 mg/L. Variations in brands of distilled water or preparation of the sample may be some reasons for differences in elevated total and total dissolved solids concentrations in blank samples.

3.6 Monitoring Summary and Recommendations

Monitoring Summary

Tributary

Fate Dam is listed in the 2004 Integrated Report for TSI (SD DENR 2004). Nail Creek drains a watershed of approximately 6,961 ha (17,202 acres) and is impounded by Fate Dam in Lyman County, South Dakota (Figure 1). Fate Dam is a recreational lake of approximately 60.7 ha (150 acres) and has been impacted by periodic algal blooms and elevated TSI values. American Creek Conservation District (ACCD) sponsored this project as part of the Medicine Creek Watershed Assessment Project.

Nail Creek was monitored using twenty separate water quality parameters. Seventeen of the twenty parameters (85 percent) had the highest average concentrations for all tributary sites in the spring of 2001. The remaining three water quality parameters (15 percent) had the highest average concentrations and/or values in the winter of 2001. During the project, Nail Creek tributary samples did not exceed water quality standards.

South Dakota water quality standards for fecal coliform bacteria do not apply to Nail Creek (designated beneficial uses, 9-Fish and wildlife propagation, recreation, and stock watering waters and 10-irrigation waters) however, during this study, one elevated fecal coliform count (1,400 colonies/100ml) collected in mid April was observed in the watershed. Although not applicable, elevated fecal coliform counts may be unhealthy when humans come in contact with contaminated water. Runoff from land-applied manure, cattle or even wildlife may be responsible for the sporadic high fecal concentrations.

Nail Creek was monitored for tributary loading to Fate Dam from April 2000 through May 2001. Approximately 3,069 acre-feet of water flowed into Fate Dam from the gauged portion of the watershed (15,869 acres) in 2000 and 2001. The export coefficient (water delivered per acre) for the Fate Dam/Nail Creek watershed was 0.16 acre-foot. Peak hydrologic load for the watershed occurred in the spring of 2001. Approximately 58.7 percent of the total hydrologic load delivered to Fate Dam was delivered in the spring of 2001.

Current data indicate increased nutrient loading (phosphorus) from the watershed (Nail Creek) to Fate Dam resulting in elevated TSI values. AnnAGNPS modeling identified priority areas and critical cells within the watershed for mitigation (treatment). Priority areas and critical cells were listed in Appendix A. All watershed nutrient parameters eventually affect in-lake concentrations and TSI values in Fate Dam so reductions in any or all of these parameters may lower in-lake TSI values.

Total phosphorus loading to Fate Dam from Nail Creek is 3,440 kg/yr; at a minimum, all modeled Best Management Practices (BMPs) should be implemented in the watershed to reduce the nutrient (phosphorus) loading to Fate Dam. Based on site-specific standards for Fate Dam, a 19.5 percent reduction in total phosphorus (approximately 671 kg/yr) is needed to fully support site specific beneficial use criteria and meet the total phosphorus TMDL of 2,769 kg/yr. AnnAGNPS modeling indicates a 19.5 percent reduction in total phosphorus is attainable in the Fate Dam watershed.

Table 47. Nail Creek watershed mitigation priority sub-watersheds for sediment, nitrogen and phosphorus, based on watershed assessment modeling.

Parameter	Sub-watershed	Priority Ranking	Export Coefficient (kg/acre)	Delivered Load (kg)
Sediment	MCT-6	1	88.1	695,893
	MCT-5	2	68.2	541,273
Nitrogen	MCT-6	1	1.3	10,538
	MCT-5	2	1.2	9,769
Phosphorus	MCT-6	1	0.3	2,206
	MCT-5	2	0.1	835

Sub-watersheds that should be targeted for sediment, nitrogen and total phosphorus mitigation, based on water quality modeling export coefficients, are presented in priority ranking in Table 47.

In-lake

Fate Dam is a 60.7 ha (150 acre) impoundment located in Lyman County, South Dakota and was included in the 1998, 2002 South Dakota’s impaired waterbodies list and the 2004 Integrated Report. Current data indicate Fate Dam exceeded Ecoregion 43 targeted TSI values based on mean TSI and is in need of a TMDL. However, no in-lake surface water quality samples exceeded standards during this study.

Current data indicate that a reduction in total phosphorus is needed in both the watershed and in Fate Dam to meet proposed site-specific designated beneficial uses based on modeled (AnnAGNPS) attainability criteria. Every effort should be made to improve current management practices to control and reduce sediment and nutrient runoff in the Fate Dam watershed. Decreasing tributary sediment, nitrogen and phosphorus inputs from Nail Creek will improve (lower) Fate Dam TSI values. Tributary reductions in these parameters will reduce Secchi, total phosphorus and chlorophyll-*a* TSI values and increase transparency (algal and non-algal turbidity).

Mean TSI values were originally used to set current ecoregional beneficial use criteria for lakes in South Dakota (SD DENR, 2000a). Currently, the target for full support in Ecoregion 43 is a mean TSI value of $\leq$ 55.00. However, current ecoregional (Ecoregion 43) target criteria do not fit Fate Dam based on AnnAGNPS watershed loading and BATHTUB in-lake eutrophication modeling. AnnAGNPS data indicate under ideal conditions converting the entire watershed to all grass would produce a total phosphorus reduction of 55.1 percent. This would result in a phosphorus TSI of 57.45 and a mean TSI of 55.88 for Fate Dam (6.9 percent mean TSI reduction). Under this extreme situation Fate Dam could not meet current ecoregional-based beneficial use criteria; obviously, this scenario is not realistic based on financial, logistical and technical constraints.

Fate Dam is listed in the 2004 Integrated Report for TSI (SD DENR 2004). Water quality data from this study identify Fate Dam as partially supporting using assigned beneficial uses criteria based on current Ecoregion 43 criteria (mean TSI $\leq$ 55.00). An alternate site-specific (watershed-specific) evaluation criterion was proposed (fully supporting, mean TSI $\leq$ 59.00). Currently, Fate Dam still only partially supports site specific beneficial use criteria.

Tributary Recommendations

Tributary recommendations are based on best management practices (BMPs) and best professional judgment. All reductions were modeled using water quality and/or AnnAGNPS data collected during this study. Reduction percentages given in Table 48 are the expected percent reduction in sediment and nutrients delivered to Fate Dam based on 2000 and 2001 loading and AnnAGNPS data. Total acreage and total percentage of the watershed by priority ranking for sediment, nitrogen and phosphorus critical cells are provided in Table 49 and Appendix A (Table A-2).

Table 48. AnnAGNPS modeled overall BMP reduction percentages for the Fate Dam/Nail Creek watershed, Lyman County, South Dakota based on data collected from 2000 through 2003.

Best Management Practice	Sediment	Nitrogen	Phosphorus
Fertilizer Reduction	**0.0**	**2.2**	**8.8**
Grazing Management Reduction	**0.0**	**2.2**	**3.1**
Conservation Tillage Reduction	**4.0**	**3.3**	**0.4**
Buffer Strips	**4.0**	**2.2**	**7.3**
Overall Watershed Percent Reduction	**8.0**	**10.0**	**19.5**

Table 49. Sediment, nitrogen and phosphorus critical cell acreage by priority ranking for the Fate Dam/Nail Creek watershed, Lyman County, South Dakota from 2000 through 2003.

	Sediment		Nitrogen		Phosphorus	
Priority Ranking	Acres	Percentage of the watershed	Acres	Percentage of the watershed	Acres	Percentage of the watershed
1	207.49	1.2	387.85	2.3	697.65	4.1
2	1,629.24	9.5	2,075.16	12.1	2,546.66	14.8
3	2,783.09	16.2	3,769.62	21.9	1,171.35	6.8
Total	**4,619.82**	**26.9**	**6,232.63**	**22.8**	**4,415.66**	**25.7**

Additional BMPs (streambank stabilization, conversion of highly erodible land to grass, etc.) should be considered and implemented in the Fate Dam/Nail Creek watershed to further reduce sediment and nutrient loads to Fate Dam and are represented in the TMDL calculation as part of the implicit margin of safety (MOS). Implementing any additional BMPs will help ensure TMDL attainability in the Fate Dam/Nail Creek watershed.

In-lake Recommendations

The in-lake recommendation is based on best management practices and best professional judgment and should be considered only after all tributary BMPs have been implemented to attain long-term success. Reductions were estimated or calculated using water quality and/or BATHTUB data collected during this study. Reduction percentages given in Table 50 are the expected percent reduction in in-lake nutrients based on 2000 through 2001 data.

Aluminum Sulfate Treatment (Alum)

Alum treatment uses an aluminum sulfate slurry that, when applied to water, creates an aluminum hydroxide precipitate (floc). The aluminum hydroxide (Al_3O_2) floc removes phosphorus and suspended solids, both organic and inorganic, from the water column by reacting with the assimilated phosphorus to create aluminum phosphate that settles to the bottom. By collecting and settling out suspended particles including algae, alum leaves the lake noticeably clearer. (improving Secchi depth). Once on the bottom of the lake, floc forms a layer that acts as a phosphorus barrier by combining with phosphorus as it is released from the sediment. The aluminum phosphate compound will not release phosphorus to the water column unless disturbed (Sweetwater, 2000).

The treatment can last up to ten years and is dependent upon the amount of alum applied, total suspended solids sedimentation rate and external phosphorus loading. Welch and Cooke (1995) studied lakes treated with alum and found that phosphorus concentrations were reduced from 30 percent to 90 percent after application. If long-term disturbance and tributary loadings are significantly reduced, a significant reduction in in-lake phosphorus is estimated based upon in-lake concentrations prior to application. The percent reductions for alum treatment in Table 50 were calculated using a conservative percent reduction in in-lake phosphorus concentrations.

Table 50. Estimated reduction percentages using BATHTUB for in-lake Alum treatment Best Management Practices for Fate Dam, Lyman County, South Dakota in 2000 and 2001.

		Percent TSI Parameter Reduction (BATHTUB)		
In-lake Best Management Practice	**In-lake Phosphorus Reduction**	**Secchi**	**Chlorophyll-*a***	**Phosphorus**
Alum Treatment	30%	0.1	0	8.1

[1] = Percent TSI reductions was estimated using predicted tributary TSI values based on BATHTUB modeling.

Implementing and alum treatment in Fate Dam to further reduce in-lake phosphorus is represented in the TMDL calculation as part of the implicit margin of safety (MOS). Implementing any additional in-lake BMPs will help ensure TMDL attainability in the Fate Dam watershed. Other in-lake BMPs should be considered to augment tributary mitigation having an overall positive impact on Fate Dam over time.

Targeted Reduction and TMDL

Alternative site specific (watershed-specific) evaluation criteria (fully supporting, mean TSI $\leq$ 59.00) was proposed based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability. This evaluation criterion was developed and calculated using measured loads and may not take into account long term annual load variation.

Based on site-specific criteria and under current conditions, mean TSI (59.91) in Fate Dam only partially supports beneficial uses using this evaluation criterion. The site (watershed) specific criteria/goals are more realistic and attainable based on AnnAGNPS modeling and BMP reductions within the Fate Dam watershed. BMP based reduction criteria for Fate Dam were estimated based on a 19.5 percent reduction in total phosphorus loads (671 kg/yr) to Fate Dam resulting in a phosphorus TMDL of 2,769 kg/yr resulting in a mean TSI of 58.91.

The 19.5 percent modeled reduction is based on AnnAGNPS watershed modeling and consisted of: (1) all priority one phosphorus fertilized fields with moderate fertilizer rates reduced one level (moderate to low) or approximately 8.8 percent phosphorus reduction; (2) converting all current pastures from fair condition to good condition or approximately 3.1 percent phosphorus reduction; (3) applying conservation tillage to all priority-one phosphorus critical cells (10-critical cells) or approximately 0.4 percent and (4) converting tilled/cropped priority-one phosphorus critical cells to all grass and results were again reduced 50 percent to better simulate typical phosphorus reduction or approximately 7.3 percent. Combining all reductions (summing all load reductions) the best estimated phosphorus reduction for the Fate Dam/Nail Creek watershed is 19.5 percent.

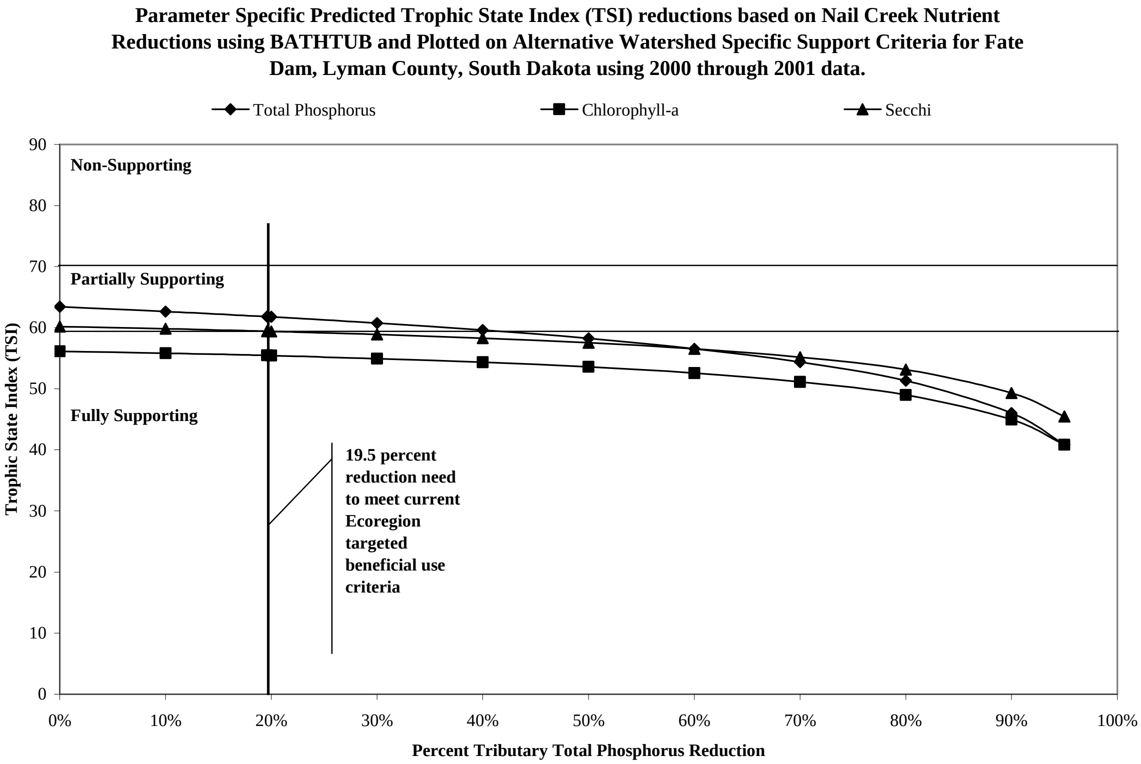


Figure 87. TMDL-predicted parameter specific Trophic State Index (TSI) reductions using the BATHTUB reduction model based on tributary BMPs reductions and ranked by watershed-specific beneficial use categories for Fate Dam, Lyman County, South Dakota using 2000 and 2001 data.

Targeted reductions for specific parameters and mean TSI values were modeled through the BATHTUB reduction model. All reductions were modeled or calculated using water quality and/or AnnAGNPS data collected during this study. Parameter-specific and mean TSI values were plotted on site specific beneficial use categories and are shown in Figure 87 and Figure 88. Tributary and in-lake TSI reductions were based on Best Management Practices, best professional judgment and conversations with the American Creek Conservation District (project sponsor). Reductions in TSI were based on tributary BMP recommendations outlined on pages 148 and 149 of this report. The Margin of Safety (MOS) for phosphorus is implicit. Implicit, in that, all modeled reduction estimations for tributary BMPs were calculated using extremely conservative reduction values/percentages and any additional tributary BMPs (not modeled) implemented would be incorporated into the TMDL equation as implicit margin of safety.

Based upon 2000 and 2001 modeled data, both phosphorus TSI (63.44) and Secchi TSI (60.18) values were partially supporting; however chlorophyll-*a* TSI values (56.12) were fully supporting based on previously defined watershed-specific beneficial use criteria (Figure 87). SD DENR-recommended targets for specific TSI parameters for Fate Dam were based on watershed-specific criteria and tributary BMP attainability. They are 61.82 for phosphorus, 55.48 for chlorophyll-*a* and 59.43 for Secchi visibility (Table 51). To reach these goals, tributary total phosphorus loads will have to be reduced by 19.5 percent (AnnAGNPS derived reduction). Reductions should improve phosphorus TSI by 2.6 percent, chlorophyll-*a* TSI by 1.2 percent and Secchi TSI by 1.3 percent, which will improve in-lake water quality. Long-term tributary and in-lake monitoring should be conducted during and after implementation to evaluate BMPs' effectiveness and determine if in-lake TSI targets have been met. SD DENR will continue to monitor Fate Dam as part of the statewide lakes assessment project.

The average TSI values for phosphorus, chlorophyll-*a* and Secchi combined as modeled using BATHTUB (Table 51 (59.91)) is also in the partially supporting category (Figure 88). The recommended target for an average TSI value in Fate Dam is 58.91 (Table 51 and Table 52). Implementing tributary BMPs in priority 1 critical cells in the watershed should decrease the in-lake mean TSI value by 1.7 percent and fully support new site-specific beneficial use criteria (mean TSI $\leq$ 59.00).

If an in-lake alum treatment is considered, all tributary BMPs should be in place and implemented before alum treatment begins to attain maximum benefit and . In-lake BMPs may improve phosphorus TSI values (an estimated 8.1 percent, based on modeled (BATHTUB) in-lake TSI reductions); however, the Total Maximum Daily Load (TMDL) is based on attainable tributary BMP reductions using conservative targeted reduction estimates. There was little evidence of major phosphorus load from in-lake sediments.

An appropriate TMDL for total phosphorus in Fate Dam is 2,769 kg/yr, producing a mean TSI of 58.91 (Equation 6, Table 51 and Table 52).

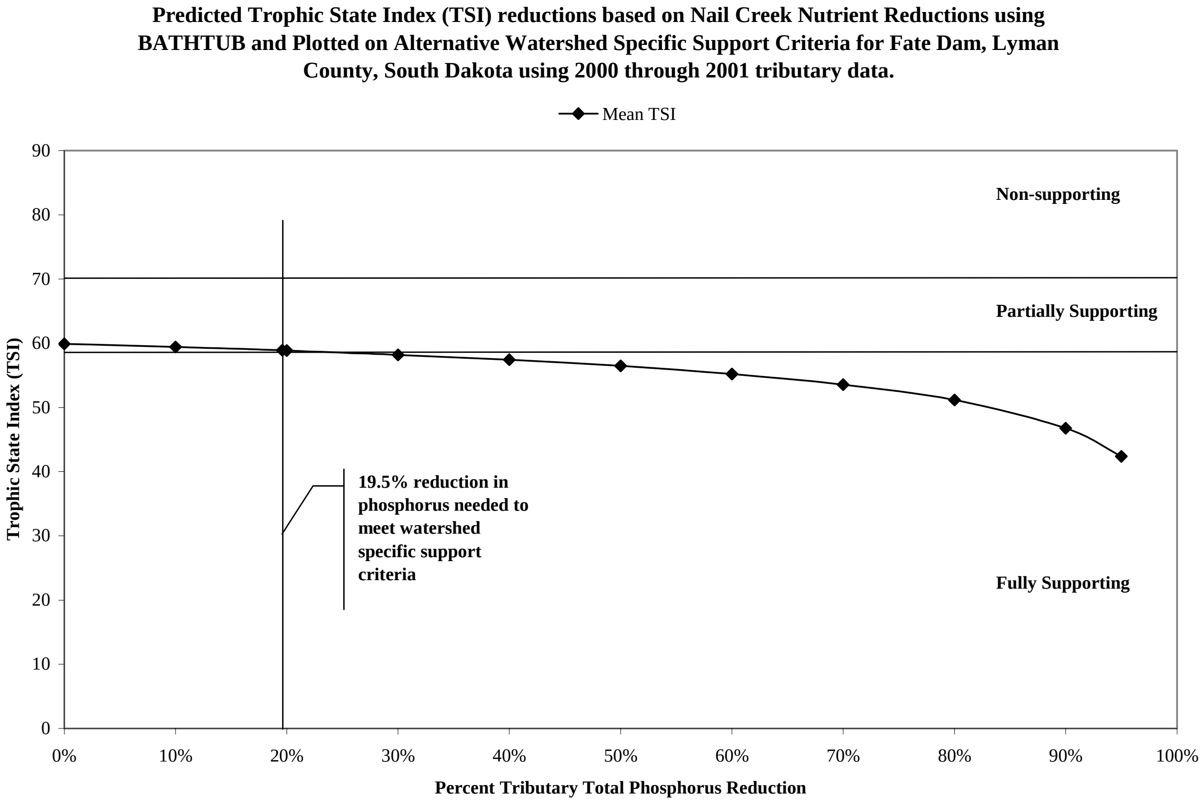


Figure 88. TMDL-predicted mean Trophic State Index (TSI) reduction using the BATHTUB reduction model based on tributary BMPs reductions ranked by Ecoregion 43 watershed-specific beneficial use categories for Fate Dam, Lyman County, South Dakota based on 2000 and 2001 data.

Mean TSI values should be reduced by 1.7 percent for modeled tributary BMPs. In-lake BMPs (alum treatment (implicit margin of safety) may be implemented to achieve additional reductions (estimated approximately 8.1 percent) after tributary BMPs to achieve maximum benefit.

Table 51. Current, targeted and percent reduction for parameter specific and mean TSI values using BATHTUB based on 2000 and 2001 data for Fate Dam, Lyman County, South Dakota.

TSI Parameter	2000 -2001 Estimated TSI Values (BATHTUB)	TMDL Targeted TSI Value	Percent TSI Reduction
Total Phosphorus	63.44	61.82	2.6
Chlorophyll-*a*	56.12	55.48	1.1
Secchi	60.18	59.43	1.2
Average	**59.91**	**58.91**	**1.7**

Table 52. Total phosphorus TMDL target loading for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Parameter	Best Management Practice	Margin of Safety	TMDL
Total Phosphorus	Tributary and In-lake BMPs	Implicit (conservative estimations)	Total Phosphorus TSI 61.82 (2,769 kg/year) (Mean TSI 58.91)

[1] = Calculated based on 2000 and 2001 in-lake and tributary loading/concentration data

Equation 6. Total phosphorus TMDL equation for Fate Dam, Lyman County, South Dakota based on 2000 through 2001 data.

Component	Maximum Load
Waste Load Allocation (WLA):	0 (kg/yr)
+ **Load Allocation (LA)**	2,769 (kg/yr)
+ **Margin of Safety:**	Implicit
TMDL[1]	**2,769 (kg/yr)**

[1] = Represents a total phosphorus tributary measured load reduction of approximately 19.5 percent, based on estimated AnnAGNPS BMP attainability.

4.0 Public Involvement and Coordination

Public involvement and coordination were the responsibility of American Creek Conservation District. As local sponsor for the project, they were responsible for issuing press releases and/or news bulletins. The project was discussed at monthly meetings of the American Creek Conservation District Board, which is also a public setting where the public is invited to attend. The project was also discussed at County Commission meetings (Lyman and Jones counties)

The American Creek County Conservation District was the appropriate lead project sponsor for this project. The Conservation District was important to this project because of its working relationship with the stakeholders within the watershed.

4.1 State Agencies

Because the South Dakota Department of Environment and Natural Resources (SD DENR) is the statewide pollution control agency, it was the appropriate lead state agency for this project. SD DENR is responsible for tracking Section 319 funds and state and local match for federal funding. The Department (SD DENR) is also responsible for coordination and data collection for all assessment and implementation projects throughout the State of South Dakota.

South Dakota Department of Agriculture (SD DOA) provided conservation commission funds for this project.

South Dakota Game, Fish and Parks (SD GF&P) provided current and long-term fisheries data, reports and endangered species list (Heritage List) for Medicine Creek which includes the Fate Dam watershed. SD GF&P should be contacted and consulted during the planning and implementation phases of this project.

4.2 Federal Agencies

Natural Resources Conservation Service (NRCS) provided office space and technical assistance for the project. NRCS is the contact for local landowners involved with conservation plans and practices. NRCS needs to be involved during all phases of the implementation process.

The United States Environmental Protection Agency (US EPA) provided financial assistance for the project. The US EPA provided $101,796 of Section 319 funds to cover project costs for the Medicine Creek watershed assessment in which the Fate Dam watershed was assessed. EPA will also review and approve this assessment and TMDL.

The United States Fish and Wildlife Service (US FWS) did not provide financial or technical assistance during the assessment project. However, they should be contacted prior to the implementation project regarding their role in the implementation of the TMDL and the potential impact on any endangered species (consultation process).

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

The American Creek County Conservation District within the Fate Dam watershed took a leading role in the planning and implementation of this project. This was evident during the assessment phase and becomes more important during the implementation phase when conservation practices need to be coordinated and implemented with local landowners.

4.4 Other Sources of Funds

The Medicine Creek Watershed Assessment project, which included Fate Dam, was funded with Section 319 and local funds. Conservation Commission funds along with funds from Lyman and Jones Counties were also secured for this project.

Funding Category	Source	Total
EPA Section 319 Funds	US EPA	$101,796.00
Conservation Commission	Local	$47,864.00
Counties	Local	$20,000.00
Over Match	Local	7,336.38
Total Budget		**$176,996.38**

5.0 Aspects of the Project That Did Not Work Well

After the project implementation plan (PIP) was approved, the funding was not released until early June 2000 which resulted in a setback for the data collection phase of this project. Fortunately, there was enough funding at the end of the first year so that the water quality data could be collected the following spring (2001). This delay could have been avoided had the funding been released in early March of 2000. The deadlines identified in the objectives/tasks and the milestone schedule would have had an increased chance of being met.

Another aspect of the project that provided some difficulty was that AGNPS modeling was outlined as the watershed model; however, after the project was started a decision was made to change the watershed model from AGNPS to an updated annualized version (AnnAGNPS). This change required different data requirements and a steep learning curve to transition from AGNPS to AnnAGNPS. This increased the modeling and analysis time required for relating AnnAGNPS data to water quality monitoring data. However, this change increased resolution and identification of critical cells within the Fate Dam watershed.

6.0 Future Activity Recommendations

The Fate Dam watershed is an estimated 6,961 ha (17,202 acres) in size. This assessment project documented priority and critical areas for erosion (sediment), total nitrogen and total phosphorus in the watershed (Appendix A). As indicated in the report, certain areas in the Fate Dam watershed have been identified as areas of concern. Implementation efforts should be undertaken to implement/install BMPs in critical areas of the Fate Dam watershed to improve overall water quality.

The Fate Dam/Nail Creek watershed can not meet current ecoregional based beneficial use criteria and are unachievable and unrealistic in the Fate Dam watershed due to logistical, financial and technical constraints. An alternative site-specific (watershed-specific) evaluation criterion (fully supporting, mean TSI < 59.00) is proposed based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability. The watershed-specific beneficial use target criteria and TMDL based on realistic and attainable goals is recommended for the Fate Dam/Nail Creek watershed. Implementation of select BMPs in the Fate Dam/Nail Creek watershed will reduce nutrient loading, allowing Fate Dam, based on watershed-specific criteria, to fully support beneficial uses.

Current data indicate that a 19.5 percent reduction in total phosphorus can be achieved in this watershed to meet the TMDL goal of 2,769 kg/yr total phosphorus for a mean in-lake TSI of 58.91. The recommended reductions will improve compliance with South Dakota’s narrative criteria and the designated beneficial uses of the watershed, specifically, warmwater permanent fish life propagation water, immersion recreation water, limited contact recreation water, fish and wildlife propagation, recreation, and stock watering water and irrigation water. Based upon data from this assessment, a phase II implementation project should be designed and initiated in this watershed to achieve this goal.

An implementation project should be initiated to reduce sediment, total nitrogen and total phosphorus loading to meet the TMDL set for Fate Dam (2,769 kg/year of total phosphorus). Critical cells by priority ranking are outlined in Fate Dam/Nail Creek AnnAGNPS final report (Appendix A). Implementing all modeled tributary BMPs outlined in this report will reduce sediment, nitrogen and phosphorus loading and improve the trophic status of Fate Dam.

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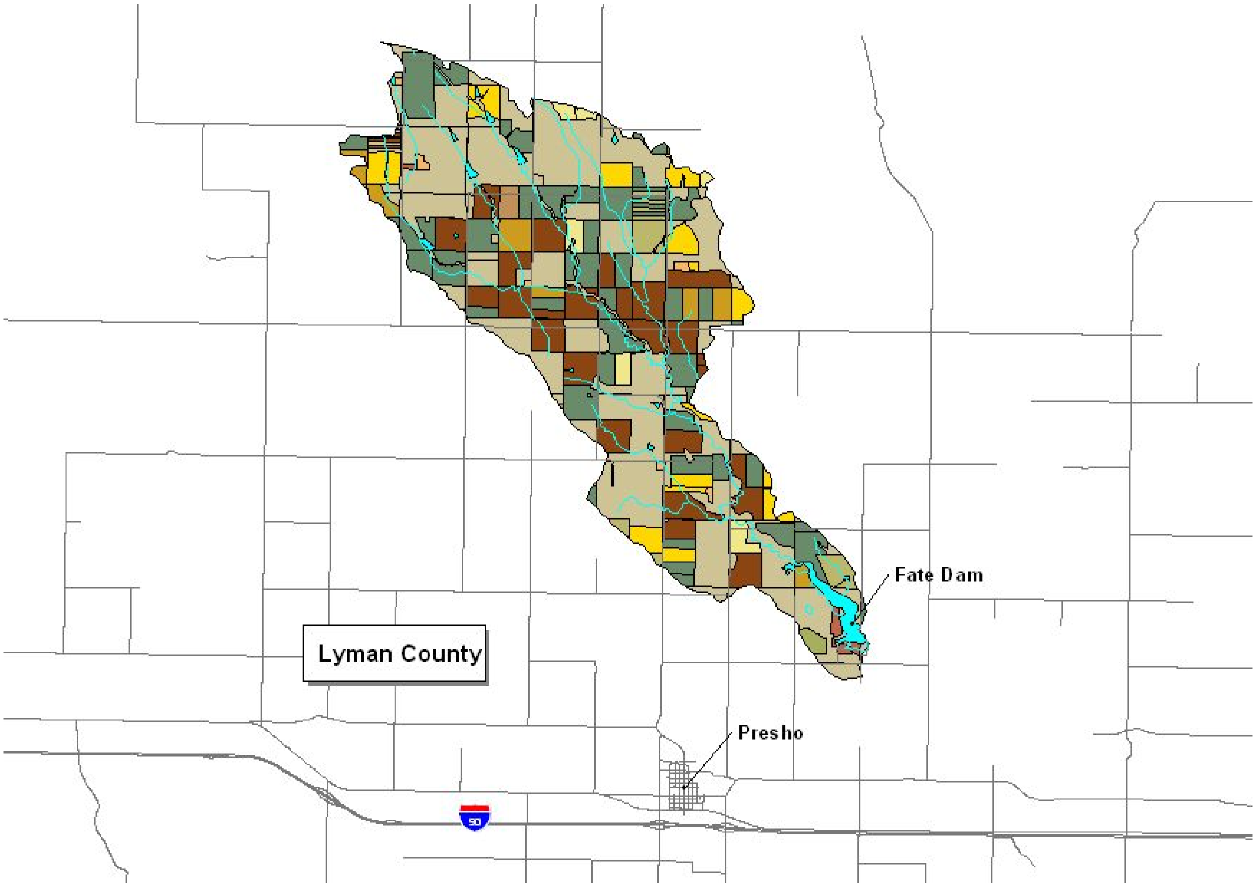
APPENDIX A

Fate Dam Annual Agricultural Non-Point Source Pollution Model (AnnAGNPS) Final Report

ANNUALIZED AGRICULTURAL NON-POINT SOURCE (AnnAGNPS) ANALYSIS OF FATE DAM/NAIL CREEK WATERSHED, LYMAN COUNTY, SOUTH DAKOTA



Prepared by:
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DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
WATER RESOURCES ASSISTANCE PROGRAM

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INTRODUCTION

Water quality is a major concern, especially in the agricultural states of the Midwestern United States. Several common water quality problems have been noted in lakes and reservoirs of the Central Plains. There have been reports of elevated plant nutrient levels, with concurrent elevations in plant biomass (Smith, 1998). Suspended solids and siltation have increased, and increases in these factors reduce light penetration, aesthetics, lake depth and volume, leading to alteration of aquatic habitats (deNoyelles et al., 1999). Water quality assessments have shown elevated levels of pesticides and other toxic chemicals (Scribner et al., 1996). Further, local and state regulatory agencies have fielded complaints regarding objectionable taste and odor conditions (e.g., KDHE, 1999). All these problems contribute to or are symptomatic of water quality degradation. However, excess nutrients and siltation, both of which result from intensive agricultural activities, are the water quality factors that contribute most to eutrophication (Carpenter et al., 1998). Eutrophication is itself a serious and widespread problem in the Midwest. According to the National Water Quality Report to Congress, 50 percent of assessed U.S. lakes and a higher percentage of reservoirs in the agriculturally dominated Midwest were considered eutrophic (USEPA, 2000).

A vital key to the development of a lake/reservoir management strategy is to identify nutrient loading that describes associated eutrophic conditions in lakes and reservoirs. Annualized Agricultural Nonpoint Source (AnnAGNPS 2.32.a. 34) is a batch-process, continuous-simulation, watershed-scale model designed for agriculturally dominated watersheds, which was developed jointly by U.S. Department of Agriculture's Agricultural Research Service and Natural Resource Conservation Service (Bosch et al., 1998; Cronshey and Theurer, 1998; Geter and Theurer, 1998; Theurer and Cronshey, 1998; Johnson et al., 2000).

AnnAGNPS requires more than 400 parameters in 34 data categories, including land use, topography, hydrology, soils, feedlot operation, field management, and climate. AnnAGNPS uses up-to-date technologies that expand the original modeling capabilities of AGNPS. For example, soil loss from each field is predicted based on the Revised Universal Soil Loss Equation (RUSLE) (Renard et al, 1997) and the sediment yield leaving each field is based on the Hydrogeomorphic Universal Soil Loss Equation (HUSLE) (Theurer and Clarke, 1991).

AnnAGNPS is an effective tool for watershed assessment. However, the complexity of modeling procedures and massive data preparation render its application tedious and time consuming. Therefore, automation of the preparation and processing of repetitive data is required. ArcView® Spatial AnnAGNPS interface is a user-friendly tool developed to assist decision-makers to conduct easier, effective watershed assessments. The Spatial AnnAGNPS interface not only assists users to extract the required soil data from the National Soil Survey Geographic Database (SSURGO) but also helps users organize input files, run the model, and visualize modeling results.

AnnAGNPS is a data-intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into cells of varying sizes based on topography. Each cell is then assigned a primary land use and soil type.

Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells and reductions in sediment and nutrient yield are calculated at the outlet to the watershed.

METHODS

The Fate Dam/Nail Creek watershed (Figure A-1) was modeled and analyzed using AnnAGNPS modeling program.

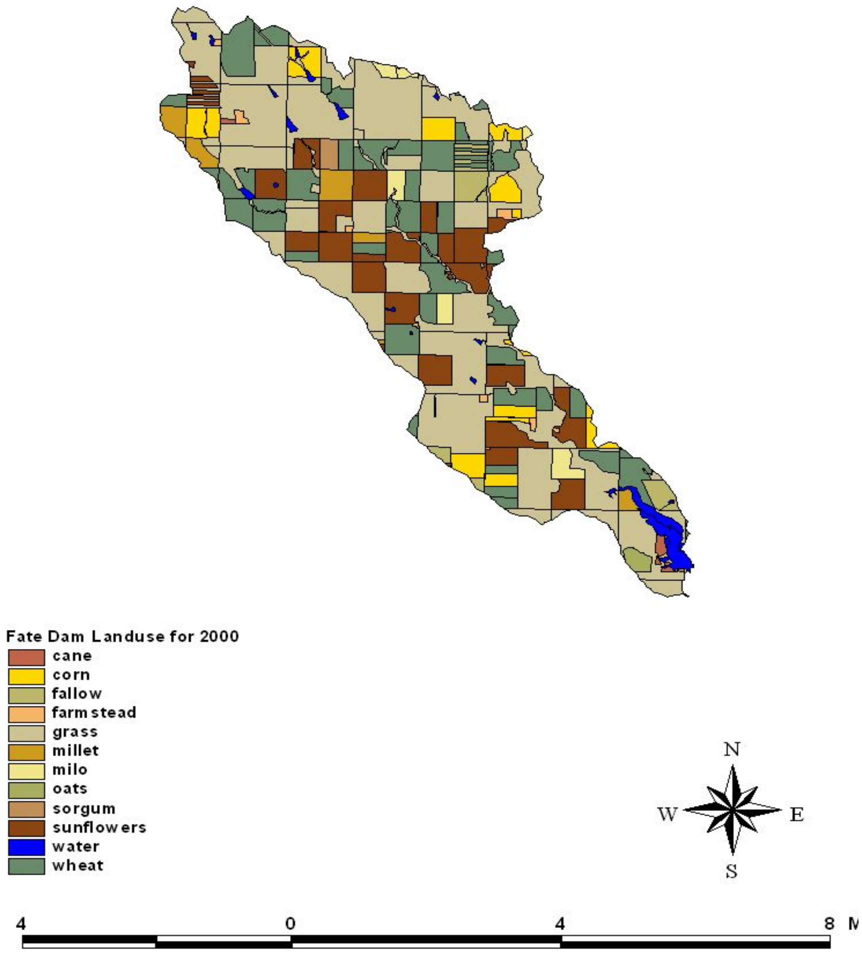

Figure A-1. Landuse in the Fate Dam/Nail Creek watershed, Lyman County, South Dakota in 2003.

ArcView® data layers for AnnAGNPS were acquired from various governmental agencies. Digital Elevation Model layers (DEMs) were downloaded from a United States Geological Survey website, soil layers were downloaded from a United States Department of Agricultural, Natural Resource Conservation Service (USDA-NRCS) website and digital NASIS (National

Soil Information System) data were obtained from the NRCS office in Huron, South Dakota. AnnAGNPS field and feedlot data and field digitizing in ArcView® for the Fate Dam/Nail Creek watershed analysis was collected/performed by personnel from the American Creek Conservation District from 2001 through 2003. Field history, planting and crop rotation data was obtained from the Farm Service Agency in Kennebec. Tillage, fertilization and feedlot data for the Fate Dam/Nail Creek watershed was acquired through the use of stakeholder surveys. Planting dates for specific crops and tillage practices were acquired for this region using RUSLE data provided by NRCS. All AnnAGNPS data modification and entry was preformed by South Dakota Department of Environment and Natural Resources (SD DENR) Water Resources Assistance Program (WRAP).

Part of the modeling process includes the assessment of Animal Feeding Operations (AFOs) located in the watershed. This assessment was completed with the assistance of the American Creek Conservation District which provided estimates on the number of animal units and duration of use in the Medicine Creek Watershed; however, there were no AFOs identified in the Fate Dam portion of the Medicine Creek Watershed and are not considered a problem in the Fate Dam/Nail Creek watershed.

Climate/weather data from Pierre, South Dakota was used to generate simulated weather data. Model results are based on one year of climate data for initializing variables prior to 25-year watershed simulation. Simulated precipitation based on climate data ranged from 13 to 29 inches per year. Mean annual precipitation for this watershed is approximately 17 inches.

Impoundment data was obtained from ArcView® Digital Ortho Quad layers (DOQs). DOQs were used to identify and quantify impoundments greater than 10 acres. Average depths were estimated based on best professional judgment using known waterbodies of similar size. Coefficients were calculated based on surface area and depth, with an equation based on impoundment morphology.

Initial critical cells for sediment, nitrogen and phosphorus were determined using simulated cell specific runoff values (kg/acre), with threshold runoff values greater than one and two standard deviations above the mean. Sediment, nitrogen and phosphorus cells analyzed and prioritized independently based on statistical characteristics. Cellular loading above two standard deviations above the mean for each category (sediment, nitrogen and phosphorus) received a priority ranking of one (1), loading cells above one standard deviation above the mean received a priority ranking of two (2) and cellular loading between one standard deviation and the mean received a priority three (3) ranking.

Fate Dam was identified in the Fate Dam/Nail Creek assessment report as having increased phosphorus loading resulting in elevated Trophic State Index (TSI) values based on Ecoregion 43 criteria. Modeled reductions were based on phosphorus critical cells only, as phosphorus is the component of concern.

The existing field conditions, three-year crop rotation and fertilizer applications were modeled through AnnAGNPS to obtain initial (current) loading values at the outlet of each cell (pounds/acre/year). Specific AnnAGNPS parameters would then be manipulated (conventional tillage converted to no-till, moderate phosphorus fertilization application converted to low fertilization applications, etc.) to represent specific BMPs applied to the watershed. The AnnAGNPS model was re-run with manipulated values, the modified loading values were compared to the initial values to estimate/calculate sediment and nutrient reduction percentages.

All reduction percentages were developed and calculated using AnnAGNPS modeled load reductions based best available landuse data.

RESULTS AND DISCUSSION

Critical Cells

Priority critical cells for sediment, nitrogen and phosphorus for the Fate Dam/Nail Creek watershed based on AnnAGNPS modeling are shown spatially in Figure A-2 (sediment), Figure A-3 (nitrogen) and Figure A-4 (phosphorus). AnnAGNPS model identified approximately 4,416 acres of critical areas for phosphorus, or 25.7 percent of the watershed, within the Fate Dam/Nail Creek watershed, based on the above criteria (Table A-1). The Fate Dam watershed has been identified as contributing increased nutrients (phosphorus) to Fate Dam (SD DENR, 1998 and SD DENR, 2002), increasing in-lake TSI values above ecoregional targets (Ecoregion 43 - mean TSI $\leq$ 55.00). Table A-2 lists sediment, nitrogen and phosphorus critical cells by priority rank for the Fate Dam/Nail Creek watershed.

Table A-1. Critical cell acreage by priority ranking for the Fate Dam/Nail Creek watershed, Lyman County, South Dakota from 2000 through 2003.

	Sediment		Nitrogen		Phosphorus	
Priority Ranking	**Acres**	**Percentage of the watershed**	**Acres**	**Percentage of the watershed**	**Acres**	**Percentage of the watershed**
1	207.49	1.2	387.85	2.3	697.65	4.1
2	1,629.24	9.5	2,075.16	12.1	2,546.66	14.8
3	2,783.09	16.2	3,769.62	21.9	1,171.35	6.8
Total	4,619.82	26.9	6,232.63	36.2	4,415.66	25.7

Spatially, all critical cells (sediment, nitrogen and phosphorus) were generally evenly distributed throughout the watershed (Figure A-2, Figure A-3 and Figure A-4). Table A-1 indicates for phosphorus critical cells approximately 4.1 percent of the total acres in the Fate Dam/Nail Creek watershed were priority one, 14.8 percent of the watershed were priority two and 6.8 percent of the watershed were priority three. All priority cells should be field verified prior to BMP implementation.

Fate Dam Critical Sediment Cells

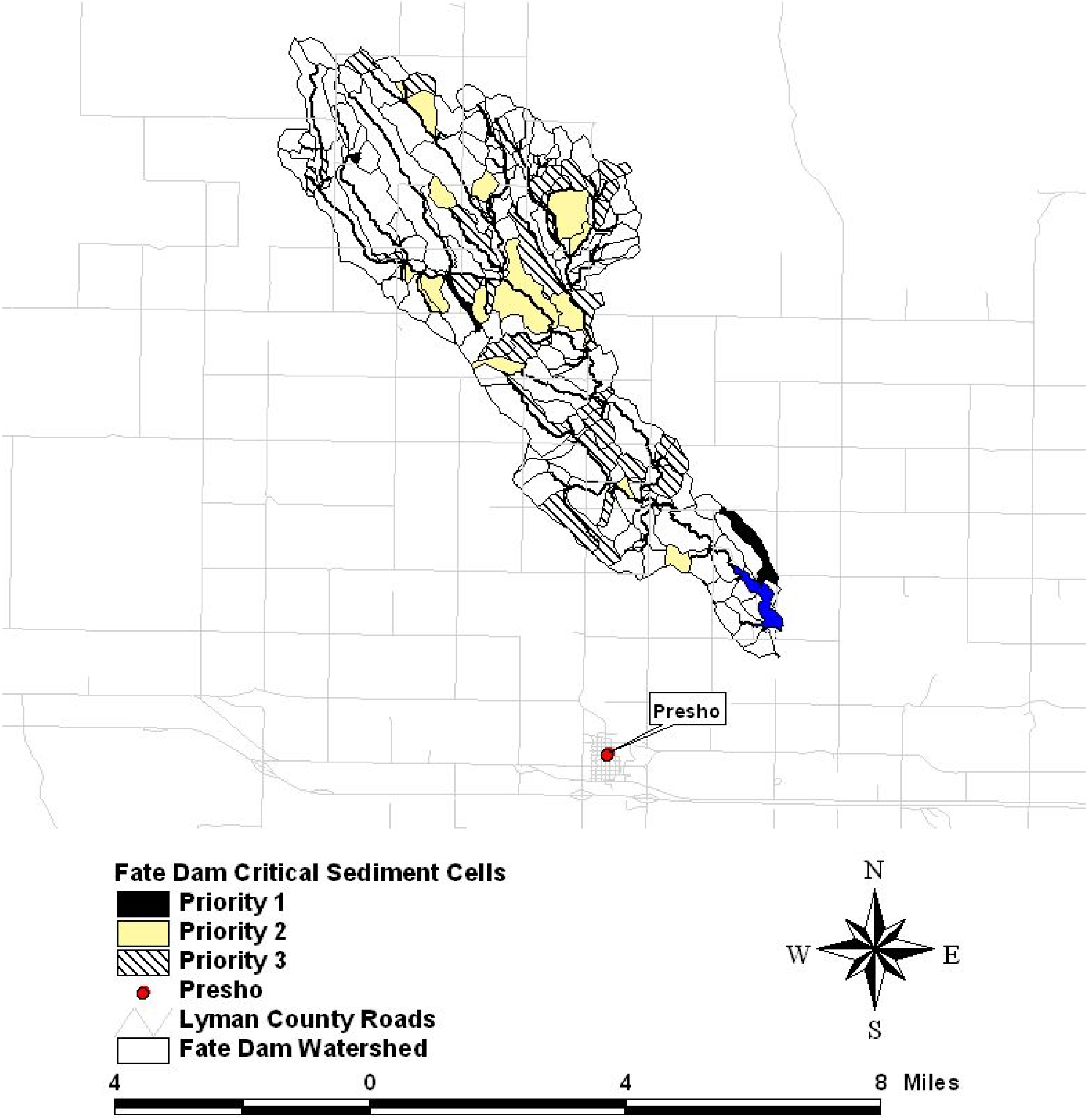

Figure A-2. AnnAGNPS Fate Dam/Nail Creek critical sediment cells by priority ranking based on data from 2000 through 2003.

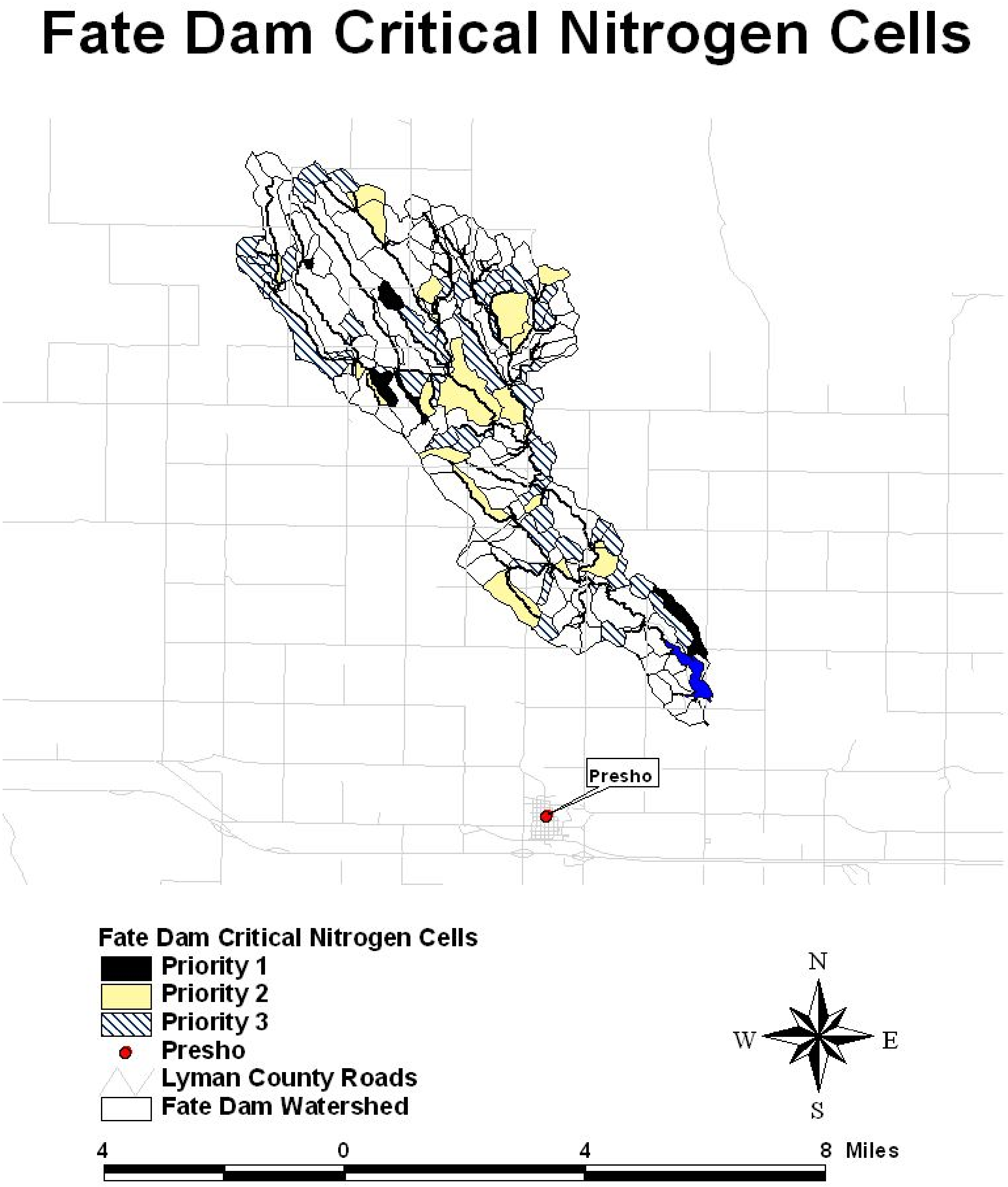

Figure A-3. AnnAGNPS Fate Dam/Nail Creek critical nitrogen cells by priority ranking based on data from 2000 through 2003.

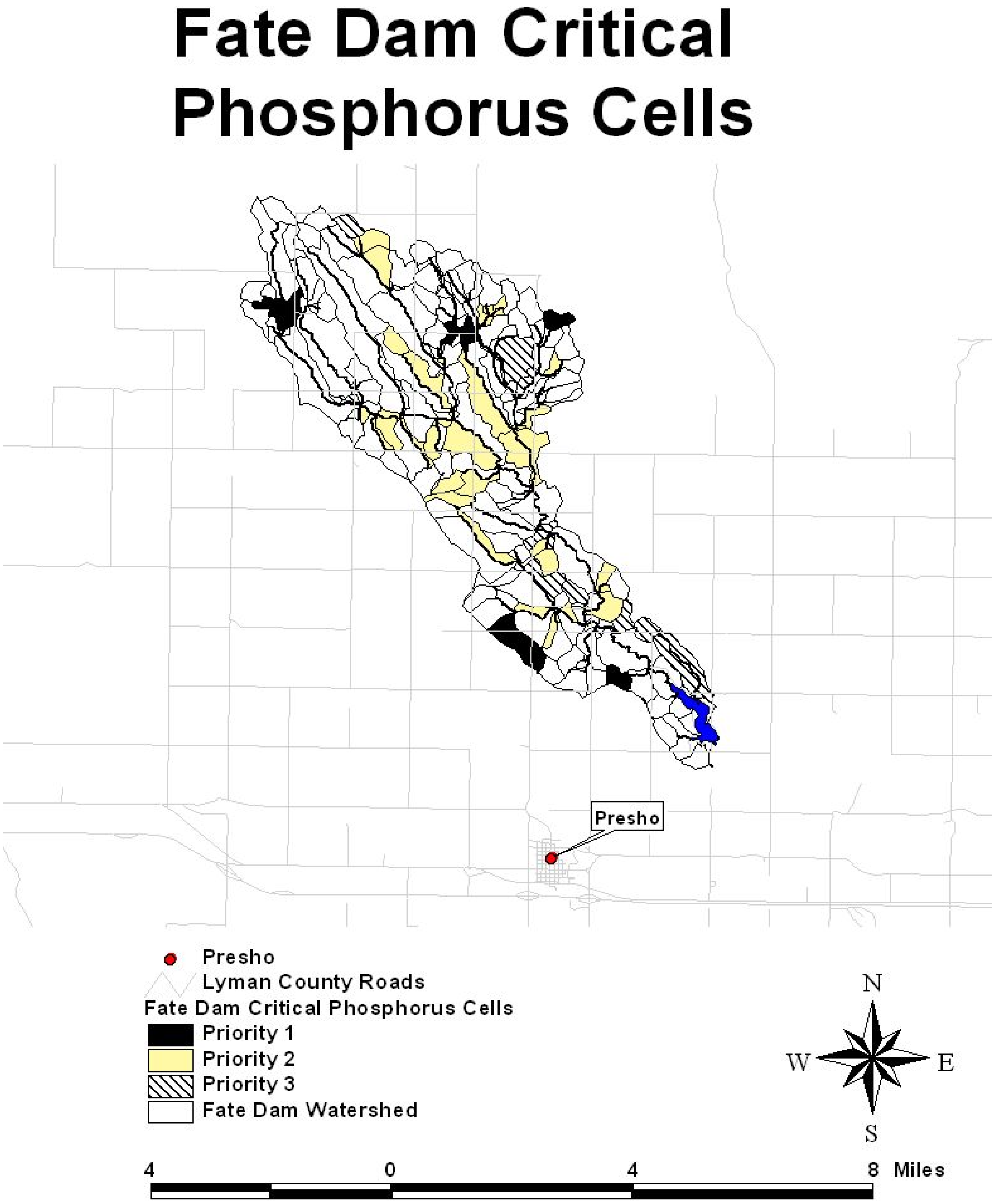

Figure A-4. AnnAGNPS Fate Dam/Nail Creek critical phosphorus cells by priority ranking based on data from 2000 through 2003.

Table A-2. Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Fate Dam/Nail Creek watershed, Lyman County, South Dakota based on 2000 through 2003 data.

Sediment			Total Nitrogen			Total Phosphorus		
Priority	**Cell**	**Area**	**Priority**	**Cell**	**Area**	**Priority**	**Cell**	**Area**
1	613	7.56	**1**	613	7.56	**1**	951	76.06
1	612	6.00	**1**	612	6.00	**1**	543	23.8
1	452	45.15	**1**	452	45.15	**1**	552	38.25
1	1023	148.78	**1**	651	82.95	**1**	542	41.14
2	173	29.8	**1**	1023	148.78	**1**	571	74.28
2	651	82.95	**1**	462	97.41	**1**	742	46.48
2	472	33.8	**2**	173	29.8	**1**	801	74.06
2	702	18.01	**2**	702	18.01	**1**	212	56.04
2	683	123.21	**2**	683	123.21	**1**	213	192.15
2	462	97.41	**2**	472	33.8	**1**	101	75.39
2	482	25.35	**2**	423	67.16	**2**	463	20.68
2	403	227.51	**2**	792	146.56	**2**	203	45.15
2	423	67.16	**2**	341	80.51	**2**	192	3.56
2	922	53.15	**2**	482	25.35	**2**	32	1.78
2	731	77.39	**2**	402	250.19	**2**	722	9.79
2	792	146.56	**2**	213	192.15	**2**	653	145.67
2	101	75.39	**2**	212	56.04	**2**	472	33.8
2	341	80.51	**2**	403	227.51	**2**	173	29.8
2	402	250.19	**2**	731	77.39	**2**	482	25.35
2	913	240.85	**2**	951	76.06	**2**	442	2.22
3	942	27.58	**2**	922	53.15	**2**	182	6
3	622	4.67	**2**	543	23.8	**2**	412	20.24
3	1001	75.17	**2**	303	110.31	**2**	793	123.43
3	911	74.06	**2**	1003	13.57	**2**	973	46.93
3	211	75.17	**2**	722	9.79	**2**	642	5.12
3	303	110.31	**2**	263	105.19	**2**	813	6
3	1003	13.57	**2**	913	240.85	**2**	902	22.91
3	703	83.4	**2**	323	31.36	**2**	883	12.23
3	263	105.19	**2**	703	83.4	**2**	882	25.58
3	522	20.91	**3**	391	74.28	**2**	962	39.59
3	43	1.78	**3**	542	41.14	**2**	892	7.78
3	933	50.93	**3**	1002	49.37	**2**	683	123.21
3	953	41.81	**3**	812	4.67	**2**	903	8.45
3	291	74.5	**3**	291	74.5	**2**	893	9.12
3	323	31.36	**3**	622	4.67	**2**	703	83.4
3	722	9.79	**3**	802	264.87	**2**	702	18.01
3	812	4.67	**3**	571	74.28	**2**	812	4.67
3	1002	49.37	**3**	942	27.58	**2**	462	97.41
3	432	101.86	**3**	522	20.91	**2**	452	45.15

Table A-2 (Continued). Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Fate Dam/Nail Creek watershed, Lyman County, South Dakota based on 2000 through 2003 data .

Sediment			Total Nitrogen			Total Phosphorus		
Priority	**Cell**	**Area**	**Priority**	**Cell**	**Area**	**Priority**	**Cell**	**Area**
3	233	137.22	3	653	145.67	2	423	67.16
3	391	74.28	3	392	115.87	2	341	80.51
3	733	2	3	642	5.12	2	43	1.78
3	951	76.06	3	122	19.35	2	391	74.28
3	642	5.12	3	911	74.06	2	802	264.87
3	122	19.35	3	321	81.4	2	392	115.87
3	332	45.81	3	233	137.22	2	792	146.56
3	802	264.87	3	742	46.48	2	303	110.31
3	213	192.15	3	552	38.25	2	1003	13.57
3	912	63.83	3	1001	75.17	2	183	44.03
3	543	23.8	3	332	45.81	2	42	3.34
3	653	145.67	3	801	74.06	2	651	82.95
3	321	81.4	3	412	20.24	2	33	0.89
3	392	115.87	3	101	75.39	2	402	250.19
3	422	34.47	3	793	123.43	2	1002	49.37
3	843	119.43	3	813	6	2	263	105.19
3	412	20.24	3	183	44.03	2	323	31.36
3	212	56.04	3	953	41.81	2	321	81.4
3	523	19.13	3	733	2	3	122	19.35
3	532	2.89	3	933	50.93	3	701	76.28
3	713	6.23	3	43	1.78	3	502	25.58
3	333	22.02	3	211	75.17	3	333	22.02
3	502	25.58	3	912	63.83	3	622	4.67
3	793	123.43	3	422	34.47	3	713	6.23
3	813	6.00	3	973	46.93	3	291	74.5
3	183	44.03	3	333	22.02	3	233	137.22
3	691	79.39	3	463	20.68	3	1011	74.95
3	463	20.68	3	502	25.58	3	332	45.81
			3	843	119.43	3	322	16.23
			3	442	2.22	3	1021	75.39
			3	322	16.23	3	1022	150.34
			3	182	6	3	1023	148.78
			3	713	6.23	3	922	53.15
			3	691	79.39	3	913	240.85
			3	432	101.86			
			3	203	45.15			
			3	532	2.89			
			3	523	19.13			
			3	621	74.28			
			3	1011	74.95			
			3	662	52.04			

Table A-2 (Continued). Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Fate Dam/Nail Creek watershed, Lyman County, South Dakota based on 2000 through 2003 data.

Sediment			Total Nitrogen			Total Phosphorus		
Priority	Cell	Area	Priority	Cell	Area	Priority	Cell	Area
			3	701	76.28			
			3	1021	75.39			
			3	192	3.56			
			3	631	75.39			
			3	1022	150.34			
			3	551	74.06			
			3	962	39.59			
			3	512	311.13			
			3	521	83.4			
			3	353	131.66			

AnnAGNPS Load Reduction Estimates

Existing conditions for the years 2000 through 2003, including row crop, pasture, fertilizer application rates, buffers, feedlots and tillage practices were modeled using AnnAGNPS in 2004. Initial conditions were modeled and loads were estimated at the outlet cell of the watershed (Table A-3). To model the best possible condition the watershed could attain, all land use in the watershed was converted to all grass. Data indicate under ideal conditions, sediment and nutrients would be dramatically reduced.

Table A-3. Modeled initial condition and best possible condition for the Fate Dam/Nail Creek watershed, Lyman County, South Dakota using AnnAGNPS based on data from 2000 through 2003.

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.025	0.090	0.840
Entire Watershed All Grass	0.002	0.040	0.377
Percent Reduction	**92.0**	**55.6**	**55.1**

Fate Dam/Nail Creek watershed has been identified as producing considerable nutrient (phosphorus) loading resulting in increased Trophic State Index (TSI) values in Fate Dam (SD DENR, 1998, SD DENR, 2002 and SD DENR, 2004). AnnAGNPS estimated reductions by converting current field conditions to all grass resulting in a total phosphorus reduction of 55.1 percent. A 55.1 percent reduction in current phosphorus loading would result in a phosphorus TSI of 57.45 and a mean TSI of 55.88 for Fate Dam (6.7 percent mean TSI reduction). Obviously, this scenario is not realistic based on logistical, technical and/or financial constraints.

Table A-4. Modeled initial condition and fertilizer reduction for the Fate Dam/Nail Creek watershed, Lyman County, South Dakota using AnnAGNPS based on data from 2000 through 2003.

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.025	0.090	0.840
Fertilizer Reduction[1]	0.025	0.088	0.766
Percent Reduction	**0**	**2.2**	**8.8**

[1] = Reduced selected phosphorus fertilizer application rates from moderate to low

AnnAGNPS was used to predict/estimate phosphorus load reduction with reduced fertilizer application rates. Fertilizer reduction modeling was done using select locations (priority one) in the Fate Dam/Nail Creek watershed using 2000 through 2003 field application rates. Application rates varied in the type and amount of fertilizer applied throughout the watershed. Nitrogen and phosphorus in combination, nitrogen only or phosphorus only may be applied depending upon field, crop and/or tillage practice. Forty two separate field operations were identified in the Fate Dam/Nail Creek watershed, nineteen (45.2 percent) applied nitrogen and phosphorus, twenty (47.6 percent) applied nitrogen fertilizer only, zero (0 percent) applied phosphorus only and three (7.1 percent) applied no fertilizer. Phosphorus applications rates also varied from moderate to low in pounds/acre.

Reductions were modeled by reducing phosphorus and nitrogen application rates in fields where phosphorus application rates were at moderate levels. Critical cell priority rating for phosphorus appeared to be related to areas in the watershed with increased phosphorus fertilization rates. By reducing phosphorus application rates in selected fields one level (moderate to low), overall estimated phosphorus loading was reduced by 8.8 percent (Table A-4).

AnnAGNPS was again used to predict/estimate phosphorus load reduction based on grazing management. Field data on pastures in Fate Dam/Nail Creek watershed indicated pasture locations but did not delineate specific grass conditions by pasture. The district manager for the American Creek Conservation District (ACCD) indicated that the majority of the pasture in this watershed was in reasonably good condition. Based on this, the rating of the existing condition used in the model for all pastures was “fair”. Phosphorus reductions were modeled by switching all existing pasture from fair (grass two to four inches in height) to “good” (grass four to six inches in height).

Phosphorus reductions based on grazing management improvements on all pasture indicated an overall estimated phosphorus reduction of 3.1 percent (Table A-5).

Table A-5. Modeled initial condition and grazing management improvements for the Fate Dam/Nail Creek watershed, Lyman County, South Dakota using AnnAGNPS based on data from 2000 through 2003.

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.025	0.090	0.840
Grazing Management[1]	0.025	0.088	0.814
Percent Reduction	**0**	**2.2**	**3.1**

[1] = Modeled all pastures from fair condition (grass two to four inches high) to good condition (grass four to six inches high).

Operational data (field practices) collected by the project sponsors indicated 13 of the 17 field operations (38.6 percent) used some type of tillage practices (mostly minimum tillage). The district manager for the ACCD indicated that stakeholder participation during BMP implementation can be expected to be approximately 20 percent. All tillage practices were modified (converted to no tillage) in all priority one phosphorus critical cells (10 critical cells or approximately 698 acres) to estimate reductions. AnnAGNPS predicted a 0.3 percent phosphorus reduction by converting critical cell tillage to no tillage (Table A-6).

Table A-6. Modeled initial condition and conservation tillage for the Fate Dam/Nail Creek watershed, Lyman County, South Dakota using AnnAGNPS based on data from 2000 through 2003.

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.025	0.090	0.840
Conservation Tillage Reduction[1]	0.024	0.087	0.837
Percent Reduction	**4.0**	**3.3**	**0.3**

[1] = Modeled selected fields that are currently minimum tillage to no tillage.

AnnAGNPS was also used to predict/estimate phosphorus load reduction based on buffer management. Phosphorus priority-one critical cells for Fate Dam/Nail Creek were converted from current crops to all grass and modeled using AnnAGNPS. Parameter specific reduction results were again reduced by 50 percent for a more conservative phosphorus reduction (better simulates typical buffer reduction). AnnAGNPS predicted a 7.3 percent phosphorus reduction by applying buffer strips to phosphorus priority-one critical cells (Table A-7).

Table A-7. Modeled initial condition and buffer strips for the Fate Dam/Nail Creek watershed, Lyman County, South Dakota using AnnAGNPS based on data from 2000 through 2003.

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.025	0.090	0.840
Buffer Strips[1]	0.024	0.088	0.779
Percent Reduction	**4.0**	**2.2**	**7.3**

[1] = Modeled for phosphorus using all priority-one critical cells.

CONCLUSION

Modeled BMP reductions were: minimum tillage to no tillage, grazing management, buffer strips and fertilizer reduction (Table A-8). The combination of increased implementation of conservation tillage, grazing management, fertilizer reduction and buffer strips will result in estimated reductions in sediment nitrogen and phosphorus. Installing these practices on priority critical cells the Fate Dam/Nail Creek will reduce the amount of sediment, nitrogen and phosphorus entering annually (Table A-8). An estimated/modeled 19.5 percent reduction in phosphorus loading would result in a phosphorus TSI of 61.82 and a mean TSI of 58.91 (approximately a 1.7 percent mean TSI reduction).

The suspected source of the elevated nutrient levels found within the Fate Dam/Nail Creek watershed is probably reduced or no buffers along fields and streams (8.8 percent reduction) and runoff from fertilized cropland (7.3 percent reduction). Therefore, it is recommended that efforts to reduce nutrients should be focused within the identified critical nutrient cells.

Table A-8. AnnAGNPS modeled overall BMP reduction percentages for the Fate Dam/Nail Creek watershed, Lyman County, South Dakota based on data from 2000 through 2003.

	Sediment		Nitrogen		Phosphorus	
Best Management Practice	**Reduction (tons/acre/yr)**	**Percent Reduction**	**Reduction (lbs/acre/yr)**	**Percent Reduction**	**Reduction (lbs/acre/yr)**	**Percent Reduction**
Fertilizer Reduction	0.0	0.0	0.002	2.2	0.074	8.8
Grazing Management Reduction	0.0	0.0	0.002	2.2	0.026	3.1
Conservation Tillage Reduction	0.001	4.0	0.003	3.3	0.003	0.3
Buffer Strips	0.001	4.0	0.002	2.2	0.061	7.3
Estimated Overall Reduction	**0.002**	**8.0**	**0.009**	**10.0**	**0.164**	**19.5**
Initial Load	**0.025**	**-**	**0.090**	**-**	**0.840**	**-**

It is recommended that efforts to reduce sediment and nutrients be targeted to the installation of appropriate BMPs that include no-tillage on cropland, fertilizer reduction, buffer/filter strips and grazing management. BMPs should also be implemented/installed in the phosphorus priority-one and two critical cells in the Fate Dam/Nail Creek watershed.

The implementation of appropriate BMPs and targeting field verified critical cells in priority sub-watersheds, should produce the most cost-effective treatment plan for reducing sediment and nutrient yields from the Fate Dam/Nail Creek watershed.

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APPENDIX B

Nail Creek Tributary Chemical Data for 2000 through 2001

Table B-1. Chemical data for Nail Creek and the outlet of Fate Dam, Lyman County, South Dakota from 2000 through 2001

Site	Date	Season	Water Temperature (°C)	Dissolved Oxygen (mg/L)	pH (s.u.)	Conductivity ($\mu S/cm^{-1}$)	Fecal Coliform (# colonies/ 100ml)	E-coli (# colonies/ 100ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	Ammonia (mg/L)	Un-ionized Ammonia (mg/L)	Nitrate (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Total Nitrogen : Total Phosphorus Ratio (mg/L)
MCT-5	03/19/01	Winter 01	2.23	10.11	8.11	277	10	2	72	205	188	17	7.0	0.23	0.00291	0.80	1.36	1.03	1.13	2.16	0.337	0.275	6.41
MCT-5	04/05/01	Spring 01	6.62	7.18	7.96	792	10	11	134	606	603	3	2.0	0.01	0.00013	7.70	0.97	7.71	0.96	8.67	0.345	0.312	25.13
MCT-5	04/12/01	Spring 01	2.63	13.14	7.87	604	130	157	94	539	457	82	20.0	0.07	0.00053	5.90	1.32	5.97	1.25	7.22	0.564	0.378	12.80
MCT-5	04/26/01	Spring 01	7.49	10.01	7.81	499	70	64.5	84	452	372	80	14.0	0.09	0.00088	4.10	0.85	4.19	0.76	4.95	0.447	0.298	11.07
MCT-6	03/19/01	Winter 01	2.50	5.71	8.12	168	5	3.1	50	149	137	12	4.0	0.26	0.00345	0.60	1.29	0.86	1.03	1.89	0.565	0.479	3.35
MCT-6	04/05/01	Spring 01	6.52	6.06	7.79	875	5	7.4	153	685	680	5	4.0	0.01	0.00009	3.30	0.87	3.31	0.86	4.17	0.338	0.301	12.34
MCT-6	04/12/01	Spring 01	2.80	13.68	7.9	558	1,400	548	114	1210	440	770	70.0	0.28	0.00230	4.90	1.27	5.18	0.99	6.17	1.410	0.294	4.38
MCT-6	04/26/01	Spring 01	14.19	6.29	7.86	486	200	365	113	576	380	196	24.0	0.06	0.00110	3.40	1.76	3.46	1.70	5.16	0.621	0.306	8.31
MCT-8	04/10/01	Spring 01	6.69	13.50	8.37	500	5	8.6	129	411	367	44	7.0	0.01	0.00033	0.60	0.53	0.61	0.52	1.13	0.140	0.035	8.07
MCT-8	04/26/01	Spring 01	10.38	11.85	8.51	480	80	93.3	111	388	341	47	8.0	0.01	0.00058	2.00	0.93	2.01	0.92	2.93	0.240	0.128	12.21
MCT-8	05/15/01	Spring 01	21.12	7.59	8.31	511	5	0.5	125	375	367	8	1.0	0.14	0.01132	1.50	1.06	1.64	0.92	2.56	0.112	0.090	22.86
MCT-8	05/13/01	Spring 01	17.23	8.82	8.26	476	5	0.5	122	381	368	13	0.5	0.12	0.00668	1.60	1.15	1.72	1.03	2.75	0.141	0.111	19.50

APPENDIX C

Fate Dam Surface and Bottom Chemical Data Tables for 2000 through 2001

Table C-1. In-lake surface chemical samples for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

Date	Site	Location	Dissolved Oxygen (mg/L)	pH (s.u.)	Conductivity (µS/cm-1)	Water Temperature (ºC)	Secchi (meters)	Fecal Coliform (# colonies/100 ml)	E-Coli Bacteria (# colonies/100 ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	Ammonia (mg/L)	Un-ionized Ammonia (mg/L)	Nitrate-Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Total Nitrogen : Total Phosphorus Ratio (mg/L)	Chlorophyll-*a* µg/L
05/01/00	FD01	Surface	8.30	8.43	-	17.0	0.762	5	-	162	345	342	3.0	1.0	0.01	0.00079	0.05	0.93	0.92	0.06	0.98	0.037	0.006	26.49	3.71
06/07/00	FD01	Surface	8.56	8.67	439	18.8	0.6096	5	-	163	356	343	13.0	2.0	0.01	0.00145	0.05	0.92	0.91	0.06	0.97	0.057	0.017	17.02	38.32
07/11/00	FD01	Surface	7.38	8.61	470	26.1	1.2192	5	-	138	332	319	13.0	7.0	0.01	0.00200	0.05	0.33	0.32	0.06	0.38	0.026	0.013	14.62	4.17
08/03/00	FD01	Surface	7.32	8.44	453	24.5	1.2192	5	-	132	320	314	6.0	0.5	0.01	0.00131	0.05	0.61	0.60	0.06	0.66	0.043	0.025	15.35	3.71
09/14/00	FD01	Surface	-	8.70	497	18.1	0.85344	5	-	145	343	334	9.0	5.0	0.01	0.00148	0.05	0.33	0.32	0.06	0.38	0.061	0.042	6.23	4.25
10/03/00	FD01	Surface	9.04	8.44	425	14.8	1.15824	5	-	147	341	338	3.0	2.0	0.01	0.00069	0.05	0.43	0.42	0.06	0.48	0.029	0.002	16.55	3.47
12/19/00	FD01	Surface	14.35	8.14	650	3.5	1.15824	5	-	185	424	423	1.0	0.5	0.01	0.00015	0.05	0.90	0.89	0.06	0.95	0.031	0.021	30.65	3.47
02/05/01	FD01	Surface	16.47	8.22	666	3.8	-	5	-	89	232	226	6.0	2.0	0.36	0.00666	0.40	0.66	0.30	0.76	1.06	0.025	0.025	42.40	0.58
03/05/01	FD01	Surface	17.50	7.96	691	2.0	-	5	-	199	477	447	3.0	0.1	0.01	0.00009	0.10	0.65	0.64	0.11	0.75	0.016	0.002	46.88	-
04/10/01	FD01	Surface	13.50	8.37	500	6.7	0.3048	5	0.5	132	363	343	20.0	2.0	0.01	0.00033	0.40	0.49	0.48	0.41	0.89	0.104	0.023	8.56	21.70
05/15/01	FD01	Surface	6.54	8.53	506	20.6	1.2192	5	2	123	387	379	8.0	3.0	0.15	0.01852	1.50	0.94	0.79	1.65	2.44	0.134	0.096	18.21	3.67
05/01/00	FD02	Surface	9.40	8.42	-	15.5	0.82296	10	-	163	344	339	5.0	0.5	0.01	0.00070	0.05	0.88	0.87	0.06	0.93	0.038	0.009	24.47	2.97
06/07/00	FD02	Surface	8.69	8.61	496	18.2	0.54864	5	-	164	359	348	11.0	2.0	0.01	0.00124	0.05	0.84	0.83	0.06	0.89	0.054	0.017	16.48	27.08
07/11/00	FD02	Surface	7.20	8.54	477	25.7	1.34112	5	-	140	338	327	11.0	6.0	0.01	0.00172	0.05	0.34	0.33	0.06	0.39	0.033	0.013	11.82	-
08/03/00	FD02	Surface	7.14	8.52	457	24.8	0.70104	5	-	134	327	319	8.0	1.0	0.11	0.01720	0.05	0.60	0.49	0.16	0.65	0.045	0.022	14.44	-
09/14/00	FD02	Surface	-	8.65	494	19.1	1.00584	5	-	146	339	332	7.0	1.0	0.01	0.00142	0.05	0.43	0.42	0.06	0.48	0.043	0.018	11.16	-
10/03/00	FD02	Surface	9.52	8.41	425	15.2	0.79248	5	-	150	353	344	9.0	0.5	0.04	0.00266	0.05	0.57	0.53	0.09	0.62	0.045	0.038	13.78	4.04
12/19/00	FD02	Surface	12.30	8.24	619	3.6	1.524	5	-	178	407	406	1.0	0.5	0.01	0.00019	0.10	0.85	0.84	0.11	0.95	0.029	0.019	32.76	-
02/05/01	FD02	Surface	15.78	8.20	665	4.4	-	5	-	175	423	415	8.0	3.0	0.03	0.00055	0.10	1.09	1.06	0.13	1.19	0.085	0.043	14.00	-
03/05/01	FD02	Surface	15.65	7.78	681	3.6	-	5	-	197	467	464	3.0	0.5	0.02	0.00013	0.10	0.70	0.68	0.12	0.80	0.016	0.002	50.00	2.68
04/10/01	FD02	Surface	12.82	8.38	528	7.3	0.3048	5	8.6	129	411	367	44.0	7.0	0.01	0.00035	0.60	0.53	0.52	0.61	1.13	0.140	0.035	8.07	-
05/15/01	FD02	Surface	7.59	8.31	511	21.1	1.2192	5	0.5	125	375	367	8.0	1.0	0.14	0.01132	1.50	1.06	0.92	1.64	2.56	0.112	0.090	22.86	-

Table C-2. In-lake bottom chemical samples for Fate Dam, Lyman County, South Dakota from 2000 through 2001.

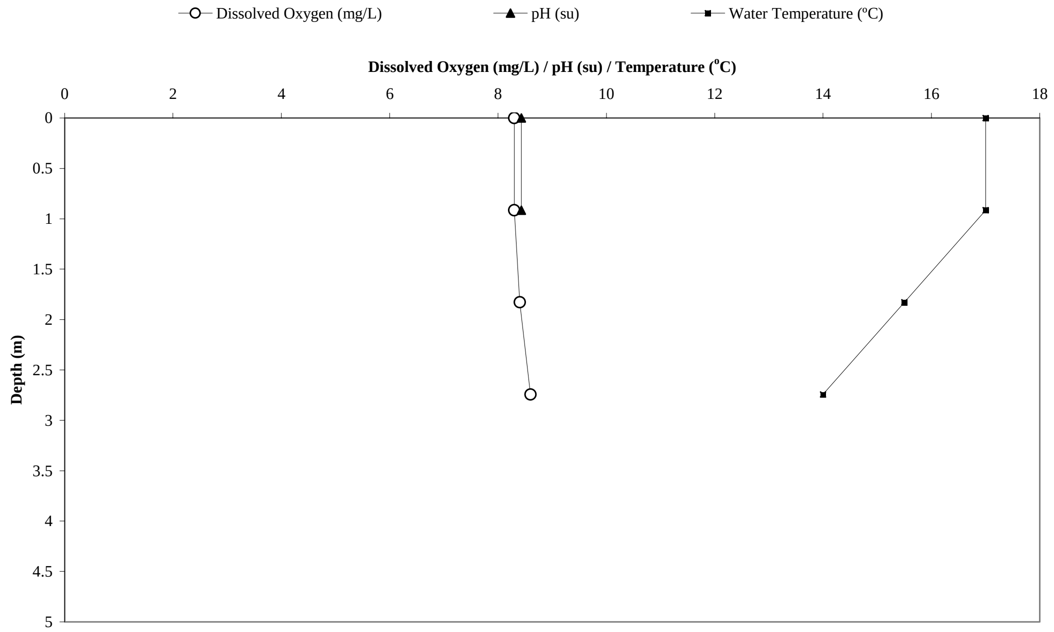
Date	Site	Location	Fecal Coliform (# colonies/100 ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	Ammonia (mg/L)	Nitrate-Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)
05/01/00	FD02	Bottom	5	162	345	338	7.0	2.0	0.01	0.05	0.90	0.89	0.06	0.95	0.054	0.009
06/07/00	FD02	Bottom	5	162	358	343	15.0	3.0	0.01	0.05	0.97	0.96	0.06	1.02	0.052	0.017
08/03/00	FD02	Bottom	5	139	328	318	10.0	1.0	0.01	0.05	0.69	0.68	0.06	0.74	0.076	0.039
07/11/00	FD02	Bottom	5	154	356	337	19.0	4.0	0.15	0.05	0.43	0.28	0.20	0.48	0.061	0.020

APPENDIX D

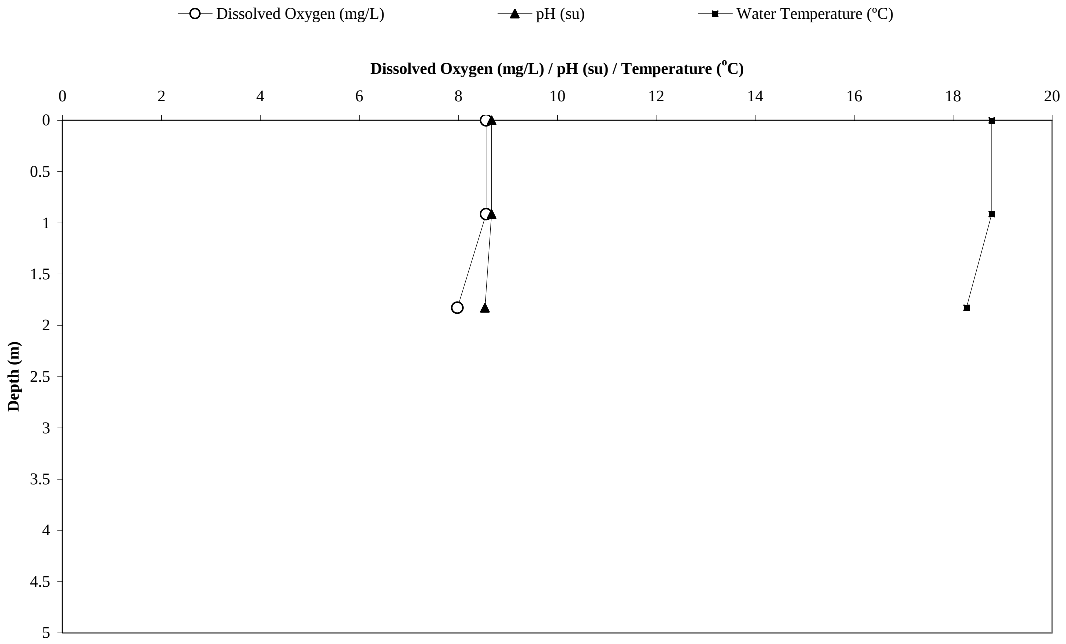
Fate Dam In-lake Temperature, Dissolved Oxygen and pH Profiles from 2000 and 2001

Fate Dam Profiles 2000 (FD-1)

Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in May 2000

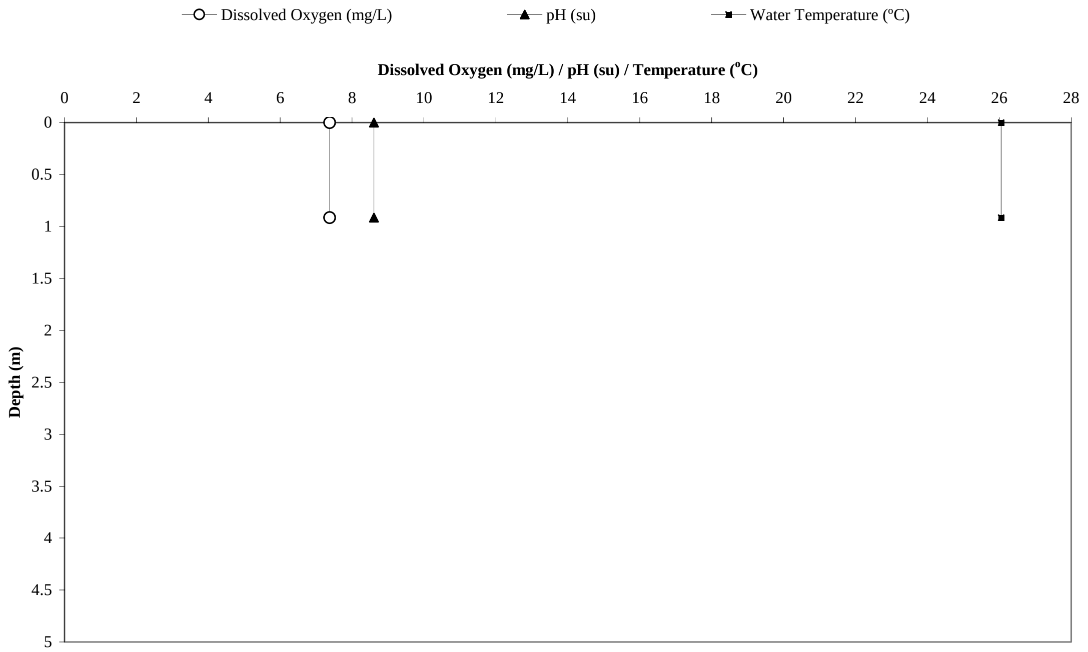


Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in June 2000

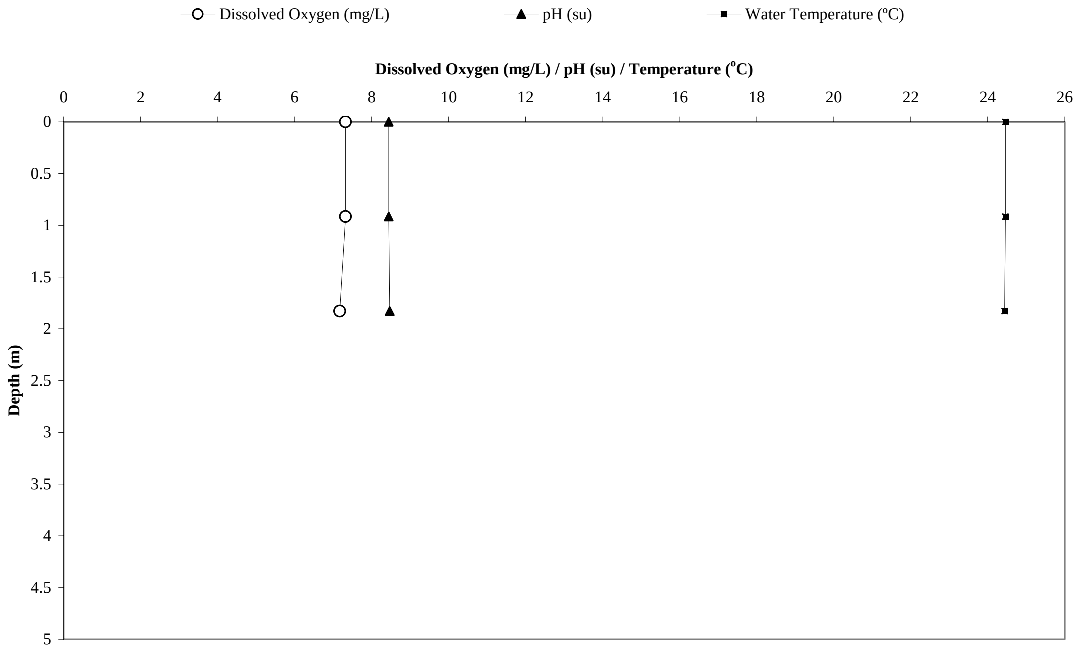


Fate Dam Profiles 2000 (FD-1)

Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in July 2000

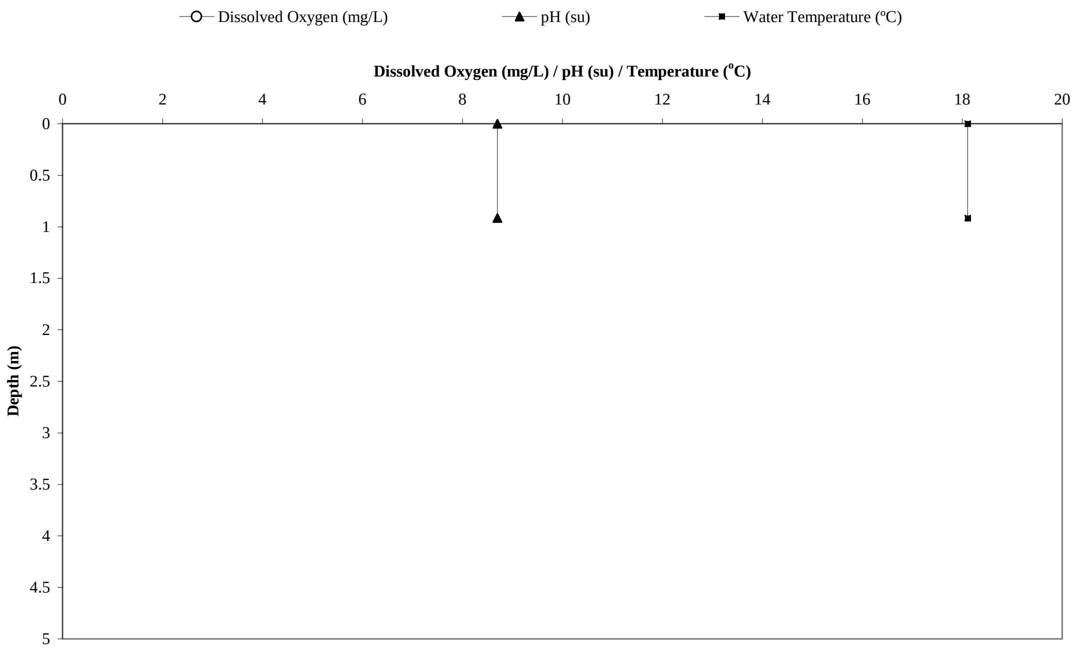


Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in August 2000

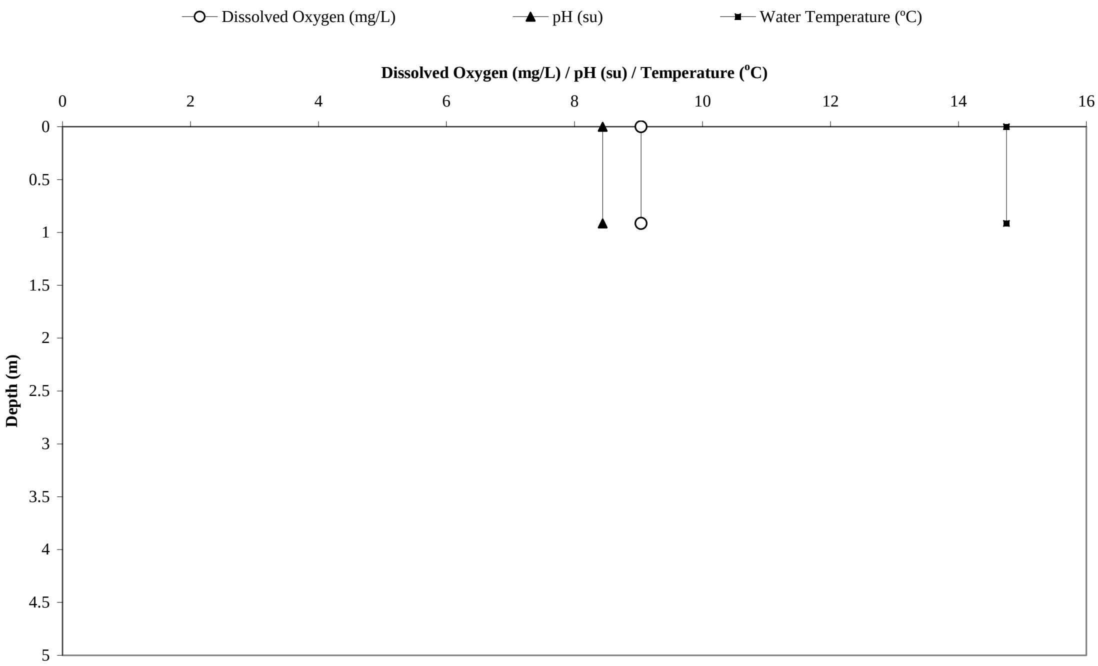


Fate Dam Profiles 2000 (FD-1)

Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in September 2000

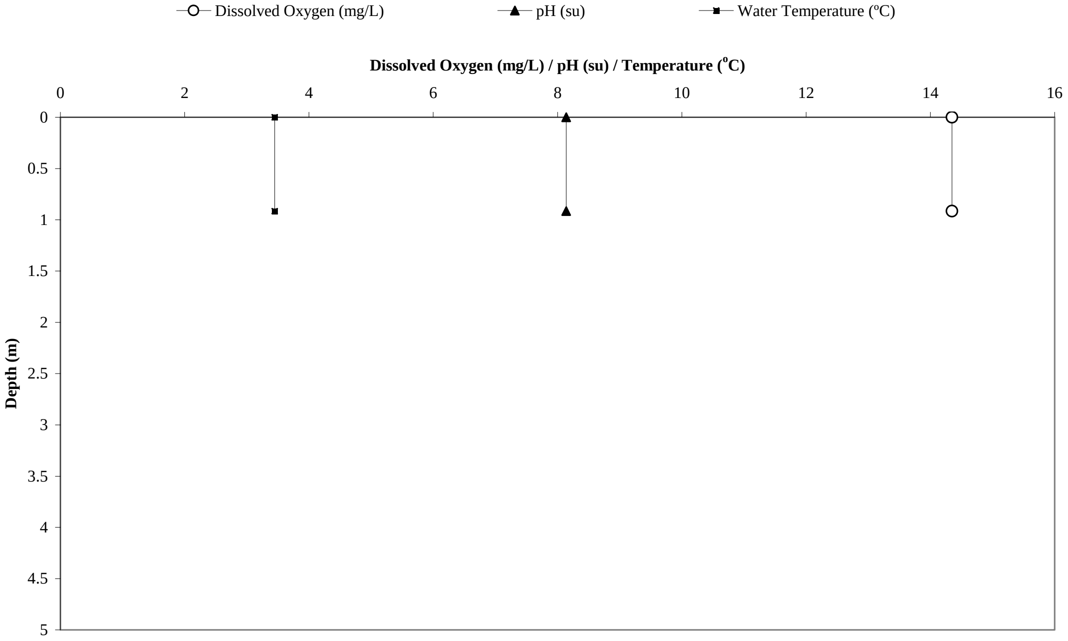


Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in October 2000



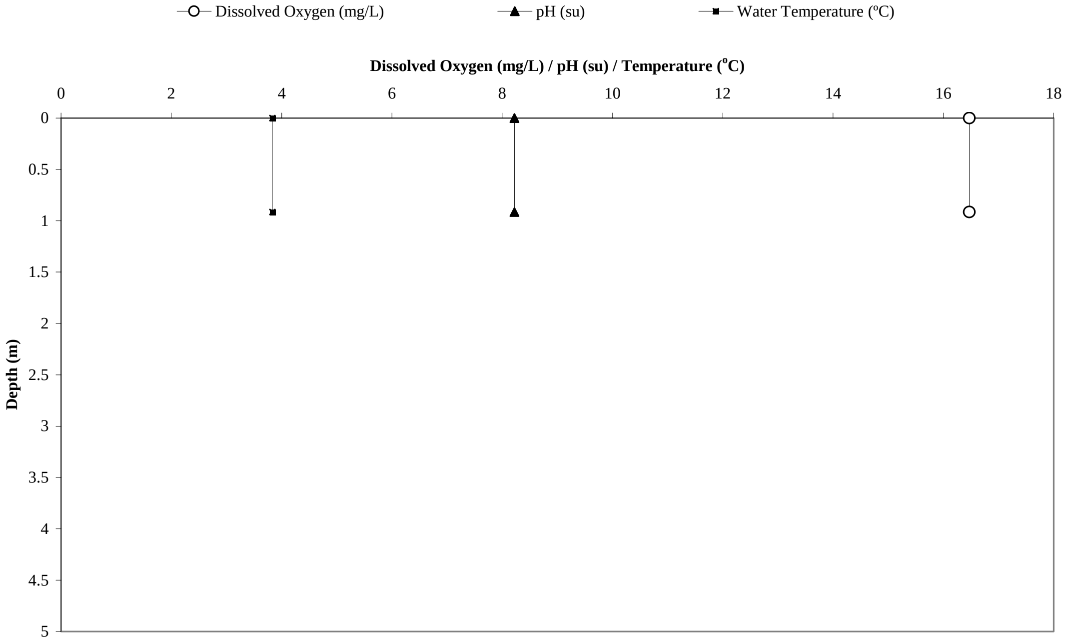
Fate Dam Profiles 2000 (FD-1)

Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in December 2000



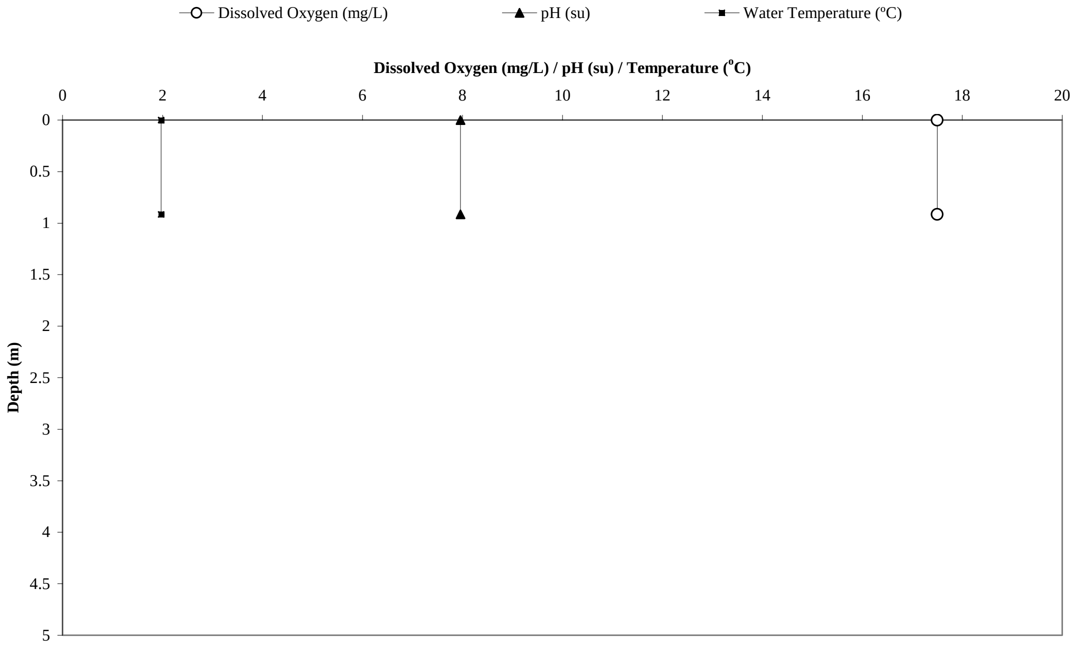
Fate Dam Profiles 2001 (FD-1)

Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in February 2001

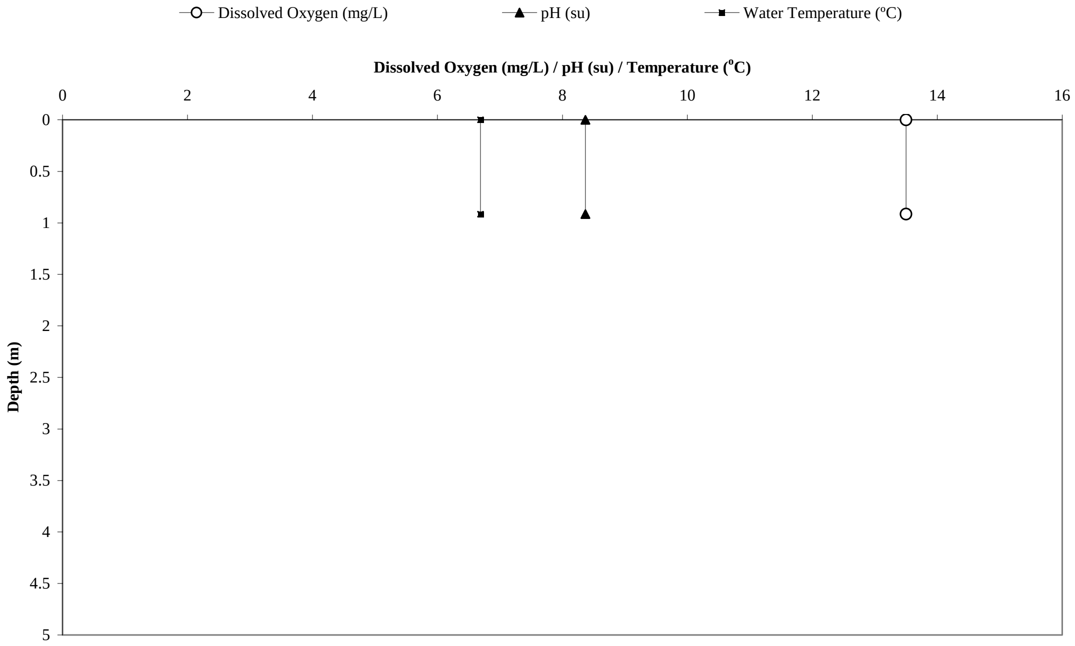


Fate Dam Profiles 2001 (FD-1)

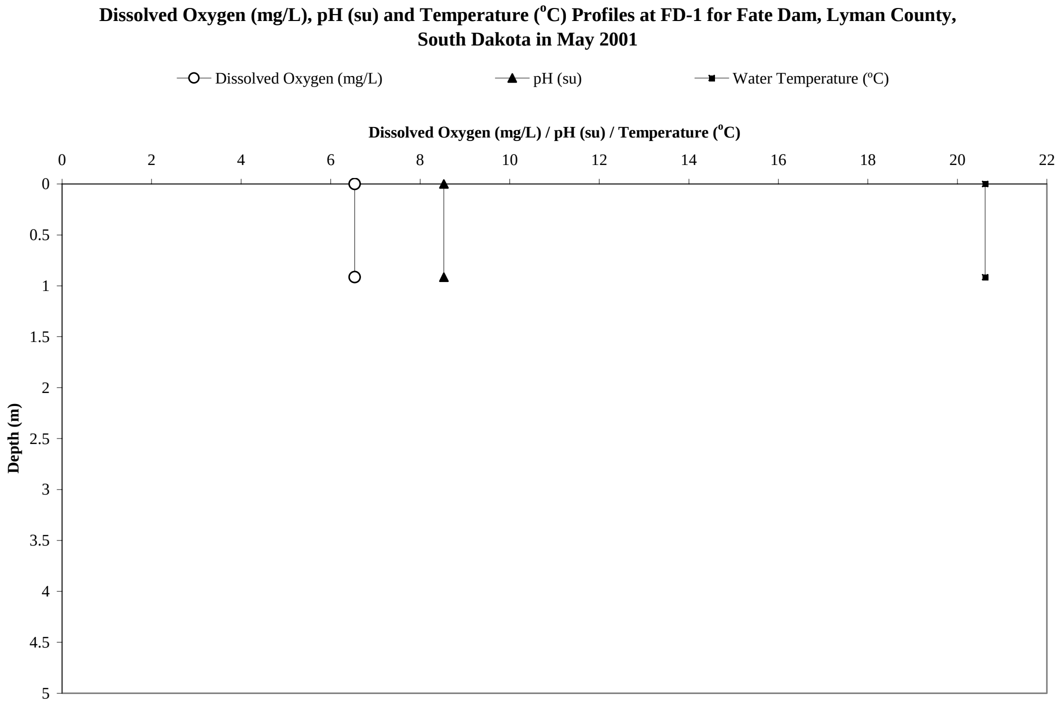
Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in March 2001



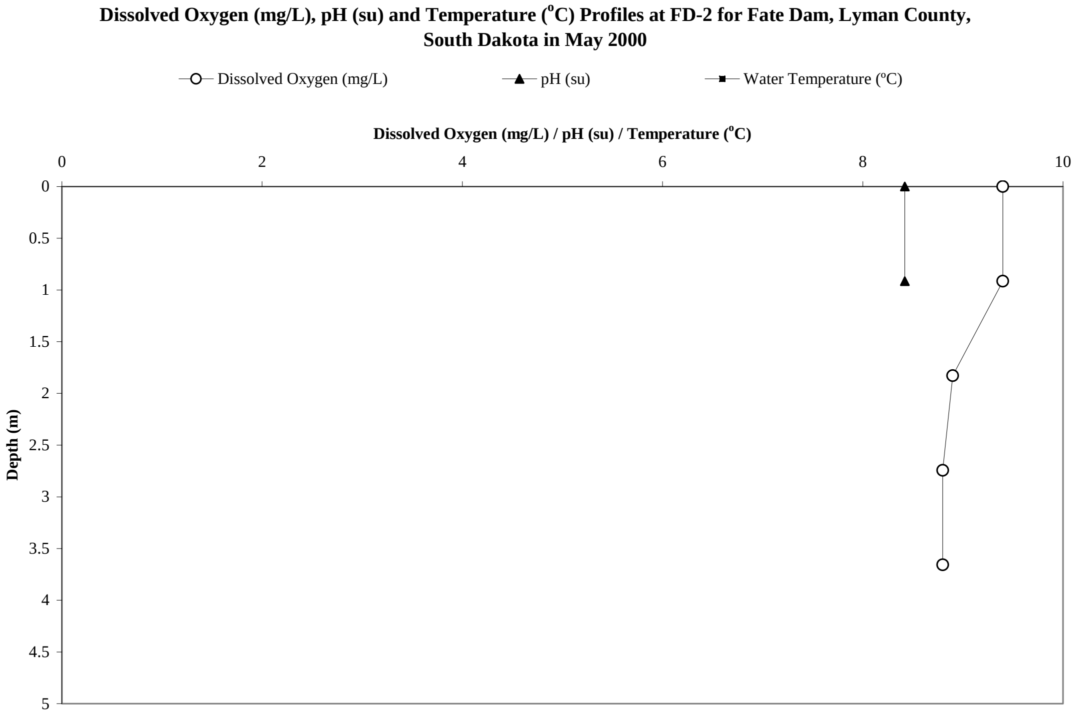
Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-1 for Fate Dam, Lyman County, South Dakota in April 2001



Fate Dam Profiles 2001 (FD-1)

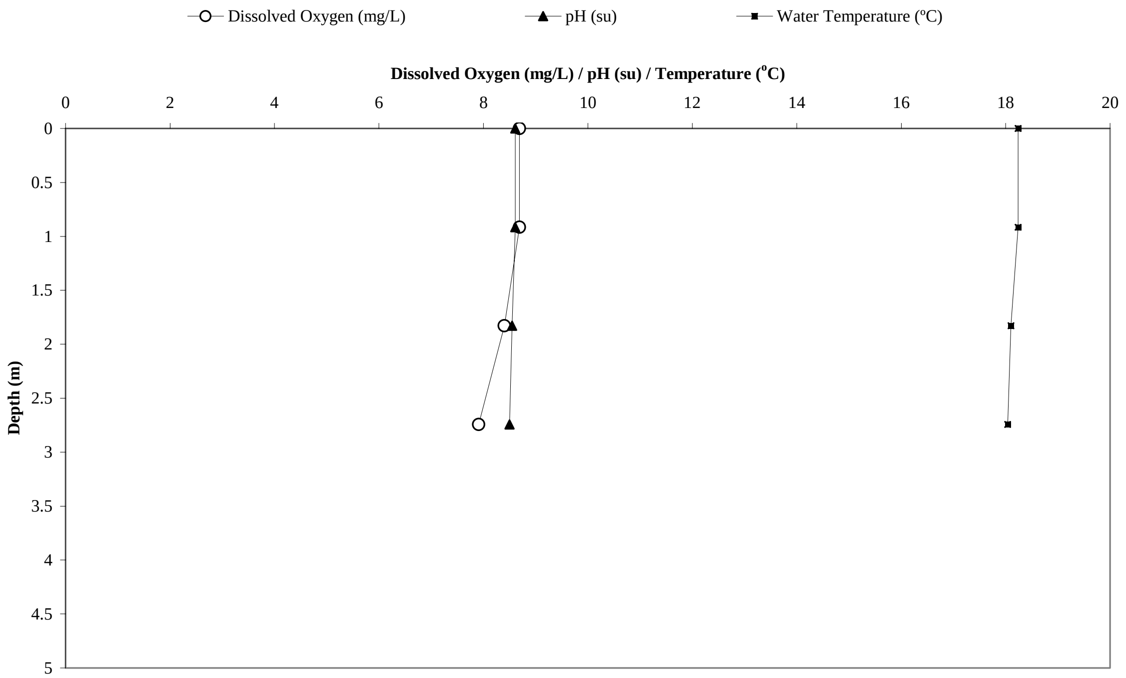


Fate Dam Profiles 2000 (FD-2)

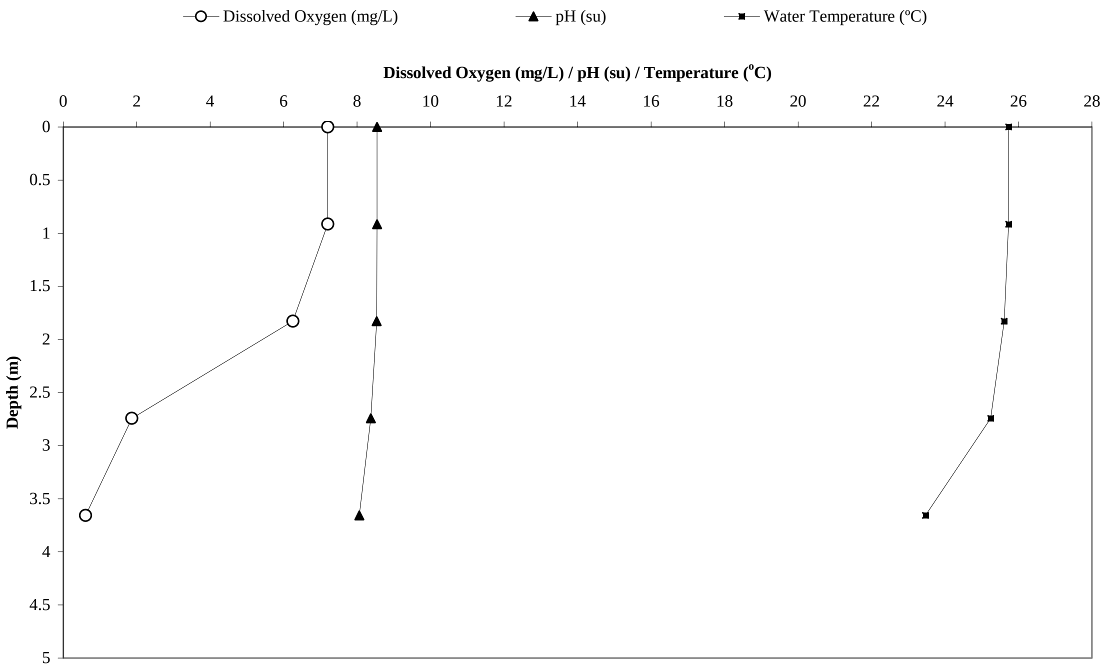


Fate Dam Profiles 2000 (FD-2)

Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at FD-2 for Fate Dam, Lyman County, South Dakota in June 2000

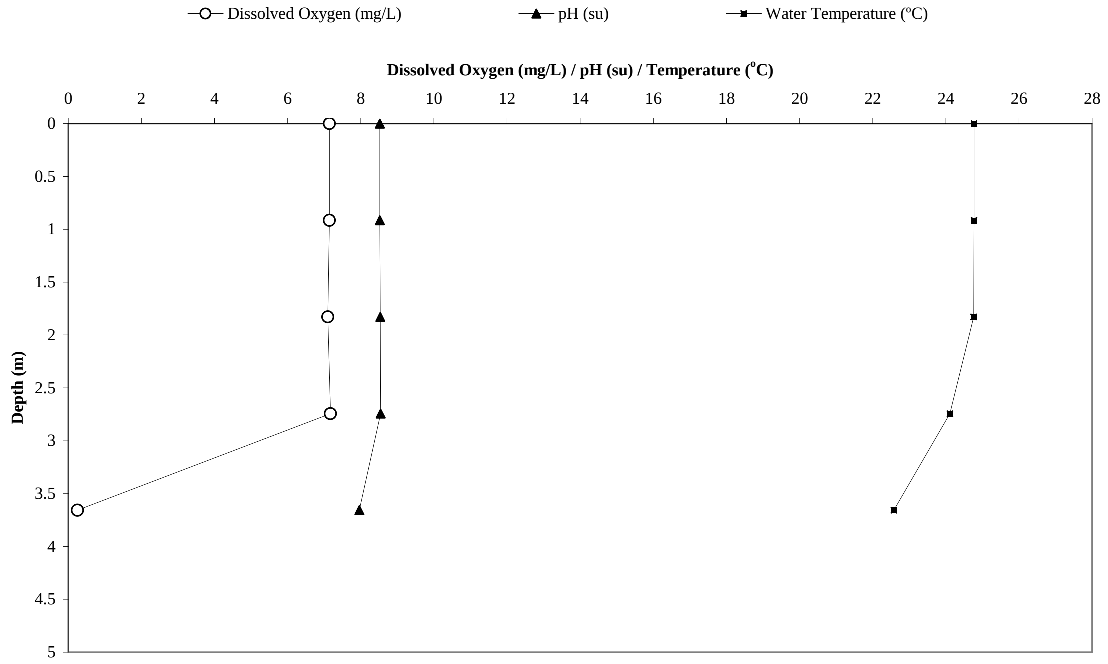


Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at FD-2 for Fate Dam, Lyman County, South Dakota in July 2000

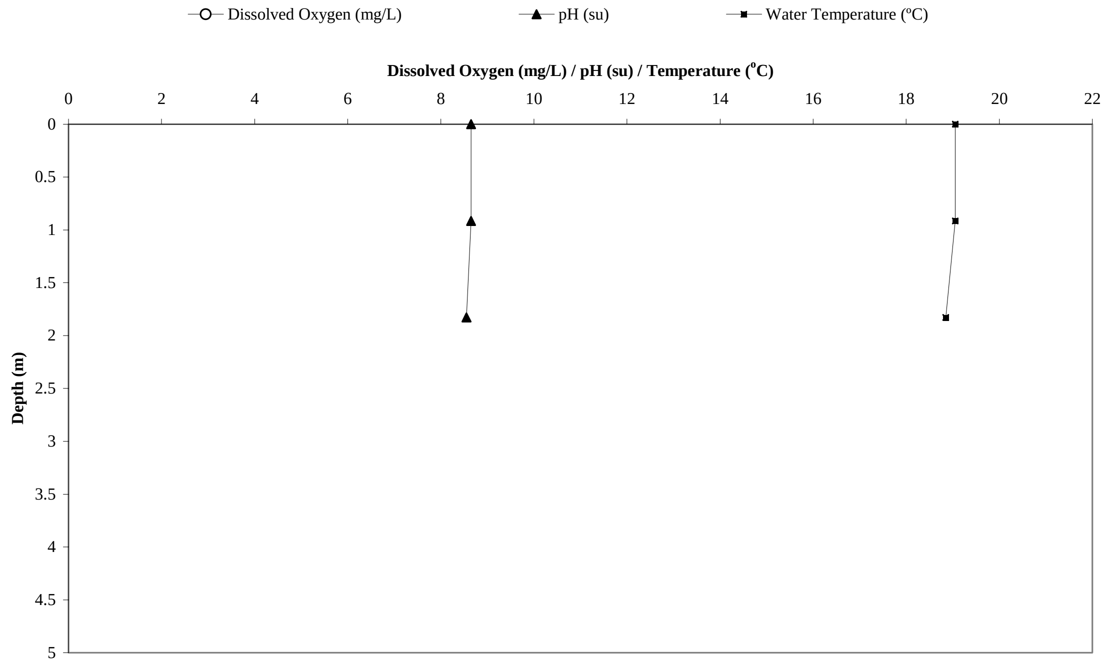


Fate Dam Profiles 2000 (FD-2)

Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-2 for Fate Dam, Lyman County, South Dakota in August 2000

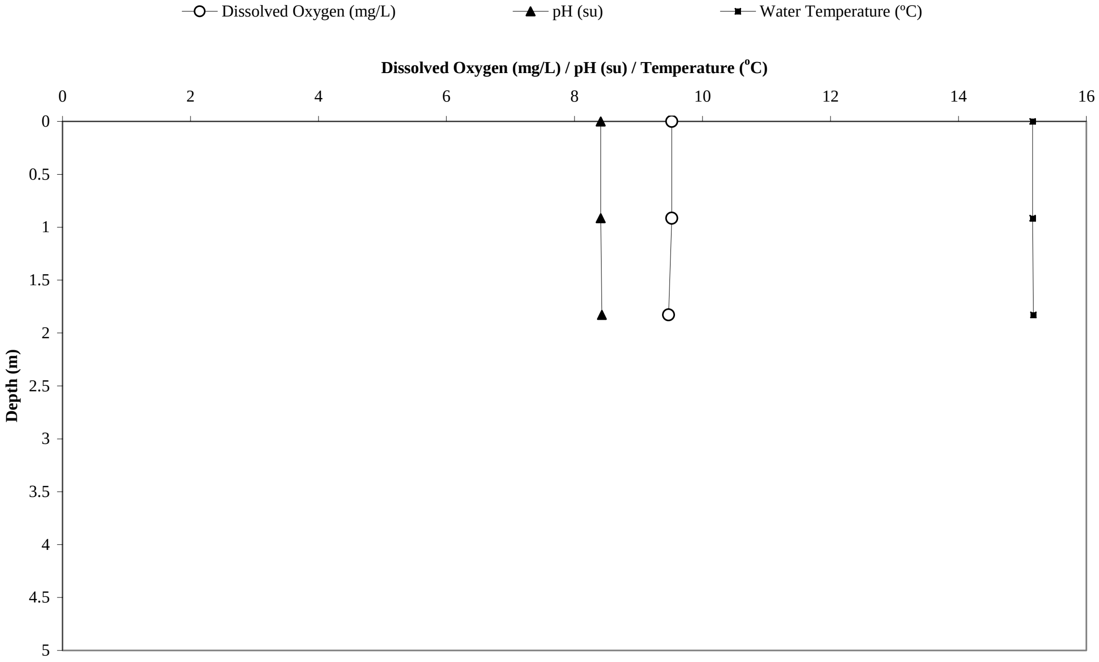


Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-2 for Fate Dam, Lyman County, South Dakota in September 2000

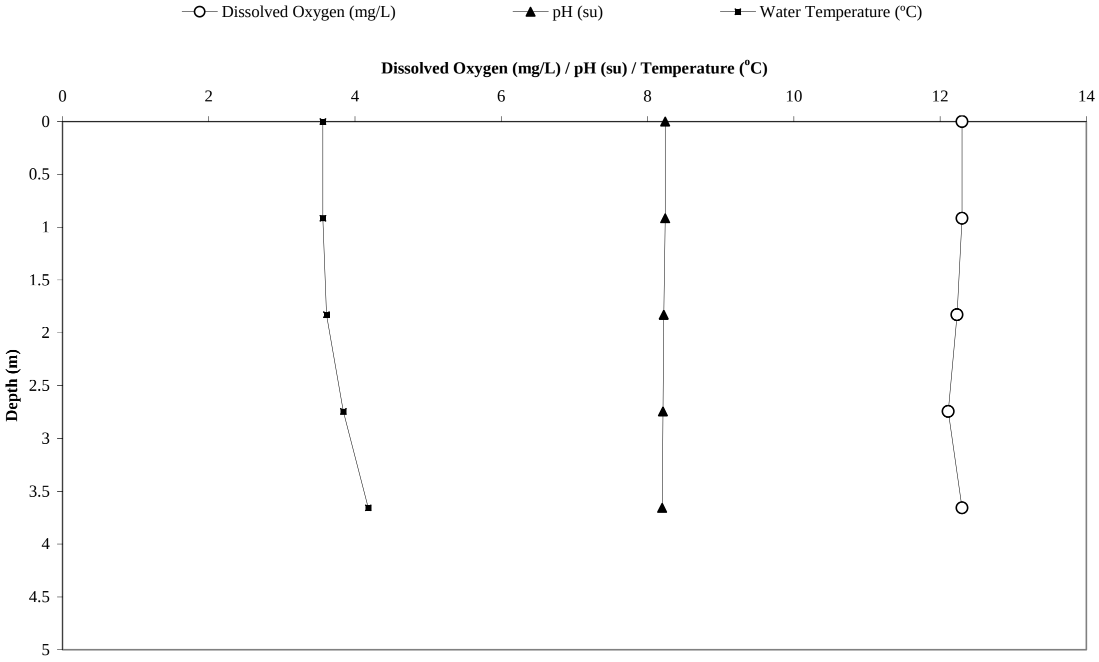


Fate Dam Profiles 2000 (FD-2)

Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-2 for Fate Dam, Lyman County, South Dakota in October 2000

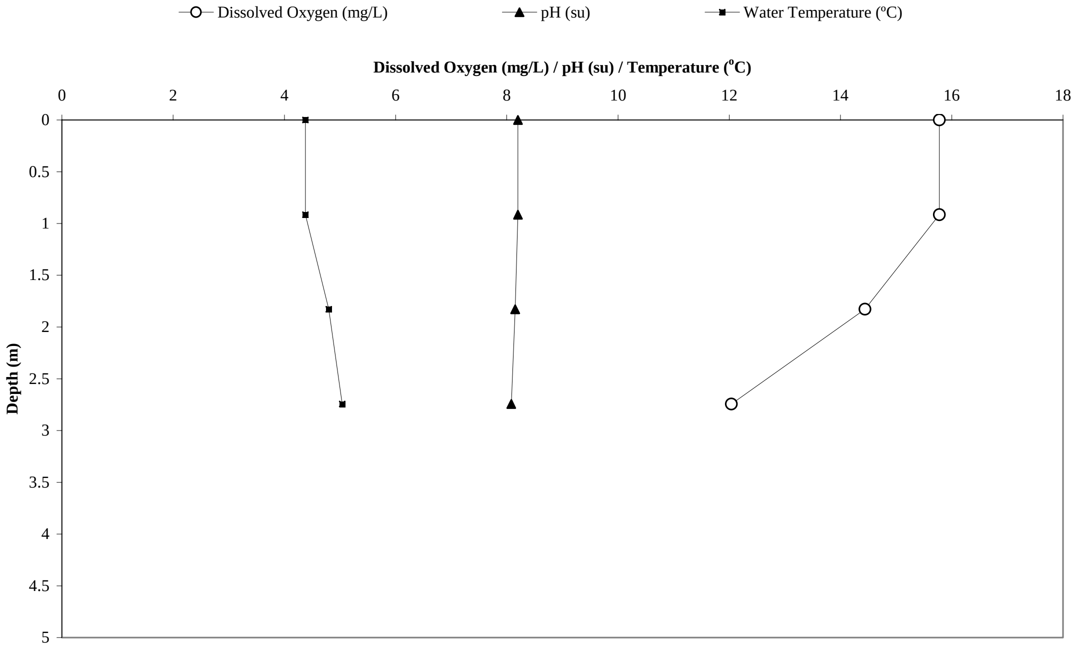


Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-2 for Fate Dam, Lyman County, South Dakota in December 2000

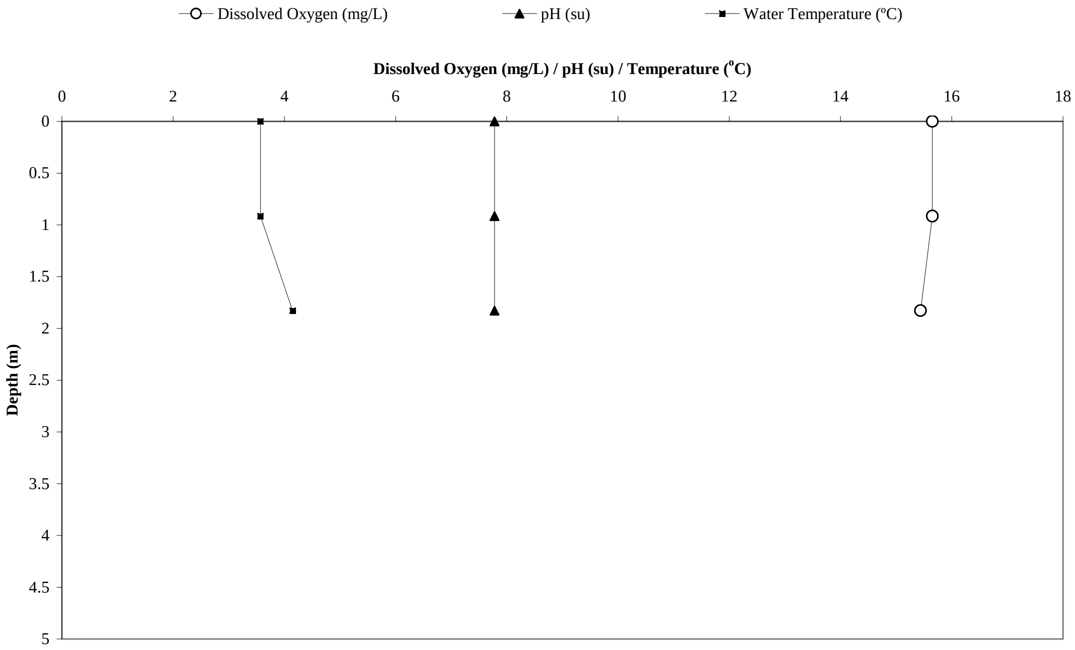


Fate Dam Profiles 2001 (FD-2)

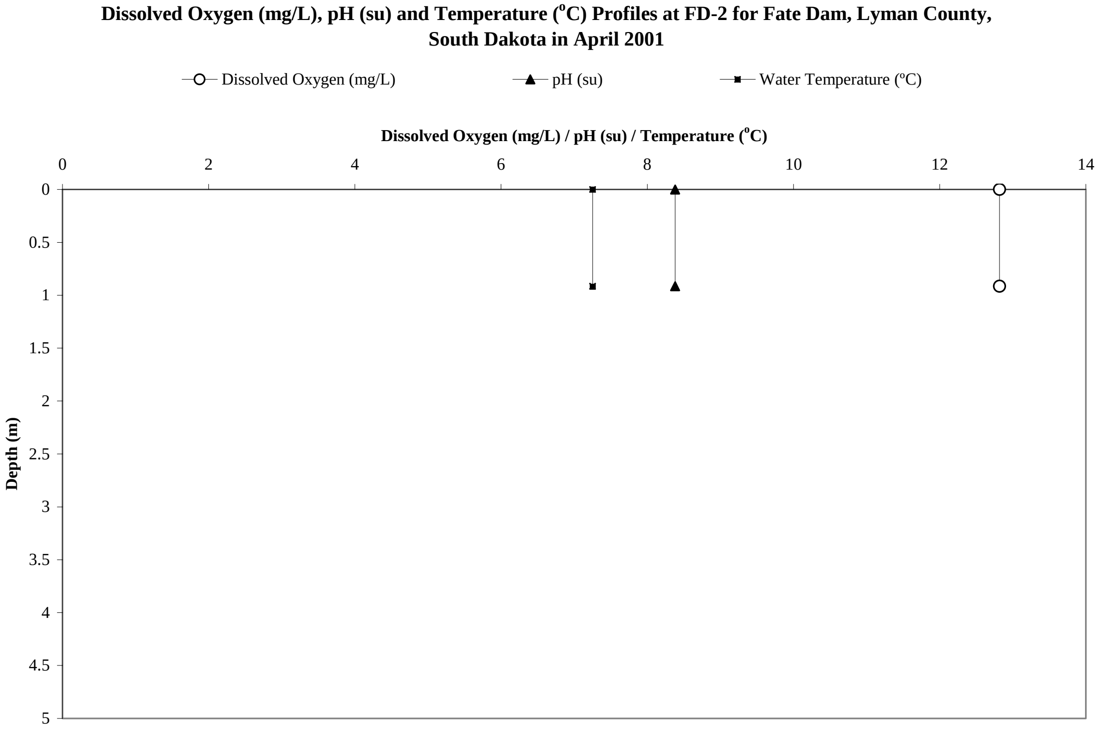
Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-2 for Fate Dam, Lyman County, South Dakota in February 2001

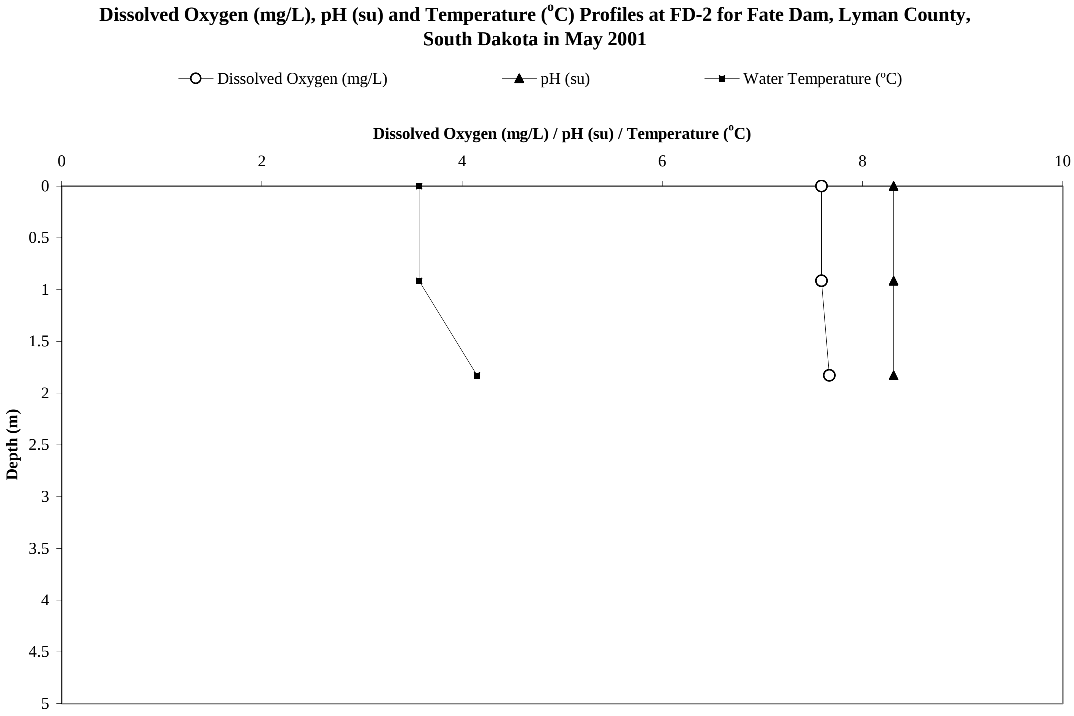


Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at FD-2 for Fate Dam, Lyman County, South Dakota in March 2001



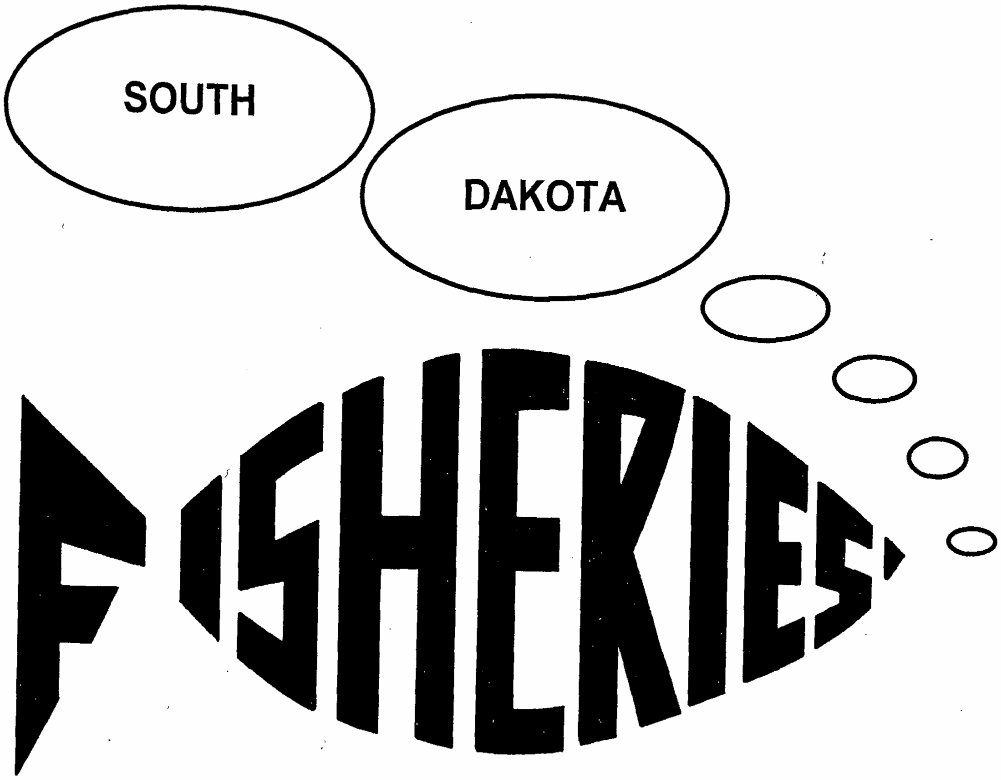
Fate Dam Profiles 2001 (FD-2)





APPENDIX E

South Dakota Game, Fish and Parks Fisheries Report for Fate Dam



STATEWIDE FISHERIES SURVEYS, 2000
SURVEY OF PUBLIC WATERS
Part 1
Lakes – Region II

South Dakota
Department of
Game, Fish and Parks
Wildlife Division
Joe Foss Building
Pierre, South Dakota 57501-3182

Annual Report
No. 01-16

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102 - F-21-R-33

Name: Fate Dam **County:** Lyman
Legal Description: Sections 25 and 36, Township 106, Range 77
Location From Nearest Town: 2 miles E, 2 1/2 miles N of Presho

Date of Present Survey: July 24-27, 2000
Date Last Surveyed: July 8-10, 1997
Most Recent Lake Management Plan: F-21-R-30 **Date:** 1997
Management Classification: Warm Water Semi-Permanent
Contour Mapped: yes **Date:** June 22, 1992

Primary Species:(game and forage)	**Secondary and Other Species:**
1. Walleye	1. Northern Pike
2. Black Crappie	2. Yellow Perch
3. Largemouth Bass	3. Pumpkinseed Sunfish
4. Bluegill	4. Black Bullhead

PHYSICAL CHARACTERISTICS

Surface Area: 164 acres **Watershed:** 13,760 acres
Maximum Depth: 19 feet **Mean Depth:** 9 feet
Lake Elevation at Survey (from known benchmark): -1 foot

1. Describe ownership of lake and adjacent lakeshore property:

The South Dakota Department of Game, Fish and Parks has ownership of approximately 80% of Fate Dam. The remainder of the lake is privately owned with easements to the State of South Dakota. Access is available on the west side of the lake through a State Game Production Area.

2. Describe watershed condition and percentages of land use:

The watershed for Fate Dam is nearly level to gently rolling hills. Soil type is medium to deep clay. Percentages of land use are approximately 60% pasture and 40% cropland. Several small dams on the watershed allow Fate Dam to fill only in years of heavy runoff.

3. Describe aquatic vegetative condition:

Emergent vegetation is common around the entire shoreline with the exception of the face of the dam. The lake is also ringed with a heavy mat of submerged vegetation.

4. **Describe pollution problems:**

Siltation and suspended sediments are an ongoing problem in Fate Dam.

5. **Describe condition of all structures, i.e. spillway, level regulators, boat ramps, etc.:**

The dam grade and spillway structure are in good condition, the boat ramp is in very poor condition.

CHEMICAL DATA

1. **Describe general water quality characteristics:**

Water quality characteristics of Fate Dam were analyzed in the field on July 24, 2000 using a Hach Water Quality Kit. Results are on Table 1.

2. **Thermocline:** no

3. **Secchi disc reading:** 3.8 feet.

4. **Stations for water chemistry located on attached map:** yes

Table 1. Water chemistry results from Fate Dam, Lyman County, July 24, 2000.

Station number	Depth feet	Temp F	DO PPM	CO2 PPM	ALK MG\L	Hardness MG\L	pH
1	Surface	74	7.5	48	124	156	8.0
1	14	74	4.7	46	125	158	8.0

BIOLOGICAL DATA

Methods:

1. **Describe fish collection methods and show sampling locations by gear type on the lake map.**

Fate Dam was sampled on July 24-26, 2000 with eight, 24 hour, 3/4 inch frame net sets. Pulsed AC electrofishing was completed on October 17th. Conductivity was 1400 Ohms; water temperature was 16° C. Standard Coefelt settings were utilized. Fish indices were calculated using the Winfin computer program. The results are listed in the following tables.

Results and Discussion:

1. Tables listing species, number, size, etc. of fish.

Table 2. Total catch of six, 10-minute electrofishing transects at Fate Dam, Lyman County, October 18, 2000.

Spec	No.	Low 80% CI	Mean CPUE F/hr	Up 80% CI	Low 90% CI	PSD	Up 90% CI	Low 90% CI	Stock Mean Wr	Up 90% CI
LMB	14	9.6	14.0	18.4	42	70	98	107.5	110.1	112.8
WAE	3	1.0	3.0	5.0	na	na	na	83.0	91.3	99.7

Table 3. Total catch of eight, 24 hour, 3/4 inch frame nets at Fate Dam, Lyman County, July 24-26, 2000.

Spec	No.	Low 80% CI	Mean CPUE	Up 80% CI	Low 90% CI	PSD	Up 90% CI	Low 90% CI	Stock Mean Wr	Up 90% CI
BLB	38	3.2	4.8	6.3	88	95	100	80.8	81.6	82.3
BLC	189	16.2	23.6	31.1	67	78	88	85.9	87.5	89.2
BLG	36	2.4	4.8	7.1	76	86	96	97.9	98.6	99.2
NOP	12	1.0	1.5	2.0	0	8	23	74.8	76.9	79.0
PUS	5	0.1	0.6	1.2	na	na	na	100.1	103.4	106.7
YEP	9	0.3	1.1	1.9	23	56	88	86.0	96.3	106.7
WAE	1	0.0	0.1	0.3	na	na	na	na	na	na

2. Brief narrative describing status of fish sampled, make reference to the tables.

Black Crappie remain the dominant panfish since the lake survey in 1997. Eight, 3/4 inch, frame nets yielded a CPUE of 23.6., a PSD of 78 with an RSD-P of 29. Wr was 87.5. In 1997, the black crappie population had a CPUE of 93.1 and a PSD of 76. Wr was a 108.

The bluegill density was low but the quality was high during the 2000 survey. CPUE was 4.8 with a PSD of 86 and an RSD-P of 28. Wr was 98.6. The last survey yielded a CPUE of 15.1 and a PSD of 60.

Black bullhead numbers also dropped sharply with a CPUE of 4.8 compared to 41.0 in 1997. PSD was 95 with an RSD-P of 65. Last survey PSD was 100. Predators seem to be keeping bullheads and other panfish in check.

Northern Pike numbers remain stable with a CPUE of 1.5. Last survey had a CPUE of 1.4.

In spite of supplemental stockings, walleye numbers remain low with eight, frame nets capturing just one fish. One hour of electrofishing yielded only three walleye. With low returns, walleye stockings should be terminated.

Largemouth bass numbers appear low with a CPUE of 14 fish per hour. The low water inhibited shocking nearly half the lake. Fate Dam was not shocked in 1997, so comparisons were not made. Judging by the quality of the panfish populations, there appears to be good bass population.

RECOMMENDATIONS

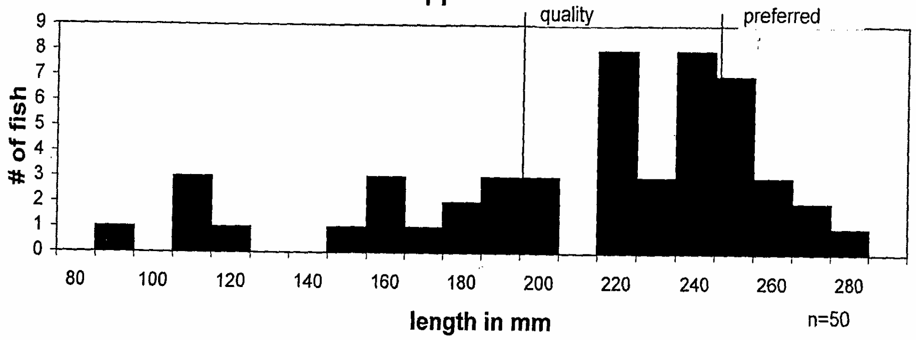
Describe management approach.

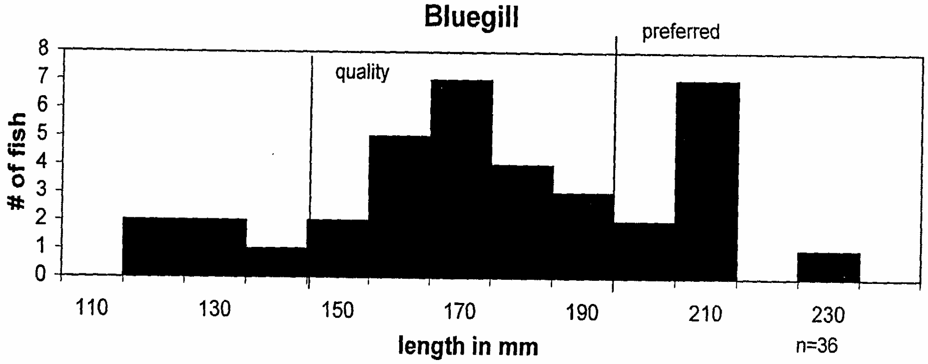
1. Resurvey in 2003 to check all fish populations.
2. Discontinue walleye stocking at this time.

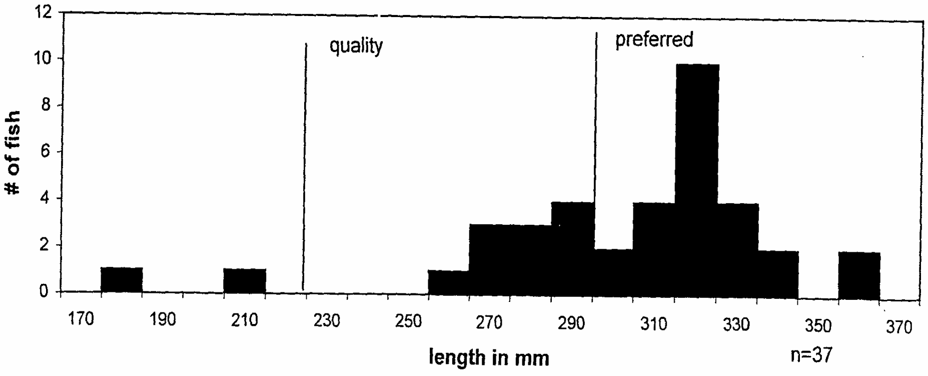
Stocking record for Fate Dam, Lyman County, 2000.

YEAR	NUMBER	SPECIES	SIZE
1990	7,500	LMB	FGL
1995	1,640	WAE	FGL
1997	32,800	NOP	FGL
1998	32,800	NOP	FGL
1999	4,100	WAE	FGL

Fate Dam


Black Crappie


Bluegill


Black Bullhead

South Dakota
Department of Game, Fish and Parks

Fate Dam

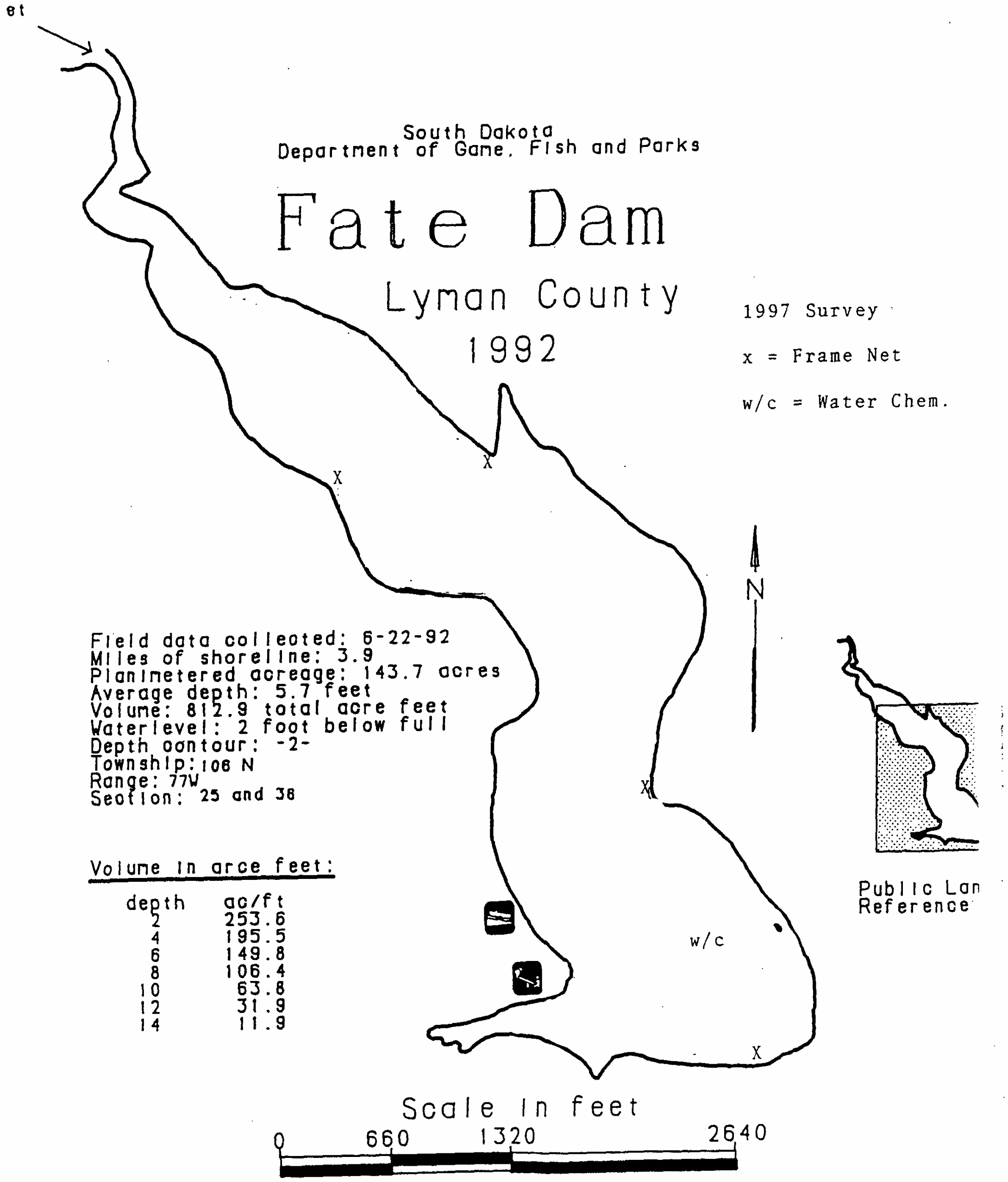
Lyman County

1992

1997 Survey

x = Frame Net

w/c = Water Chem.



Field data collected: 6-22-92
Miles of shoreline: 3.9
Planimetered acreage: 143.7 acres
Average depth: 5.7 feet
Volume: 812.9 total acre feet
Waterlevel: 2 foot below full
Depth contour: -2-
Township: 106 N
Range: 77W
Section: 25 and 36

Volume in arce feet:

depth	ac/ft
2	253.6
4	195.5
6	149.8
8	106.4
10	63.8
12	31.9
14	11.9

APPENDIX F

Rare, Threatened and Endangered Species Documented in Fate Dam Watershed and Medicine Creek, Lyman and Jones Counties, South Dakota as of December 2002

Key to Codes Used in Natural Heritage Database Reports

FEDERAL STATUS
LE = Listed endangered
LT = Listed threatened
LELT = Listed endangered in part of range, threatened in part of range
PE = Proposed endangered
PT = Proposed threatened
C = Candidate for federal listing, information indicates that listing is justified.

STATE STATUS
SE = State Endangered
ST = State Threatened

An endangered species is a species in danger of extinction throughout all or a significant portion of its range. (applied range wide for federal status and statewide for state status)

A threatened species is a species likely to become endangered in the foreseeable future.

Global Rank	State Rank	Definition (applied rangewide for global rank and statewide for state rank)
G1	S1	Critically imperiled because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2	S2	Imperiled because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.
G3	S3	Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors; in the range of 21 of 100 occurrences.
G4	S4	Apparently secure, though it may be quite rare in parts of its range, especially at the periphery. Cause for long term concern.
G5	S5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.
GU	SU	Possibly in peril, but status uncertain, more information needed.
GH	SH	Historically known, may be rediscovered.
GX	SX	Believed extinct, historical records only.
G?	S?	Not yet ranked
_?	_?	Inexact rank
_T		Rank of subspecies or variety
_Q		Taxonomic status is questionable, rank may change with taxonomy
	SZ	No definable occurrences for conservation purposes, usually assigned to migrants
	SP	Potential exists for occurrence in the state, but no occurrences
	SR	Element reported for the state but no persuasive documentation
	SA	Accidental or casual

Bird species may have two state ranks, one for breeding (S#B) and one for nonbreeding seasons (S#N). Example: Ferruginous Hawk (S3B, SZN) indicates an S3 rank in breeding season and SZ in nonbreeding season.

Rare, Threatened or Endangered Species Documented in Fate Dam and Medicine Creek Watershed HUC 10140104
South Dakota Natural Heritage Database
12//9/2002

NAME	TOWNSHIP RANGE & SECTION	COUNTY	LAST OBSERVED	FEDERAL STATUS	STATE STATUS	STATE RANK	GLOBAL RANK	EODATA
WHOOPING CRANE *Grus americana*	107N079W 11	Lyman	1997-10-29	LE	SE	SZN	G1	3 CRANES FLYING
BURROWING OWL *Athene cunicularia*	107N079W 34	Lyman	1998-07		S3S4B	SZN	G4	ONE NESTING PAIR, ONE JUVENILE OWL IN JULY.
SWAINSON'S HAWK *Buteo swainsoni*	108N079W 33	Lyman	1994		S4B	SZN	G5	ACTIVE NET IN 1994
FERRUGINOUS HAWK *Buteo regalis S*	107N079W 11	Lyman	1999-04-09		S4B	SZN	G4	ADULT SITTING ON NEST IN 1994. 1998-ON NEST, SAME LOCATION, ON APRIL 16 AND 30. ON NEST ON APRIL 9, 1999.
SWAINSON'S HAWK *Buteo swainson*	107N078W 27	Lyman	1999-04-28		S4B	SZN	G5	SWAINSON'S HAWK AT NEST
BURROWING OWL *Athene cunicularia*	107N078W 21	Lyman	1999-07-15		S3S4B	SZN	G4	FOUR ACTIVE OWL NESTS, ONE JUVENILE OWL IN JULY. 1999-2 BURROWING OWLS REPORTED IN THIS DOG TOWN.
BURROWING OWL *Athene cunicularia*	001N031E 33	Jones	1998-07		S3S4B	SZN	G4	THREE ACTIVE NESTS, 4+ JUVENILES IN JULY.
PLAINS SPOTTED SKUNK *Spilogale putorius interrup*	001S031E 32	Jones	1993-04-05		S3		G5T4	ROAD KILL
BAIRD'S SPARROW *Ammodramus bairdii*	001N031E 9	Jones	1997-08-29		S2B	SZN	G4	AT LEAST 2 SINGING IN THIS AREA, PRESENT ALL SUMMER
BURROWING OWL *Athene cunicularia*	107N079W 34	Lyman	1998-07		S3S4B	SZN	G4	ONE ACTIVE NEST, 2 JUVENILE OWLS IN JULY.
SPRAGUE'S PIPIT *Anthus spragueii*	107N078W 7	Lyman	1997-07-29		S2B	SZN	G4	AT LEAST TWO SINGING IN SECTION 7, OTHERS HEARD IN SECTIONS 16 AND 17. HEARD IN AREA ALL SUMMER.
BAIRD'S SPARROW *Ammodramus bairdi*	107N078W 9	Lyman	1997-07-29		S2B	SZN	G4	AT LEAST FIVE SEEN OR HEARD, OTHERS IN SECTION 8 TO THE WEST AND IN SEC. 26 T108N R78W. PRESENT IN THESE AREAS ALL SUMMER.
WHOOPING CRANE *Grus Americana*	105N076W 31	Lyman	1998-05-07	LE	SE	SZN	G1	ONE CRANE ON GROUND FOR 5 DAYS

APPENDIX G

Fate Dam Total Maximum Daily Load Document

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

TOTAL PHOSPHORUS (TSI)

In

FATE DAM

NAIL CREEK WATERSHED

(HUC 10140104)

LYMAN COUNTY,
SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

August, 2004

Fate Dam Total Maximum Daily Load August, 2004

Waterbody Type:	Lake (Impounded)
303(d) Listing Parameters:	Total phosphorus (TSI)
Designated Uses:	Warmwater permanent fish life propagation water; Immersion recreation water; Limited contact recreation waters; Fish and wildlife propagation, recreation and stock watering water.
Size of Waterbody:	60.7 hectare (15 acres)
Size of Watershed:	6,961 hectare (17,202 acres)
Water Quality Standards:	Narrative and numeric
Indicators:	Average TSI
Analytical Approach:	BATHTUB, FLUX and AnnAGNPS
Location:	HUC Code: 10140104
TMDL Goal	
Total Phosphorus:	19.5% reduction in total phosphorus (671 kg/yr.)
TMDL Target	
Total Phosphorus:	TSI 61.81, mean TSI 58.91 (2,769 kg/yr.)

Objective:

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

Introduction

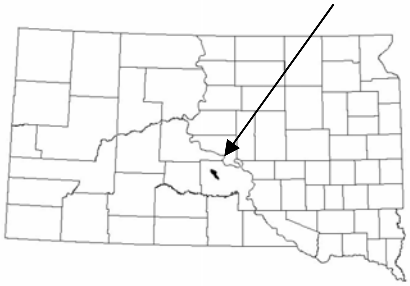


Figure 1. Fate Dam watershed location in South Dakota.

Fate Dam is a 60.7 hectare (150-acre) man-made impoundment located in western Lyman County, South Dakota (Figure 1). Fate Dam is listed in the 2004 South Dakota Integrated Report for Surface Water Quality (combined 303(d) and 305(b) reports) as not meeting the ecoregional based TSI criteria. Watershed and in-lake modeling indicated that even under extreme conditions (unattainable), Fate Dam could not meet current ecoregional TSI targets. This condition is unattainable due to logistical, financial and technical constraints. AnnAGNPS tributary modeling data was used to develop watershed/site specific TSI target criteria for Fate Dam. Fate Dam was identified for TMDL development for trophic state index (TSI), increased eutrophication.

The Fate Dam/Nail Creek watershed encompasses approximately 6,961 ha (17,202 acres) and is drained by Nail Creek (Figure 2). The damming of Nail Creek near the town of Presho, South Dakota created the lake, which has an average depth of approximately 3.0 meters (9.8 feet) and over 5.9 kilometers (3.7 miles) of shoreline. The lake has a maximum depth of 7.6 meters (25 feet) and holds 1,500 acre-feet of water. The outlet for the lake empties back into Nail Creek, which empties into Medicine Creek and eventually reaches the Missouri River.

Problem Identification

Nail Creek drains predominantly agricultural land (approximately 60.2 percent cropland and

39.8 percent pastureland) and flows into Fate Dam. The stream carries nutrient (total nitrogen and total phosphorus) and sediment loads, which degrade the water quality of the reservoir, and cause increased eutrophication.

Mean TSI values were originally used to set current ecoregional beneficial use criteria for lakes in South Dakota (SD DENR, 2000a). The target for full support in ecoregion 43 according to that document is a mean TSI values $\leq$ 55.00. However, current ecoregional (ecoregion 43) target criteria appear not to fit Fate Dam based on AnnAGNPS watershed loading and BATHTUB in-lake eutrophication modeling. AnnAGNPS model was used to estimate watershed loading under ideal conditions (entire watershed converted to grassland). Modeling indicates that maximum phosphorus reduction in this watershed would be 55.1 percent (Appendix A). BATHTUB was then used to model AnnAGNPS phosphorus reduction to in-lake trophic response under ideal conditions. Data indicate under ideal conditions (extreme conditions, Fate Dam mean TSI 55.88); Fate Dam could not meet ecoregional-based beneficial use criteria based on current targets. However, this condition is unrealistic and unattainable due to logistical, financial and technical constraints.

Current watershed conditions (loading) result in a modeled mean in-lake TSI value of 59.91 (Table 51, Assessment Report page 153). The Fate Dam/Nail Creek watershed can not feasibly meet current ecoregional based beneficial use criteria which are unrealistic and unachievable. Alternative site specific (watershed specific) evaluation criteria (fully supporting, mean TSI $\leq$ 59.00) is proposed based on AnnAGNPS modeling, BMPs and watershed specific phosphorus reduction attainability. The site specific criteria is developed and based on measured loads during the project period and may not take into account long term average annual loading.

Currently, the total phosphorus load to Fate Dam is 3,440 kg/year (1.72 tons/year). Annual total phosphorus loads need to be reduced by 671 kilograms (19.5 percent), resulting in a total phosphorus TMDL of 2,769 kilogram per year, including background, producing a modeled mean Trophic State Index (TSI) of 58.91 (total phosphorus TSI of 61.82).

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

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

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

Individual parameters, including the lake's mean TSI value, determine the support of beneficial uses and compliance with standards. Fate Dam experiences nutrient enrichment and some nuisance algal blooms, which are typical signs of the eutrophication process. Fate Dam was identified in the 2004 Fate Dam/Nail Creek Watershed Assessment Report and the 2000 Ecoregion Targeting for Impaired Lakes in South Dakota as partially supporting based on mean TSI value and watershed/site specific beneficial use criteria developed using Annualized Agricultural Non-Point Source model (AnnAGNPS) modeling.

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

If adequate numeric criteria are not available, the South Dakota Department of Environment and Natural Resources (SD DENR) uses surrogate measures to assess the trophic status of a lake. SD DENR uses the mean (combined) Trophic State Index or TSI (Carlson, 1977) which incorporates a combination of Secchi depth, chlorophyll-*a* and total phosphorus concentrations. SD DENR has developed an EPA-approved protocol that establishes desired TSI levels for lakes based on an ecoregion approach. This protocol was used to assess impairment and determine a numeric target for Fate Dam.

Figure 2. Fate Dam/Nail Creek watershed.

Fate Dam measured load currently has a modeled total phosphorus TSI of 63.44, a chlorophyll-*a* TSI of 56.12 and a Secchi TSI of 60.18 which translates to an average TSI of 59.91, which is indicative of increased levels of primary productivity (assessment final report, page 153). Assessment monitoring indicates that the primary cause of high productivity is increased total phosphorus loads from the watershed.

SD DENR recommends specific TSI parameters for Fate Dam. The TMDL numeric target established to reduce total phosphorus loading to Fate Dam will lower the mean TSI to 58.91based on current measured loads (assessment final report, Table 51, page 153).

Pollutant Assessment

Point Sources

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

Nonpoint Sources/Background Sources

Nonpoint/background sources for the Fate Dam/Nail Creek Watershed were estimated using FLUX and AnnAGNPS modeling.

Under current conditions, total nonpoint source loading of total phosphorus from the watershed to Fate Dam was estimated to be 3,440 kg/yr and were attributed to agricultural sources. Nonpoint source/background load allocation of total phosphorus (2,769 kg/yr).

Linkage Analysis

Water quality data was collected from three monitoring sites within the Fate Dam/Nail Creek watershed. Samples from each site were collected according to South Dakota's Standard Operating Procedures for Field Samplers, Volume I. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on approximately 10% of the samples according to South Dakota's Non-Point Source Quality Assurance/ Quality Control Plan. Details concerning water-sampling techniques, analysis, and quality control are addressed on pages 8 through 10, page 17, page 68 and 142 through 146 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AnnAGNPS model was used to estimate potential nutrient load reductions from conservation tillage, fertilizer reduction, grazing management and buffer strips within the watershed through the implementation of various BMPs. See the AnnAGNPS final report, Appendix A.

In-lake (aluminum sulfate treatment) BMPs were also used to estimate total phosphorus reductions and were incorporated into the TMDL equation via the implicit margin of safety. Five other BMPs were suggested (streambank stabilization, conversion of highly erodible cropland to rangeland, riparian management, shoreline stabilization and submerged aquatic macrophytes) however total phosphorus reduction percentages were not estimated because data was unavailable to calculate viable responses. Sediment and nutrient reductions for these BMPs are incorporated into the TMDL calculation by way of the implicit margin of safety. All estimates were based on conservative percent reductions applied to priority subwatersheds (assessment final report, pages 150 through 154).

Reducing the current total phosphorus load (3,440 kg/yr) a minimum of 19.5 percent (671 kg/yr) will reduce the average TSI value from 59.91 to 58.91. This can be accomplished by implementing modeled tributary BMPs with an implicit margin of safety to support the TMDL target.

TMDL and Allocations

TMDL

Total phosphorus (kg) = 19.5 percent reduction

	0 kg/yr	(WLA)
+	2,769 kg/yr	(LA)
+	Implicit	(MOS)
	2,769 kg/yr	(TMDL)[1]

[1] = TMDL Equation implies a 19.5 percent based on BMP attainability in measured total phosphorus load reduction with modeled tributary BMPs.

Wasteload Allocations (WLAs)

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

Load Allocations (LAs)

The result of the AnnAGNPS model indicates that conversion of select minimum tillage fields to no tillage could achieve a 0.36 percent (12 kg/yr) reduction and reduced fertilizer application could achieve an 8.81 percent (303 kg/yr) reduction in total phosphorus loading to Fate Dam.

Tributary total phosphorus reductions for grazing management 3.09 percent (106 kg/yr.) and buffer strips 7.26 percent (250 kg/yr.) were estimated using AnnAGNPS.

In-lake total phosphorus reductions in TSI were also estimated for Fate Dam. They include and an aluminum sulfate treatment, 30 percent reduction in in-lake phosphorus concentrations resulting in a 8.1 percent reduction in in-lake total phosphorus TSI values.

A total phosphorus reduction of 19.5 percent (671 kg/yr) is needed to improve the mean TSI of Fate Dam to 58.91.

The 19.5 percent modeled reduction is based on AnnAGNPS watershed modeling and consisted of: (1) all phosphorus fertilized fields with moderate fertilizer rates were reduced one level (moderate to low) resulting in a 8.8 percent phosphorus reduction; (2) converting all current pastures from fair condition to good condition for a 3.1 percent reduction; (3) applying conservation tillage to all priority-one phosphorus critical cells (10-critical cells consisting of three rotations) for a 0.3 percent and (4) converting tilled/cropped priority-one phosphorus critical cells to all grass and results were again reduced 50 percent to better simulate typical phosphorus reduction or 7.3 percent. Summing all BMP reductions, the best estimated phosphorus reduction for the Fate Dam/Nail Creek watershed is 19.5 percent (assessment final report, pages 150 through 154). AnnAGNPS modeling indicated that implementing only modeled BMPs in the Fate Dam/Nail Creek watershed would meet watershed specific beneficial use criteria set for Fate Dam (mean TSI $\leq$ 59.00).

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in temperature, precipitation and agricultural practices. To determine seasonal differences, Fate Dam samples were separated into winter (January-March, spring (April-June), summer (July-September) and fall (October-December). During the 2000 sampling season, 41.3 percent of the hydrologic load entered Fate Dam from Nail Creek (MCT-6); however, no water quality samples were collected during this time period. Seasonal concentrations and loads for 2000 were calculated through FLUX modeling using 2001 concentration data. Under this scenario, the spring 2001 sampling season had the highest loading for all parameters.

Margin of Safety

All modeled total phosphorus reductions were calculated based on conservative estimations built into the model and conservative total phosphorus reduction percentages using best professional judgment. Along with conservative modeling, any additional implemented tributary and/or in-lake BMP reductions were incorporated into the TMDL calculation in an implicit margin of safety (assessment final report, page and 154). Fate Dam needs a 19.5 percent total phosphorus reduction to improve average TSI values.

Critical Conditions

Based upon the 2000 through 2001 assessment data, nutrient loading to Fate Dam are most severe during the spring (runoff events) and impairments to Fate Dam are most severe during the late summer and early fall. This is the result of increased loading, warm water temperatures and increased algal growth.

Follow-Up Monitoring

Fate Dam is currently on the SD DENR statewide lake assessment project and remains on the South Dakota Game, Fish and Parks normal lake survey to monitor and evaluate long-term trophic status, biological communities and ecological trends.

Periodically during the implementation project and once it is completed, monitoring will be necessary to assure that the TMDL has been reached and improvements in average TSI values occur.

Public Participation

During the Medicine Creek watershed Assessment Project, the Fate Dam watershed assessment project was initiated during the spring of 2000 with EPA Section 319 funds. Fate Dam is on the priority list of Section 319 Nonpoint Source Pollution Control projects; based on current watershed assessment data Fate Dam partially supports TSI criteria. American Creek Conservation District agreed to sponsor the project. Federal grant funds totaled $101,796 of which, Fate Dam was assessed. Funds were used for water quality analyses, equipment, supplies, travel, and wages for the local coordinator.

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

1. American Creek Conservation District Board Meetings (20)
2. County Commission Meetings (2)
3. Individual contact with landowners in the watershed (continuous throughout the project).
4. Articles/surveys/pamphlets sent to landowners in the watershed (5)
5. Newspaper articles (2)
6. Final results presentation (1)

The findings from these public meetings and comments have been taken into consideration in the development of the Fate Dam TMDL.

Implementation Plan

The South Dakota DENR is working with the American Creek Conservation District to initiate an implementation project in the future.

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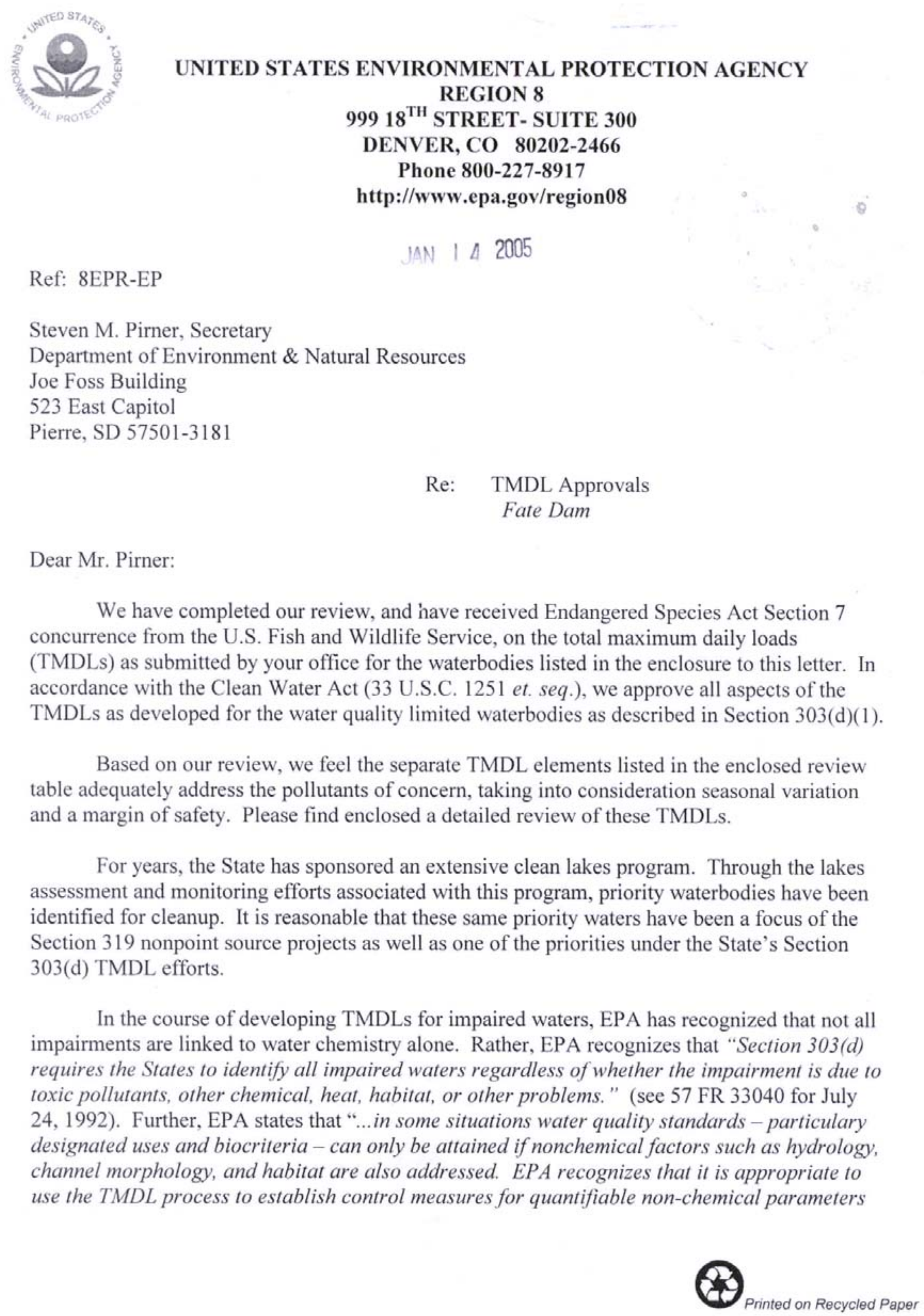

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
999 18TH STREET- SUITE 300
DENVER, CO 80202-2466
Phone 800-227-8917
http://www.epa.gov/region08

JAN 14 2005

Ref: 8EPR-EP

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

Re: TMDL Approvals
Fate Dam

Dear Mr. Pirner:

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

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

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

In the course of developing TMDLs for impaired waters, EPA has recognized that not all impairments are linked to water chemistry alone. Rather, EPA recognizes that *"Section 303(d) requires the States to identify all impaired waters regardless of whether the impairment is due to toxic pollutants, other chemical, heat, habitat, or other problems."* (see 57 FR 33040 for July 24, 1992). Further, EPA states that "*...in some situations water quality standards – particulary designated uses and biocriteria – can only be attained if nonchemical factors such as hydrology, channel morphology, and habitat are also addressed. EPA recognizes that it is appropriate to use the TMDL process to establish control measures for quantifiable non-chemical parameters*

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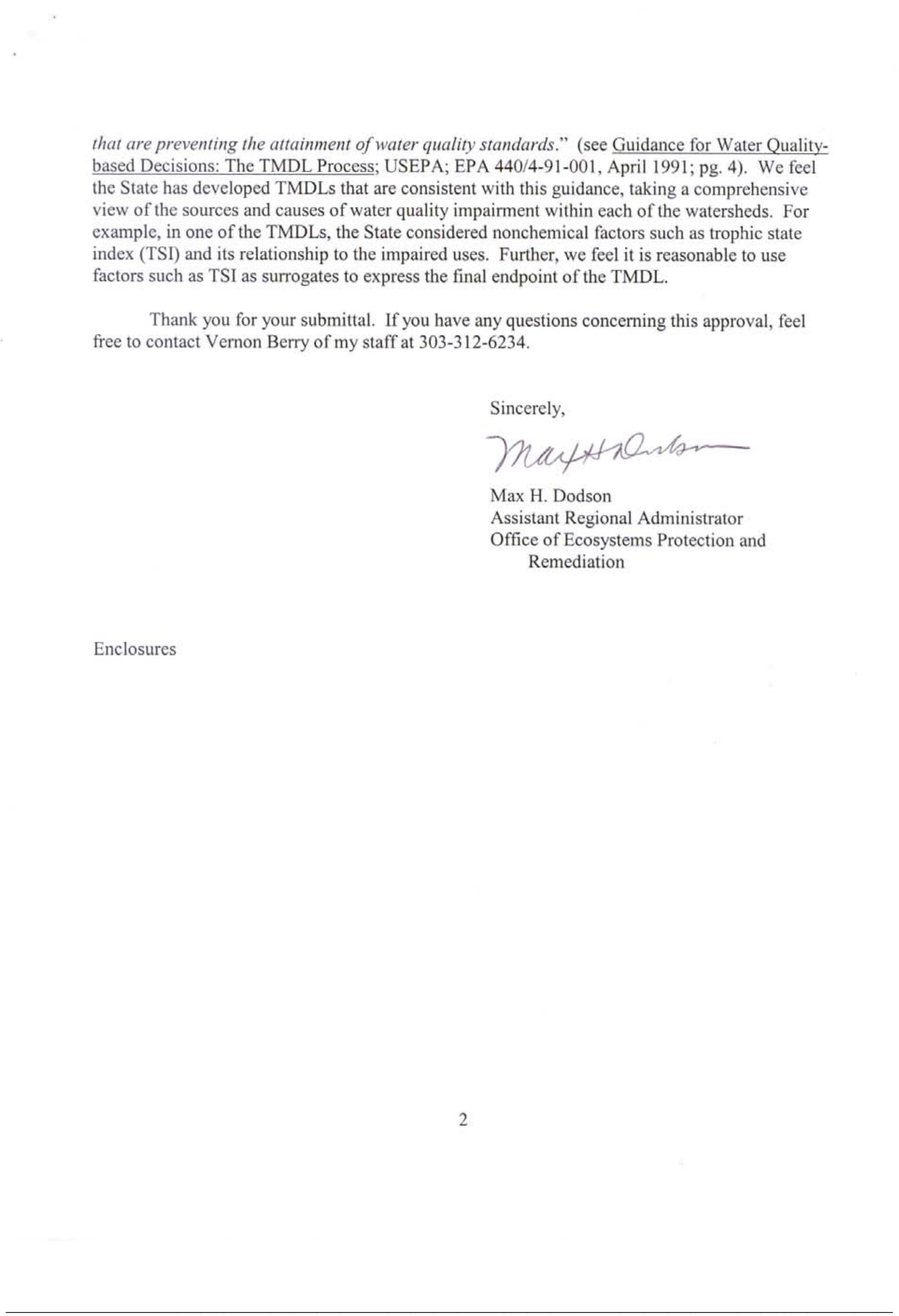

that are preventing the attainment of water quality standards." (see Guidance for Water Quality-based Decisions: The TMDL Process; USEPA; EPA 440/4-91-001, April 1991; pg. 4). We feel the State has developed TMDLs that are consistent with this guidance, taking a comprehensive view of the sources and causes of water quality impairment within each of the watersheds. For example, in one of the TMDLs, the State considered nonchemical factors such as trophic state index (TSI) and its relationship to the impaired uses. Further, we feel it is reasonable to use factors such as TSI as surrogates to express the final endpoint of the TMDL.

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

Sincerely,

Max H Dodson

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

Enclosures

ENCLOSURE 1

APPROVED TMDLS

Waterbody Name*	**TMDL Parameter/ Pollutant**	**Water Quality Goal/Endpoint**	**TMDL**	**Section 303(d)1 or 303(d)3 TMDL**	**Supporting Documentation** (not an exhaustive list of supporting documents)
Fate Dam*	phosphorus	TSI mean ≤ 59.0	2,769 kg/yr total phosphorous load to the lake (19.5% reduction in average annual total phosphorus load)	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report and TMDL, Fate Dam/Nail Creek, Lyman County, South Dakota (SD DENR, August 2004)

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

APPENDIX H

Public Comments and Responses to Fate Dam/Nail Creek Assessment Report and Total Maximum Daily Load Summary Document

Thirty-Day Notice Comments:

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Fate Dam**
Submitted by:	**Gene Stueven, SD DENR**
Date Received:	**November 22, 2004**
Review Date:	**December 20, 2004**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Informal – Public Notice**

This document provides a standard format for EPA Region 8 to provide comments to the South Dakota Department of Environment and Natural Resources on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 12 review criteria:

1. Water Quality Impairment Status
2. Water Quality Standards
3. Water Quality Targets
4. Significant Sources
5. Technical Analysis
6. Margin of Safety and Seasonality
7. Total Maximum Daily Load
8. Allocation
9. Public Participation
10. Monitoring Strategy
11. Restoration Strategy
12. Endangered Species Act Compliance

Each of the 12 review criteria are described below to provide the rational for the review, followed by EPA's comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Water Quality Impairment Status

Criterion Description – Water Quality Impairment Status

TMDL documents must include a description of the listed water quality impairments. ***While*** *the 303(d) list identifies probable causes and sources of water quality impairments, the information contained in the 303(d) list is generally not sufficiently detailed to provide the reader with an adequate understanding of the impairments. TMDL documents should include a thorough description/summary of all available water quality data such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and/or appropriate water quality standards.*

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Fate Dam is a 150 acre man-made reservoir located in the Medicine Creek watershed of the Missouri River Basin, Lyman County, South Dakota. It is listed on SD's 2004 303(d) list as impaired for trophic state index (TSI) due to nonpoint sources and is ranked as priority 1 (i.e., high priority) for TMDL development. The watershed drains predominantly agricultural land. Approximately 49.3% of the landuse is cropland and 50.7% is pastureland in the watershed. The mean TSI during the period of the project assessment was 59.91, and is not currently meeting its designated beneficial use for warmwater permanent fish life propagation.

2. Water Quality Standards

Criterion Description – Water Quality Standards

The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.

☒ Satisfies Criterion
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☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Fate Dam is impaired for TSI which is a surrogate measure used to determine whether the narrative standards are being met. South Dakota has applicable narrative standards that may be applied to the undesirable eutrophication of lakes. Data from Fate Dam indicates problems with nutrient enrichment and nuisance algal blooms, which are typical signs of the eutrophication process. The narrative standards being implemented in this TMDL are:

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

Other applicable water quality standards are included on pages 70 and 71 of the assessment report.

3. Water Quality Targets

Criterion Description – Water Quality Targets

Quantified targets or endpoints must be provided to address each listed pollutant/water body combination. Target values must represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the TMDL target. For pollutants with narrative standards, the narrative standard must be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

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

The overall mean TSI for Fate Dam during the period of the assessment was 59.91. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 62% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use TSI target of 55 or less. However, Fate Dam does not appear to fit the ecoregion-based beneficial use criteria due to legacy phosphorous loading to the lake and the technical and financial inability to fully treat new loading to the lake. Therefore, a site specific TSI of 59 was chosen for Fate Dam which will fully support its beneficial uses and is achievable given the expected landowner participation in the watershed.

The water quality target used in this TMDL is: **maintain a mean annual TSI at or below 59**

4. Significant Sources

Criterion Description – Significant Sources

TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

☒ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed. In particular, a loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors. Cropland and pastureland are the primary sources identified. Approximately 60.2% of the landuse is cropland and 39.8% is pastureland in the watershed.

5. Technical Analysis

Criterion Description – Technical Analysis

*TMDLs must be supported by an appropriate level of technical analysis. It applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of technical analysis.*

☒ Satisfies Criterion
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☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
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SUMMARY – The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 19.5% reduction in average annual total phosphorous loads to Fate Dam. Based on the loads measured during the period of the assessment the total phosphorous load should be 2,769 kg/yr to achieve the desired TSI target. This reduction is based in large part on the BATHTUB mathematical modeling of the Dam and its predicted response to nutrient load reductions.

The FLUX model was used to develop nutrient and sediment loadings for the Fate Dam inlet and outlet sites. This information was used to derive export coefficients for nutrients and sediment to target areas within the watershed with excessive loads of these pollutants.

The Annualized Agricultural Non-Point Source Model (AnnAGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The nutrient loading source analysis, that was used to identify necessary controls in the watershed, was based on the identification of targeted or “critical” cells. Cell priority was assigned based on the mean phosphorous loads produced that ultimately reach the outlet of the watershed. Cells that produce phosphorous loads greater than two standard deviations over the mean for the watershed were determined to be priority 1, and cells producing loads greater than one standard deviation over the mean were determined to be priority 2. The initial load reductions under this TMDL will be achieved through controls on the priority 1 and 2 critical cells within the watershed.

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety/Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required.

Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered when establishing TMDLs , targets, and allocations.

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SUMMARY – An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, more BMPs were specified than are necessary to meet the targets, and ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

7. TMDL

Criterion Description – Total Maximum Daily Load

TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR. 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

☒ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
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SUMMARY – The TMDL established for Fate Dam is a 2,769 kg/yr total phosphorus load to the lake (19.5% reduction in annual total phosphorus load). This is the “measured load” which is based on the flow and concentration data collected during the period of the assessment. The annual loading will vary from year-to-year; therefore, this TMDL is considered a long term average percent reduction in phosphorous loading.

8. Allocation

Criterion Description – Allocation

TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources.

In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

Allocating load reductions to specific sources is generally the most contentious and politically sensitive component of the TMDL process. It is also the step in the process where management direction is provided to actually achieve the desired load reductions. In many ways, it is a prioritization of restoration activities that need to occur to restore water quality. For these reasons, every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles.

☒ Satisfies Criterion
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SUMMARY – This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Fate Dam. The allocation for the TMDL is a “load allocation” attributed to nonpoint sources. There are no significant point source contributions in this watershed. The source allocations for phosphorous are assigned to runoff from cropland and pastureland. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorous reductions can be achieved through modifications to critical cells within the watershed.

9. Public Participation

Criterion Description – Public Participation

The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA.

☒ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
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SUMMARY – The State’s submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, individual contact with residents in the watershed, and widespread solicitation of comments on the draft TMDL. The State also employed the Internet to post the draft TMDL and to solicit comments. The level of public participation is found to be adequate.

10. Monitoring Strategy

Criterion Description – Monitoring Strategy

TMDLs may have significant uncertainty associated with selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL documents to articulate the means by which the TMDL will be evaluated in the field, and to provide supplemental data in the future to address any uncertainties that may exist when the document is prepared.

At a minimum, the monitoring strategy should:

- *Articulate the monitoring hypothesis and explain how the monitoring plan will test it.*
- *Address the relationships between the monitoring plan and the various components of the TMDL (targets, sources, allocations, etc.).*
- *Explain any assumptions used.*
- *Describe monitoring methods.*
- *Define monitoring locations and frequencies, and list the responsible parties.*

☐ Satisfies Criterion
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☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Fate Dam will continue to be monitored through the statewide lake assessment project. Post-implementation monitoring will be necessary to assure the TMDL has been reached and maintenance of the beneficial use occurs, and because the long term average TSI and phosphorous loading may be higher than was recorded during this assessment due to the lower loading from the watershed due to the lack of flow from Nail Creek into the reservoir.

11. Restoration Strategy

Criterion Description – Restoration Strategy

At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality <u>*is not*</u> *currently a regulatory requirement, but is considered a value added component of a TMDL document.*

☐ Satisfies Criterion
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☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The South Dakota DENR is working with the local conservation district to develop a plan for an implementation project for Fate Dam. The implementation of various best management practices throughout the watershed is expected to meet or exceed the WQ and TMDL targets/goals. This includes conversion of a portion of the critical cells from conventional to conservation or no till systems, improved grazing management practices, management plans for a reduction in fertilizer application, and buffer strips along areas of critical cells. Additional BMPs that could be implemented if necessary include streambank stabilization, conversion of highly erodible cropland to pasture, riparian management, lakeshore stabilization and in-lake treatment with aluminum sulfate.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance

EPA's approval of a TMDL may constitute an action subject to the provisions of Section 7 of the Endangered Species Act ("ESA"). EPA will consult, as appropriate, with the US Fish and Wildlife Service (USFWS) to determine if there is an effect on listed endangered and threatened species pertaining to EPA's approval of the TMDL. The responsibility to consult with the USFWS lies with EPA and is not a requirement under the Clean Water Act for approving TMDLs. States are encouraged, however, to participate with FWS and EPA in the consultation process and, most importantly, to document in its TMDLs the potential effects (adverse or beneficial) the TMDL may have on listed as well as candidate and proposed species under the ESA.

☐ Satisfies Criterion
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☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – EPA has received ESA Section 7 concurrence from the FWS for this TMDL.

13. Miscellaneous Comments/Questions

Thirty-Day Notice Comments (continued):

My congratulations to the folks who conducted this TMDL and wrote this final report. It is the most thorough I have read.

Mike Williams
mikewill@iw.net

605 3rd Ave. NW
Watertown, SD 57201
605-882-5250
FAX 605-882-5251

Final Submittal Comments:

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Fate Dam**
Submitted by:	**Gene Stueven, SD DENR**
Date Received:	**January 7, 2005**
Review Date:	**January 12, 2005**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Formal – Final Approval**

This document provides a standard format for EPA Region 8 to provide comments to the South Dakota Department of Environment and Natural Resources on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 12 review criteria:

13. Water Quality Impairment Status
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17. Technical Analysis
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19. Total Maximum Daily Load
20. Allocation
21. Public Participation
22. Monitoring Strategy
23. Restoration Strategy
24. Endangered Species Act Compliance

Each of the 12 review criteria are described below to provide the rational for the review, followed by EPA’s comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Water Quality Impairment Status

Criterion Description – Water Quality Impairment Status

TMDL documents must include a description of the listed water quality impairments. ***.*** *While the 303(d) list identifies probable causes and sources of water quality impairments, the information contained in the 303(d) list is generally not sufficiently detailed to provide the reader with an adequate understanding of the impairments. TMDL documents should include a thorough description/summary of all available water quality data such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and/or appropriate water quality standards.*

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☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
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☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Fate Dam is a 150 acre man-made reservoir located in the Medicine Creek watershed of the Missouri River Basin, Lyman County, South Dakota. It is listed on SD's 2004 303(d) list as impaired for trophic state index (TSI) due to nonpoint sources and is ranked as priority 1 (i.e., high priority) for TMDL development. The watershed drains predominantly agricultural land. Approximately 49.3% of the landuse is cropland and 50.7% is pastureland in the watershed. The mean TSI during the period of the project assessment was 59.91, and is not currently meeting its designated beneficial use for warmwater permanent fish life propagation.

2. Water Quality Standards

Criterion Description – Water Quality Standards

The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.

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SUMMARY – Fate Dam is impaired for TSI which is a surrogate measure used to determine whether the narrative standards are being met. South Dakota has applicable narrative standards that may be applied to the undesirable eutrophication of lakes. Data from Fate Dam indicates problems with nutrient enrichment and nuisance algal blooms, which are typical signs of the eutrophication process. The narrative standards being implemented in this TMDL are:

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

Other applicable water quality standards are included on pages 70 and 71 of the assessment report.

3. Water Quality Targets

Criterion Description – Water Quality Targets

Quantified targets or endpoints must be provided to address each listed pollutant/water body combination. Target values must represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the TMDL target. For pollutants with narrative standards, the narrative standard must be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

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

The overall mean TSI for Fate Dam during the period of the assessment was 59.91. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 62% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use TSI target of 55 or less. However, Fate Dam does not appear to fit the ecoregion-based beneficial use criteria due to legacy phosphorous loading to the lake and the technical and financial inability to fully treat new loading to the lake. Therefore, a site specific TSI of 59 was chosen for Fate Dam which will fully support its beneficial uses and is achievable given the expected landowner participation in the watershed.

The water quality target used in this TMDL is: **maintain a mean annual TSI at or below 59**

4. Significant Sources

Criterion Description – Significant Sources

TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

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SUMMARY – The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed. In particular, a loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors. Cropland and pastureland are the primary sources identified. Approximately 60.2% of the landuse is cropland and 39.8% is pastureland in the watershed.

5. Technical Analysis

Criterion Description – Technical Analysis

*TMDLs must be supported by an appropriate level of technical analysis. It applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of technical analysis.*

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SUMMARY – The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 19.5% reduction in average annual total phosphorous loads to Fate Dam. Based on the loads measured during the period of the assessment the total phosphorous load should be 2,769 kg/yr to achieve the desired TSI target. This reduction is based in large part on the BATHTUB mathematical modeling of the Dam and its predicted response to nutrient load reductions.

The FLUX model was used to develop nutrient and sediment loadings for the Fate Dam inlet and outlet sites. This information was used to derive export coefficients for nutrients and sediment to target areas within the watershed with excessive loads of these pollutants.

The Annualized Agricultural Non-Point Source Model (AnnAGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The nutrient loading source analysis, that was used to identify necessary controls in the watershed, was based on the identification of targeted or “critical” cells. Cell priority was assigned based on the mean phosphorous loads produced that ultimately reach the outlet of the watershed. Cells that produce phosphorous loads greater than two standard deviations over the mean for the watershed were determined to be priority 1, and cells producing loads greater than one standard deviation over the mean were determined to be priority 2. The initial load reductions under this TMDL will be achieved through controls on the priority 1 and 2 critical cells within the watershed.

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety/Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required.

Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered when establishing TMDLs , targets, and allocations.

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SUMMARY – An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, more BMPs were specified than are necessary to meet the targets, and ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

7. TMDL

Criterion Description – Total Maximum Daily Load

TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR. 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

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SUMMARY – The TMDL established for Fate Dam is a 2,769 kg/yr total phosphorus load to the lake (19.5% reduction in annual total phosphorus load). This is the “measured load” which is based on the flow and concentration data collected during the period of the assessment. The annual loading will vary from year-to-year; therefore, this TMDL is considered a long term average percent reduction in phosphorous loading.

8. Allocation

Criterion Description – Allocation

TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources.

In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

Allocating load reductions to specific sources is generally the most contentious and politically sensitive component of the TMDL process. It is also the step in the process where management direction is provided to actually achieve the desired load reductions. In many ways, it is a prioritization of restoration activities that need to occur to restore water quality. For these reasons, every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles.

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SUMMARY – This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Fate Dam. The allocation for the TMDL is a “load allocation” attributed to nonpoint sources. There are no significant point source contributions in this watershed. The source allocations for phosphorous are assigned to runoff from cropland and pastureland. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorous reductions can be achieved through modifications to critical cells within the watershed.

9. Public Participation

Criterion Description – Public Participation

The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA.

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SUMMARY – The State’s submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, individual contact with residents in the watershed, and widespread solicitation of comments on the draft TMDL. The State also employed the Internet to post the draft TMDL and to solicit comments. The level of public participation is found to be adequate.

10. Monitoring Strategy

Criterion Description – Monitoring Strategy

TMDLs may have significant uncertainty associated with selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL documents to articulate the means by which the TMDL will be evaluated in the field, and to provide supplemental data in the future to address any uncertainties that may exist when the document is prepared.

At a minimum, the monitoring strategy should:

- *Articulate the monitoring hypothesis and explain how the monitoring plan will test it.*
- *Address the relationships between the monitoring plan and the various components of the TMDL (targets, sources, allocations, etc.).*
- *Explain any assumptions used.*
- *Describe monitoring methods.*
- *Define monitoring locations and frequencies, and list the responsible parties.*

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SUMMARY – Fate Dam will continue to be monitored through the statewide lake assessment project. Post-implementation monitoring will be necessary to assure the TMDL has been reached and maintenance of the beneficial use occurs, and because the long term average TSI and phosphorous loading may be higher than was recorded during this assessment due to the lower loading from the watershed due to the lack of flow from Nail Creek into the reservoir.

11. Restoration Strategy

Criterion Description – Restoration Strategy

At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document.

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SUMMARY – The South Dakota DENR is working with the local conservation district to develop a plan for an implementation project for Fate Dam. The implementation of various best management practices throughout the watershed is expected to meet or exceed the WQ and TMDL targets/goals. This includes conversion of a portion of the critical cells from conventional to conservation or no till systems, improved grazing management practices, management plans for a reduction in fertilizer application, and buffer strips along areas of critical cells. Additional BMPs that could be implemented if necessary include streambank stabilization, conversion of highly erodible cropland to pasture, riparian management, lakeshore stabilization and in-lake treatment with aluminum sulfate.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance

EPA's approval of a TMDL may constitute an action subject to the provisions of Section 7 of the Endangered Species Act ("ESA"). EPA will consult, as appropriate, with the US Fish and Wildlife Service (USFWS) to determine if there is an effect on listed endangered and threatened species pertaining to EPA's approval of the TMDL. The responsibility to consult with the USFWS lies with EPA and is not a requirement under the Clean Water Act for approving TMDLs. States are encouraged, however, to participate with FWS and EPA in the consultation process and, most importantly, to document in its TMDLs the potential effects (adverse or beneficial) the TMDL may have on listed as well as candidate and proposed species under the ESA.

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SUMMARY – EPA has received ESA Section 7 concurrence from the FWS for this TMDL.

13. Miscellaneous Comments/Questions


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