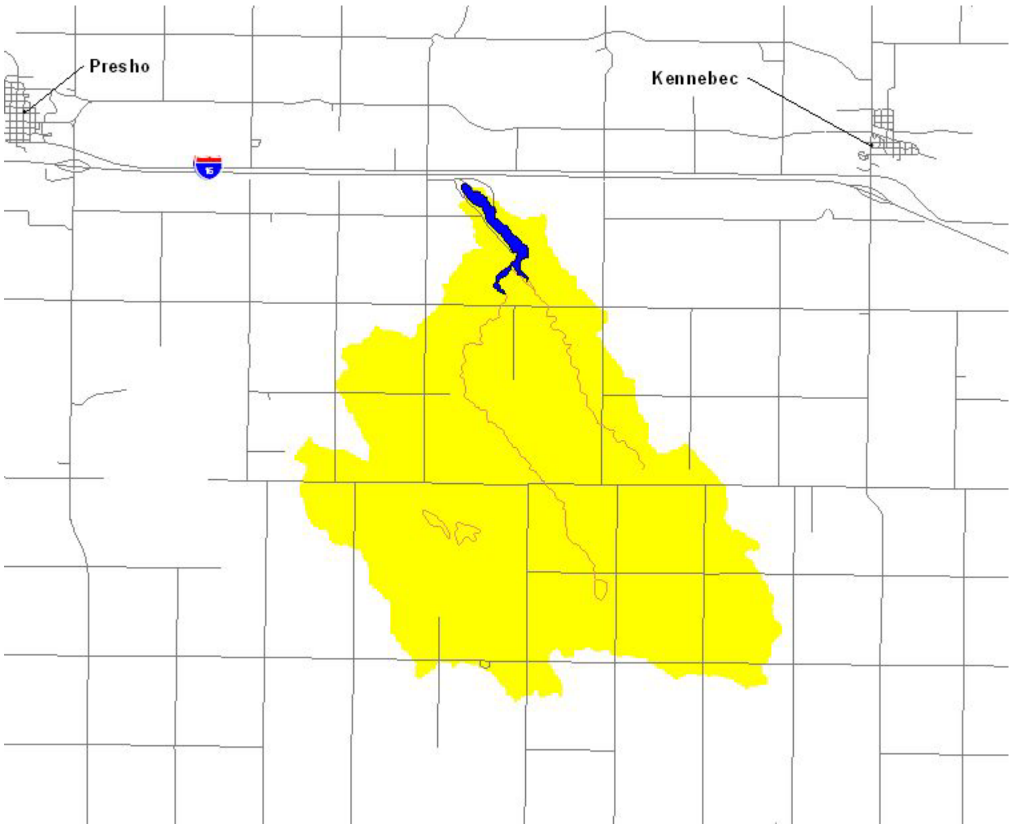
PHASE I
WATERSHED ASSESSMENT FINAL REPORT
AND TMDL

BRAKKE DAM/(BRAKKE 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

APRIL, 2004

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Steven M. Pirner, Secretary

Prepared By

Robert L. Smith, Environmental Program Scientist

State of South Dakota
M. Michael Rounds, Governor

April, 2004

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

BRAKKE DAM/BRAKKE CREEK WATERSHED ASSESSMENT AND TMDL

(PART OF THE MEDICINE CREEK WATERSHED ASSESSMENT PROJECT)

by:
Robert L. Smith

Project Sponsor:
American Creek Conservation District

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

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

Total EPA Budget: $ 101,796

Total Expenditures of EPA Funds: $ 101,796

Total Section 319 Match Accrued: $ 75,238.38

Budget Revisions: No Revisions

Total Expenditures: $ 177,034.38

Summary of Accomplishments

Brakke Dam is a reservoir located in the Northwestern Great Plains (43) ecoregion (Level III) in central South Dakota and is located at 43.884496° North Latitude and 99.944617° West Longitude. An unnamed tributary (henceforth, Brakke Creek) drains a watershed of approximately 4,568 ha (11,288 acres) and is impounded by Brakke Dam. Brakke Dam is a recreational lake of approximately 52.6 ha (130 acres) and has been impacted by increased TSI values and periodic algal blooms. The assessment project was sponsored by the American Creek Conservation District (ACCD). Brakke Dam is listed on South Dakota's 1998 and 2002 303(d) Total Maximum Daily Load (TMDL) Waterbody List.

This assessment was the initial phase of a watershed-wide restoration project. Water quality monitoring, stream gauging and land use analyses were used to document the sources of impairment and calculate a TMDL for Brakke Dam.

A total of 10 tributary and 22 in-lake samples were collected by the sponsor from April 2000 through May 2001. Water quality and hydrologic data from Brakke Creek was modeled using the FLUX model. FLUX data was used to calculate the annual sediment and nutrient loading to Brakke Dam. In-lake water quality data was modeled using the BATHTUB model. BATHTUB was used to model TSI reductions based on tributary load reductions. Loading and reduction data was used to determine the TMDL for Brakke Dam.

Landuse data from the watershed was also collected by the project sponsor for use in the AnnAGNPS model. 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 model was used to identify critical areas and 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 loading and AnnAGNPS data were sufficient to develop a TMDL for Brakke Dam.

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 ≤ 55.00. However, current ecoregional (Ecoregion 43) target criteria appear not to fit Brakke 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 88.2 percent resulting in a phosphorus TSI of 52.40 and a mean TSI of 54.37 for Brakke Dam (21.2 percent mean TSI reduction). Under this extreme situation Brakke Dam could meet current ecoregional-based beneficial use criteria; obviously, this scenario is not realistic based on financial, logistical and technical constraints. Alternative site specific (watershed-specific) evaluation criteria (fully supporting, mean TSI ≤ 65.00) was proposed based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability.

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, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation, and stock watering and irrigation water. Based on data from this assessment, an implementation project should be designed and initiated in this watershed to achieve this goal.

The TMDL for total phosphorus in Brakke Dam is 501 kg/yr producing a mean TSI of 64.51. The load allocation for total phosphorus is 501 kg/yr and includes the background load for total phosphorus based on 2000 through 2001 assessment data.

Acknowledgements

The cooperation of the following organizations and individuals is gratefully appreciated. The assessment of Brakke 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

Table of Contents

Table of Contents (continued)

Table of Contents (continued)

List of Figures

List of Figures (continued)

List of Figures (continued)

List of Figures (continued)

List of Figures (continued)

List of Figures (continued)

List of Tables

List of Tables (continued)

List of Tables (continued)

List of Tables (continued)

List of Equations

List of Appendices

Waterbody Type:	Lake
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:	Brakke Dam- 52.6 hectares (130.0 acres).
Size of Watershed:	4,568.1 hectares (11,288 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 Brakke Dam.

1.0 Introduction

Brakke Dam is a reservoir located in the Northwestern Great Plains (43) ecoregion (Level III) in central South Dakota. Brakke Dam (Brakke Lake) was constructed in 1935 by the Civilian Conservation Corp (CCC). Brakke Dam "Brakke Dam" was named in honor of Andrew T. Brakke, an early settler who lived near the lake (WWP, 1941). Brakke Dam is located at 43.927642° Latitude and 99.939203° Longitude and is located on land owned by South Dakota Department of Game, Fish and Parks (SD GF&P).

Brakke Dam is listed on the 1998 and 2002 303(d) Impaired Waterbody List (SD DENR 1998 and SD DENR 2002). An unnamed tributary of Medicine Creek (henceforth, Brakke Creek) drains a watershed of approximately 4,568.1 ha (11,288 acres) and is impounded by Brakke Dam in Lyman County, South Dakota (Figure 1). Brakke Dam is a recreational lake of approximately 52.6 ha (130 acres) and has been impacted by increasing TSI values and periodic algal blooms. The Brakke Dam watershed is within the boundaries of the American Creek Conservation District (ACCD) who sponsored the Medicine Creek Watershed Assessment Project.

This project is intended to be the initial phase of a watershed-wide restoration project. Water quality monitoring, stream gauging and land use analysis were used to document the sources of impairment to the Brakke Creek tributaries and Brakke 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 49.3 percent of the landuse is cropland (cultivated and non-cultivated) and 50.7 percent is range and pastureland. Currently, no animal feeding areas/operations are located in the Brakke Dam watershed.

The major soil association found in the Brakke 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.

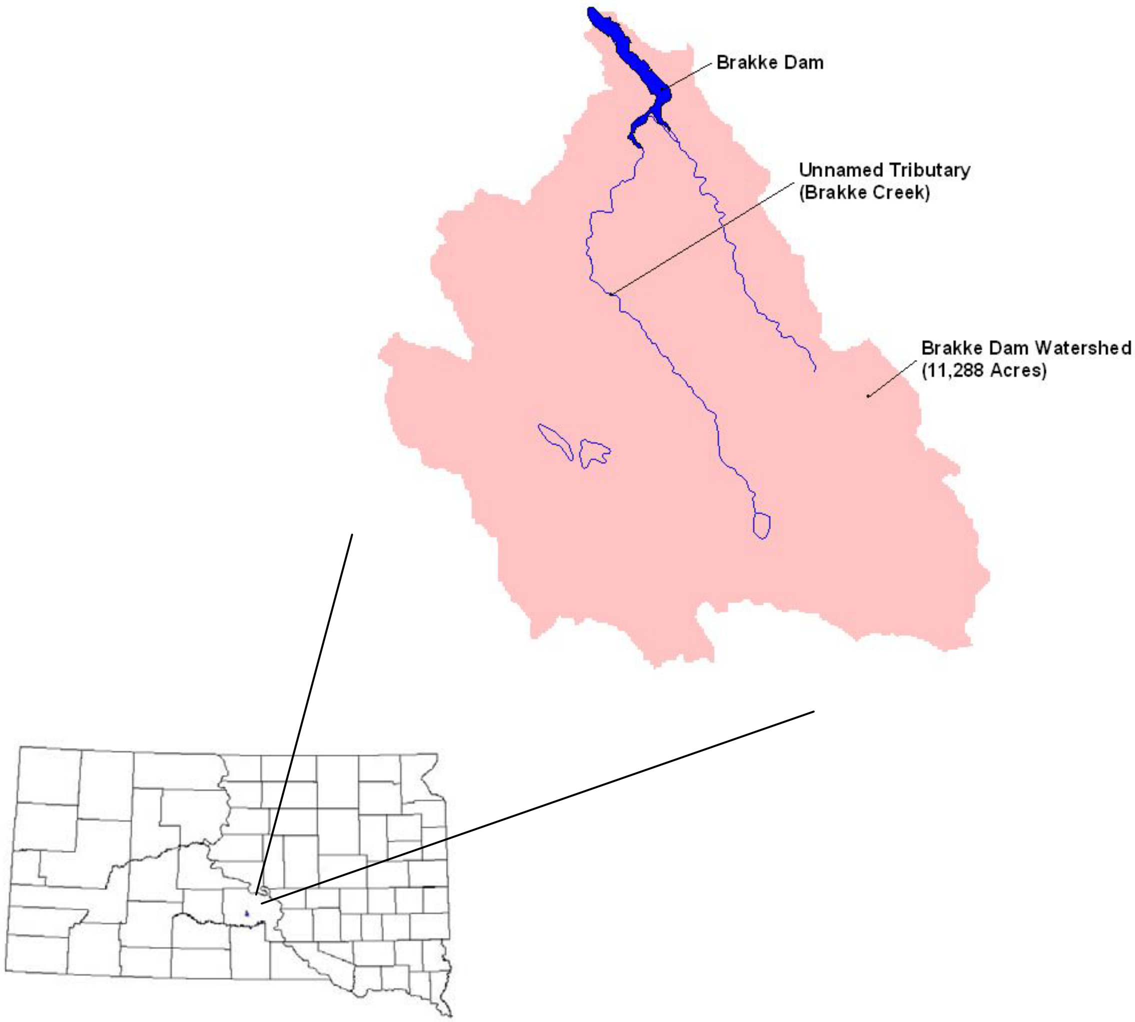


Figure 1. The Brakke Dam watershed and its location in the State of South Dakota.

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, 1984).

Land elevation within the watershed ranges from about 1,735.6 feet (529 m) msl in the northern areas of the watershed to about 1,870.1 feet (570 m) msl in the southern part.

The 2000 305(b) report to the U.S. Congress reported the 5-year water quality trend for lake assessment in Brakke Dam as unknown, while the 2002 305(b) report (the most current) reported that Brakke Dam based on lake assessment as hyper-eutrophic (SD DENR, 2000 and SD DENR, 2002). The 2002 305(b) also listed Brakke 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 (partially supporting) with use support as unknown due to lack of data (SD DENR, 2002). The overall use support for Brakke Dam based upon lake assessment is partially supporting. The causes for partial support based upon magnitude are listed as algal growth/chlorophyll-*a* (very slight), nutrients (moderate) and siltation (moderate). A high magnitude of agriculture is listed as the source of impairment for partial support (SD DENR, 2002). South Dakota Department of Environment and Natural Resources (SD DENR) has and continues to monitor Brakke Dam as part of the statewide lakes assessment. Assessment data will be used as an indication of use support for Brakke Dam.

The entire Brakke 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 Brakke 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., 1997).

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 weighted based on the density of TMDL acres 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).

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 with the creeks and lakes in the watershed. This project will result in four TMDL reports for three 303(d) 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 receives runoff from agricultural operations and both the creek and lakes have experienced declining water quality. The Medicine Creek watershed is approximately 437,892 acres with 11,288 acres above Brakke Dam, 16,957 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 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. Figure 2 is a map of the lake sampling sites.

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

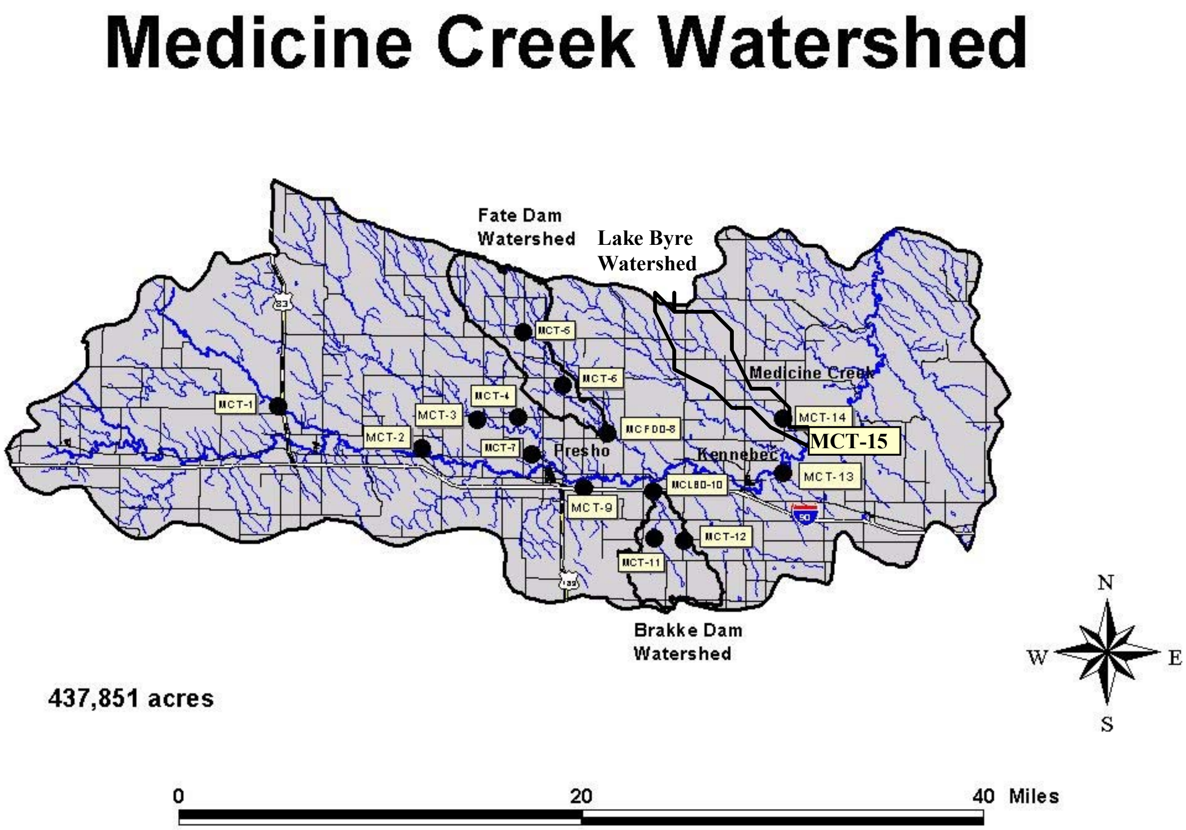


Figure 2. Medicine Creek watershed, Lyman and Jones Counties, South Dakota.

<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.

TASK 9 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.

TASK 10 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.

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

TASK 12 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:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

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.

<u>TASK 24</u> 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.

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

<u>TASK 26</u> 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

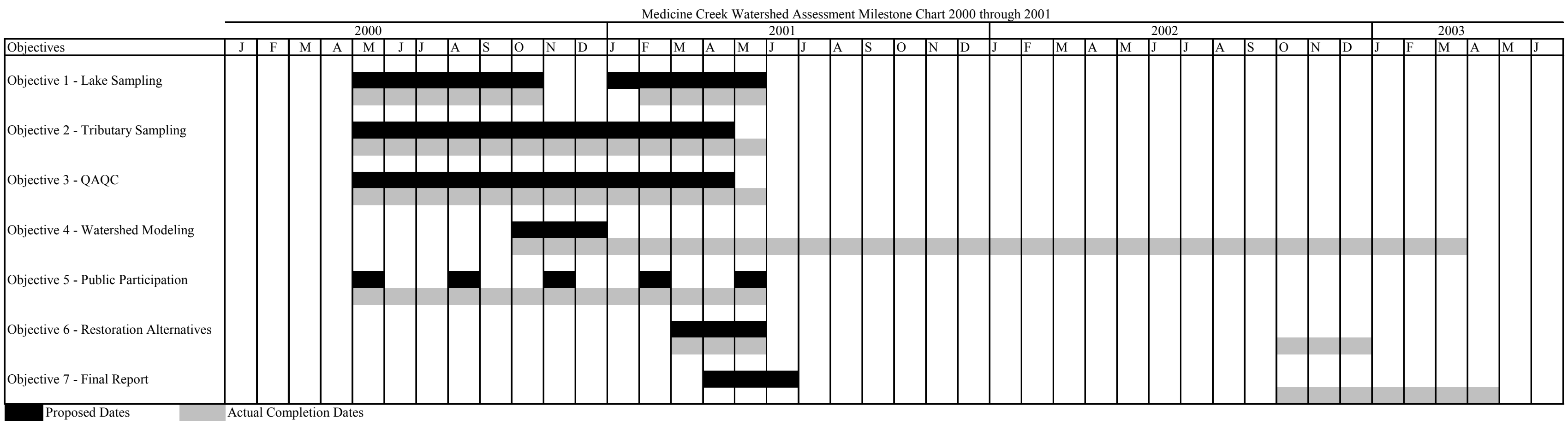
WORK ACTIVITIES:

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 Brakke Dam/Brakke Creek Assessment Project milestone table (Table 1).

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



2.2 Evaluation of Goal Achievement

Fate Dam and Brakke Dam are listed on the State of South Dakota's 303(d) list of impaired waterbodies as priority-one waterbodies for Trophic State Index (TSI) for increased nutrients. Medicine Creek is also listed on the state's 303(d) list for conductivity and total dissolved solids. Byre Lake is not listed on the state's 303(d) list; however, watershed and lake data was collected to assess trophic condition and to see if it was meeting its designated beneficial uses. 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 recommended 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 land use 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 critical cells of 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

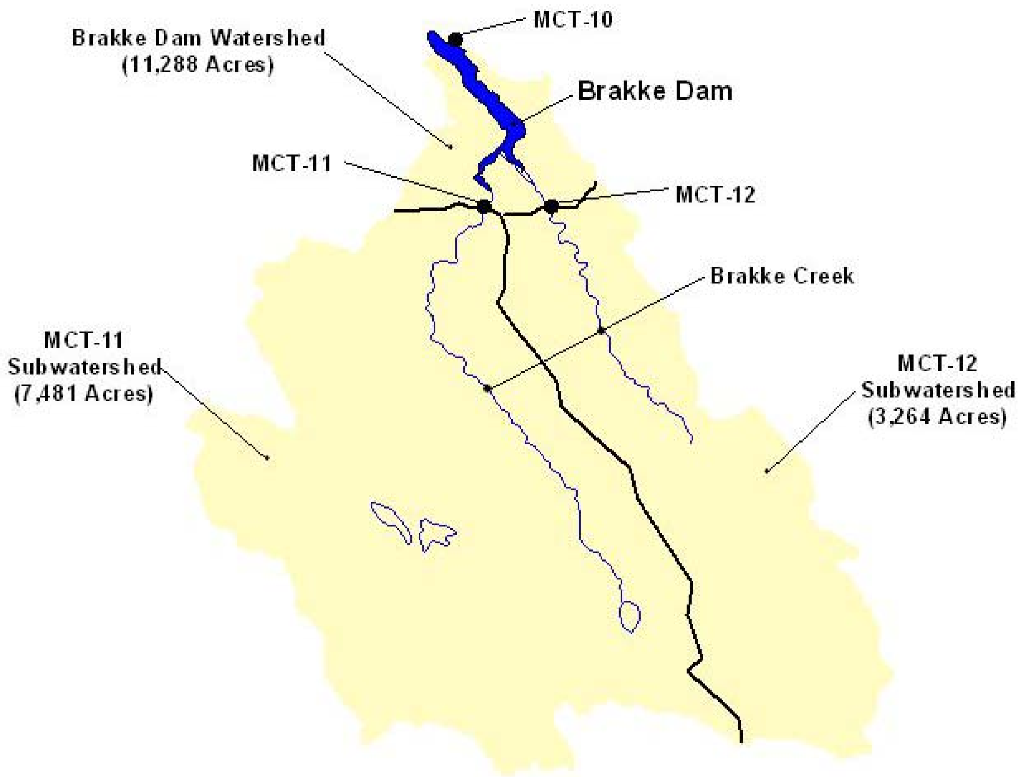


Figure 3. Brakke Creek subwatersheds and sampling sites and sub-watersheds for 2000 through 2001.

Three tributary locations were chosen for collecting hydrologic and nutrient information from the Brakke 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. OTT Thalimedes data loggers were placed on the east and west tributaries of Brakke Creek near the inlets to Brakke Dam (MCT-11 and MCT-12) and near the outlet spillway (MCT-10) to record the lake level (stage) in Brakke Dam and was used to calculate lake discharge back to the Brakke 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). Actual stage and discharge measurements from MCT-12 (unnamed east tributary, Brakke Creek) were used to calculate a regression equation (Appendix A). This equation was used to calculate average daily discharge for this site. Stage data collected at MCT-11 (unnamed west tributary, Brakke Creek) was adjusted using water depth measurements inside the corrugated metal conduit under the section road. Adjusted average depth measurements were used to calculate discharge using the Manning's formula (Equation 1).

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 perimeter)
S = Slope of the hydraulic gradient
n = Manning's coefficient of roughness dependent upon material of conduit

Average daily outlet (MCT-10) stage data for the Brakke Dam spillway was used to calculate discharge using a standard weir equation (Equation 2).

Equation 2. Brakke Dam weir discharge equation.

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

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. The stage and flow data from MCT-12 was used to develop a stage/discharge table that was used to calculate average daily loadings. Average daily stage measurements were used to calculate discharge at MCT-10, MCT-11 and MCT-12.

Tributary Water Quality Sampling

Samples collected at each tributary site were taken according to South Dakota's EPA approved *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 http://www.state.sd.us/denr.

Table 2. Tributary physical, chemical and biological parameters analyzed in , 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	
Conductivity	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	

Tributary Modeling Methods

Tributary Loading Calculations

The FLUX program was used to develop nutrient and sediment loadings for MCT-11(Brakke Creek west tributary) and MCT-12 (Brakke Creek east tributary), Brakke Dam inlets and MCT-10 (Brakke Dam outlet to Brakke Creek). The US Army Corp of Engineers developed the FLUX program for eutrophication (nutrient enrichment) assessment and prediction for reservoirs (Walker, 1996). 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 sites (inlet sites) and the outlet site of Brakke Dam to calculate nutrient and sediment loadings 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 nutrient 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 Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

	MCT-11 (West Inlet)		MCT-12 (East Inlet)		MCT-10 (Brakke Outlet)	
Parameter	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)
Alkalinity	IJC	0.126	Q wt C	0.214	IJC	0.015
Total Solids	Q wt C	0.261	Q wt C	0.160	Q wt C	0.016
Total Dissolved Solids	Q wt C	0.187	Q wt C	0.124	IJC	0.044
Total Suspended Solids	Q wt C	0.473	Q wt C	0.286	Q wt C	0.193
Volatile Total Suspended Solids	IJC	0.126	Q wt C	0.561	IJC	0.231
Ammonia	IJC	0.679	IJC	0.335	IJC	0.196
Nitrate-Nitrite	Q wt C	0.153	IJC	0.431	Q wt C	0.143
Total Kjeldahl Nitrogen	IJC	0.300	Q wt C	0.204	Q wt C	0.080
Organic Nitrogen	IJC	0.276	Q wt C	0.207	IJC	0.095
Inorganic Nitrogen	IJC	0.184	IJC	0.364	IJC	0.149
Total Nitrogen	IJC	0.226	IJC	0.157	Q wt C	0.017
Total Phosphorus	Q wt C	0.182	Q wt C	0.658	Q wt C	0.378
Total Dissolved Phosphorus	IJC	0.068	Q wt C	0.678	Q wt C	0.495

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 (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.

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

		Concentration		Loading	
Parameter	N	Kruskal-Wallis (H)	p-value	Kruskal-Wallis (H)	p-value
Alkalinity	9	4.66	0.097	1.16	0.561
Total Solids	9	4.36	0.113	1.87	0.393
Total Dissolved Solids	9	6.49	0.039	1.16	0.561
Total Suspended Solids	9	2.98	0.225	1.69	0.430
Volatile Total Suspended Solids	9	4.21	0.122	1.07	0.587
Ammonia	9	0.21	0.901	1.69	0.430
Nitrate-Nitrite	9	2.78	0.249	2.76	0.252
Total Kjeldahl Nitrogen	9	2.76	0.252	1.07	0.587
Organic Nitrogen	9	4.36	0.113	1.16	0.561
Inorganic Nitrogen	9	1.42	0.491	1.87	0.393
Total Nitrogen	9	3.86	0.148	1.87	0.393
Total Phosphorus	9	5.60	0.061	1.42	0.491
Total Dissolved Phosphorus	9	3.83	0.147	2.49	0.288

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

Landuse Modeling – Annualized Agricultural Non-Point Source Model, version 2.2 (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. Weather data was generated using a synthetic weather generator based on climate information from the Kennebec weather station. It is important to note that these model results are based on 25 simulated years of data with precipitation ranging from 13.4 to 29.6 inches per year. Mean annual precipitation for this watershed is about 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 conservation district which provided estimates on the number of animal units and duration of use. The older AGNPS (3.65) model, developed by the United States Department of Agriculture (Young et al., 1986) was used to calculate feedlot/feeding area nutrient and rating values for use in the AnnAGNPS program. Twenty-one parameters were collected for 40-acre cells with feedlot/feeding areas in the /Brakke Dam watershed. The twenty-one main parameters needed to run the AGNPS program to determine feedlot rating and nutrient values include:

1) Cell Number	2) Receiving Cell	3) Aspect Ratio
4) NRCS Curve #	5) Land Slope	6) Slope Length
7) Slope Shape	8) Manning's Coefficient	9) Soil Erodibility
10) Cropping Factor	11) Practice Factor	12) Surface Constant
13) Soil Texture	14) Fertilizer Level	15) Available Fertilizer
16) Point Source	17) Gully Source	18) COD Factor
19) Impoundment	20) Channel Indicator	21) Channel Slope

The point source indicator (16) allows the data collector to enter a value if an animal feeding area is present in the cell. If the cell does contain an animal feeding area, there are approximately eight more parameters to collect to describe the feeding area. These parameters are:

1) Cell Number
2) Feedlot Area
3) Roofed Area
4) Curve Number
5) Buffer Data
6) Area of land contributing water through the feedlot
7) Animal Data
8) Area of land between the feedlot and channeled flow

Parameters #5, #6, and #7, in the feedlot section, may require multiple sets of sub-data if the curve numbers change over the land areas. The animal data (#7) may also require multiple parameters depending on how many different types of animals are in a given feeding area. Output data from the AGNPS (3.65) model can be entered into the AnnAGNPS model to estimate overall loading in the Brakke Dam watershed; however, no animal feeding areas were located in the Brakke Dam 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 B.

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 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.

Brakke 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 Brakke Creek (unnamed tributary), Lyman County South Dakota.

Water Body	From	To	Beneficial Uses*	County
**Brakke Creek (a tributary of Medicine Creek)	Lake Sharpe	U.S. Highway 83	9, 10	Lyman
All Streams	Entire State	Entire State	9, 10	All

*** = See Table 3 above**
**** = Brakke Creek is an unnamed tributary of Medicine Creek of which these beneficial uses apply.**

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 the unnamed tributary. Four of the fourteen parameters (total petroleum hydrocarbon, oil and grease, un-disassociated hydrogen sulfide and sodium adsorption ratio) listed for beneficial use classification were not sampled during this project.

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

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

[1] = The daily maximum for total alkalinity as calcium carbonate is ≤ 1,313 mg/L or ≤ 750 mg/L for a 30-day average.
[2] = The daily maximum for total dissolved solids is ≤ 4,375 mg/L or ≤ 2,500 mg/L for a 30-day average.
[3] = The daily maximum for conductivity at 25° C is ≤ 4,375 µS/cm^{-1} or ≤ 2,500 µS/cm^{-1} for a 30-day average.
[4] = The daily maximum for nitrates is ≤ 88 mg/L or ≤ 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)

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

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

Brakke Creek Water Quality Exceedances

There were no tributary water quality standards violations based on assigned beneficial uses for Brakke Creek, (9) Fish and wildlife propagation, recreation, and stock watering water and (10) Irrigation water during the project (Appendix C). Although no violations occurred, an elevated fecal coliform count was collected from the east tributary to Brakke Dam (MCT-12) in April 2001 (Table 8). This high fecal coliform count (> 29,000 colonies/100 ml) was collected during increasing flow conditions in late April (spring) of 2001. Runoff from land-applied manure, cattle pastured in riparian areas, poor manure or wildlife management may be responsible for the high fecal concentrations. Since the majority of the Brakke Dam watershed is agricultural, most elevated fecal coliform counts can be attributed to agricultural runoff.

Concentrations from Brakke Dam outlet (MCT-10) to Brakke Creek were mitigated by hydrologic and nutrient residence time and dilution in Brakke Dam before being discharged back into Brakke Creek loading Medicine Creek.

Table 8. Elevated fecal coliform bacteria count in Brakke Creek above Brakke Dam in 2001.

Site	Date	Hydrologic Event	Fecal Coliform (#Colonies/100 ml)
MCT-12 **(east tributary)**	4/25/01	Increasing (Rising Stage)	29,000

Seasonal Tributary Water Quality

Typically, water quality parameters will vary depending upon season due to changes in temperature, precipitation and agricultural practices. Ten tributary water quality samples were collected during the project (Appendix C). These data were separated seasonally: winter (January – March) and spring (April – June). No runoff was recorded during 2000 at either sampling site. During this project, approximately two discrete samples were collected in the winter at MCT-11 and MCT-12 (Brakke Dam inlets) and seven samples were collected in the spring at MCT-10 (Brakke Dam outlet) and MCT-11 and MCT-12 (Brakke Dam inlets).

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 tributary monitoring sites by year and season are provided in Table 9.

Tributary Concentrations

Table 9. Average seasonal tributary concentrations from the Brakke Creek tributaries to Brakke Dam and Medicine Creek, Lyman County, South Dakota[1] for 2000 and 2001[4].

Year / Station / Season

	2000						2001											
	MCT-10, MCT-11 and MCT-12						MCT-10 (outlet)				MCT-11 (west tributary)				MCT-12 (east tributary)			
	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	15.8	1	0.6	2	3.7	1	6.3	2	10.1
Dissolved Oxygen	-	-	-	-	-	-	-	-	4	11.8	1	11.0	2	13.1	1	8.5	2	5.6
pH (su)[2]	-	-	-	-	-	-	-	-	4	8.49	1	8.65	2	8.13	1	7.95	2	8.19
Conductivity (µS/cm^{-1})	-	-	-	-	-	-	-	-	4	317	1	490	2	194	1	247	2	340
Fecal Coliform Bacteria (#colonies/100 ml)	-	-	-	-	-	-	-	-	4	9	1	5	2	12.5	1	5	2	14550
Alkalinity (mg/L)	-	-	-	-	-	-	-	-	4	119	1	11	2	77	1	74	2	148
Total Solids (mg/L)	-	-	-	-	-	-	-	-	4	244	1	63	2	226	1	269	2	353
Total Dissolved Solids (mg/L)	-	-	No Flow in 2000		-	-	-	-	4	218	1	56	2	161	1	218	2	275
Total Suspended Solids (mg/L)	-	-	-	-	-	-	-	-	4	20	1	7	2	66	1	51	2	78
Volatile Total Suspended Solids (mg/L)	-	-	-	-	-	-	-	-	4	2	1	1	2	4	1	4	2	8
Ammonia (mg/L)	-	-	-	-	-	-	-	-	4	0.05	1	0.62	2	0.03	1	0.48	2	0.08
Un-ionized Ammonia (mg/L)	-	-	-	-	-	-	-	-	4	0.00610	1	0.02324	2	0.00029	1	0.00588	2	0.00082
Nitrate - Nitrite (mg/L)	-	-	-	-	-	-	-	-	4	0.30	1	0.80	2	0.65	1	4.40	2	0.29
Total Kjeldahl Nitrogen (mg/L)	-	-	-	-	-	-	-	-	4	0.77	1	2.17	2	0.60	1	1.94	2	1.72
Inorganic Nitrogen (mg/L)	-	-	-	-	-	-	-	-	4	0.43	1	1.42	2	0.68	1	4.88	2	0.37
Organic Nitrogen (mg/L)	-	-	-	-	-	-	-	-	4	0.54	1	1.55	2	0.57	1	1.46	2	1.64
Total Nitrogen (mg/L)	-	-	-	-	-	-	-	-	4	1.12	1	2.97	2	1.25	1	6.34	2	2.00
Total Phosphorus (mg/L)	-	-	-	-	-	-	-	-	4	0.130	1	0.390	2	0.324	1	0.736	2	0.918
Total Dissolved Phosphorus (mg/L)	-	-	-	-	-	-	-	-	4	0.080	1	0.345	2	0.184	1	0.617	2	0.711
Total Nitrogen : Total Phosphorus Ratio	-	-	-	-	-	-	-	-	4	8.69	1	7.62	2	3.82	1	8.61	2	4.66

[1] = Highlighted areas are the highest recorded average concentrations for a given parameter in 2001.
[2] = pH is highest seasonal concentration not average.
[3] = One sample not an average.
[4]= No summer or fall runoff during the project.

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. Season-long grazing, runoff from manure applied fertilizer and/or poor manure management were the most likely sources of increased fecal coliform counts.

Higher total, dissolved, suspended and volatile total suspended solids concentrations were observed in the spring at MCT-12. Intense rains on agricultural lands and harvested crops typically cause higher erosion and higher solids in streams.

Average nitrate-nitrite, inorganic nitrogen and total nitrogen concentrations were higher in the winter at MCT-12. The highest average organic nitrogen concentration occurred in the spring also at MCT-12. Total Kjeldahl Nitrogen (TKN) concentrations were highest in the winter at MCT-11.

Ammonia and un-ionized ammonia concentrations were highest in the winter of 2001 at MCT-11. Sources for high ammonia concentrations could be from decomposition of organic matter or runoff from land applied fertilizer and/or manure.

Average total phosphorus and total dissolved phosphorus concentrations were highest in the spring at MCT-12 (Table 9). Increased phosphorus concentrations often coincide with higher fecal coliform or suspended solids concentrations. Average fecal coliform, total suspended solids, total phosphorus and total dissolved phosphorus concentrations were highest in the spring.

Seasonalized Tributary Hydrologic Loadings

Two tributary monitoring sites were set up on the inlets to Brakke Dam (MCT-11 and MCT-12) and one (MCT-10) at the outlet of Brakke Dam. All sites were monitored 394 days from April 2000 through May 2001 excluding the winter months. Approximately 1.5 million cubic meters (1,295 acre-feet) of water flowed into Brakke Dam from Brakke Creek over the project period. The overall tributary export coefficient (amount of water delivered per acre) was 148.7 m^3/acre (0.12 acre-foot/acre). Export coefficients and seasonal loading percentages for MCT-10, MCT-11 and MCT-12 are provided in Table 10.

The peak hydrologic load for Brakke Dam and Medicine Creek (MCT-11 and MCT-12) occurred during the spring of 2001. Approximately 89.2 percent of the hydrologic load was delivered to Brakke Dam and 99.8 percent was delivered to Medicine Creek during the spring sampling period.

Table 10. Cumulative hydrologic loading and export coefficients for Brakke Creek (Brakke Dam inlets) and Brakke Dam outlet (Brakke Creek to Medicine Creek), Lyman County, South Dakota in 2000 and 2001.

		Seasonal Hydrologic Loading			Export Coefficient	
Site	**Season**	**Meters^3**	**Acre-feet**	**Percent**	**Meters^3/acre**	**Acre-feet/acre**
MCT-11	**Spring - 00**	0	0	0	0	0
	Summer - 00	0	0	0	0	0
	Fall - 00	0	0	0	0	0
	Winter - 01	36,000	29.19	2.46	4.81	0.004
	Spring - 01	1,425,000	1,155.25	97.54	190.48	0.15
MCT-11	**Inlet Total**	**1,461,000**	**1,184.44**	**100.00**	**195.29**	**0.15**
MCT-12	**Spring - 00**	0	0	0	0	0
	Summer - 00	0	0	0	0	0
	Fall - 00	0	0	0	0	0
	Winter - 01	30,000	24.32	21.90	9.19	0.007
	Spring - 01	107,000	86.74	78.10	32.78	0.03
MCT-12	**Inlet Total**	**137,000**	**111.06**	**100.00**	**41.97**	**0.03**
Brakke Dam	**Total Input**	**1,598,000**	**1,295.50**	**100.00**	**148.72**	**0.12**
MCT-10	**Spring - 00**	0	0	0	0	0
	Summer - 00	0	0	0	0	0
	Fall - 00	0	0	0	0	0
	Winter - 01	2,000	1.62	0.22	0.18	0.00
	Spring - 01	899,000	728.19	99.78	83.85	0.07
Medicine Creek	**Total**	**901,000**	**729.81**	**100.00**	**84.03**	**0.07**

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). Tributary dissolved oxygen concentrations averaged 10.15 mg/L (median 10.71 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.

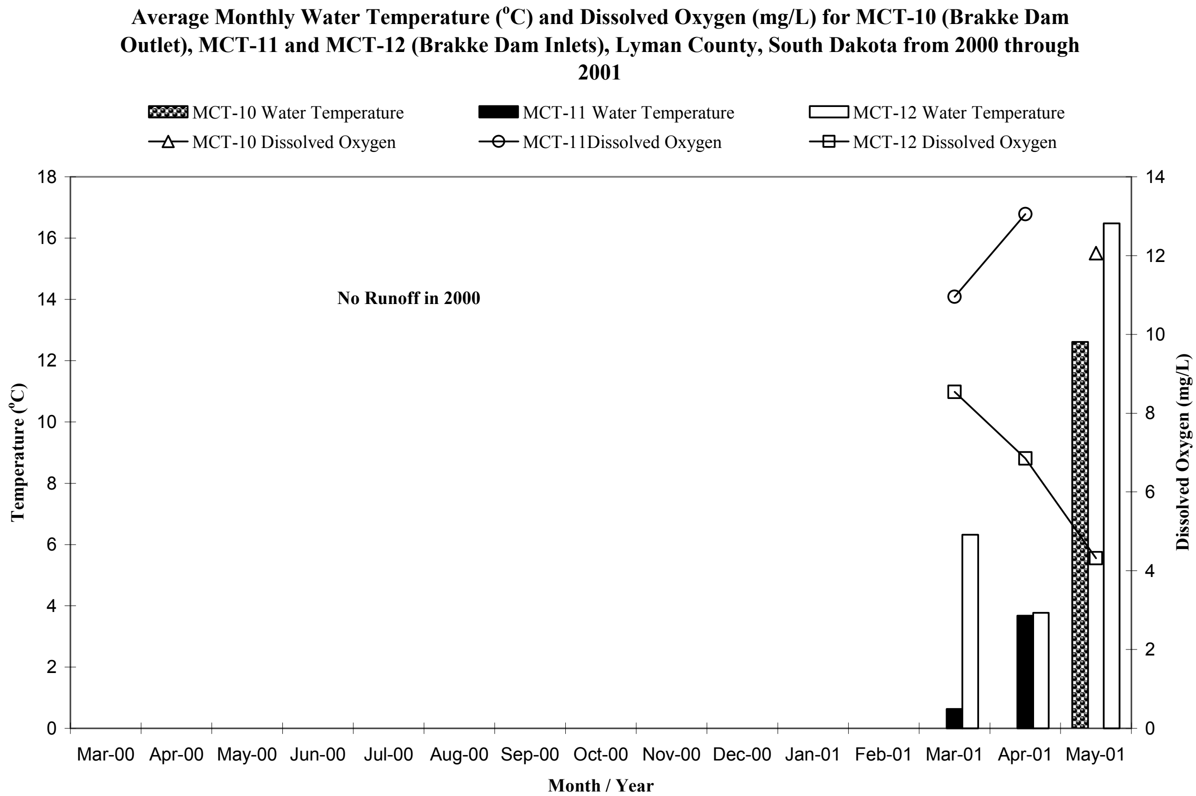


Figure 4. Monthly average dissolved oxygen concentrations and temperature for Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

The maximum dissolved oxygen concentration in Brakke Creek was 14.3 mg/L. The sample was collected at site MCT-11 (west tributary) on April 12, 2001 (Appendix C). The minimum dissolved oxygen concentration was 4.32 mg/L at MCT-12 (east tributary) on May 13, 2001 (Figure 4). Brakke Dam with its increased hydrologic retention time and algae production modified/increased dissolved oxygen concentrations at the downstream (MCT-10) sampling site (Figure 4).

Dissolved oxygen concentrations in Brakke Creek were significantly different ($p<0.05$) between inlet monitoring sites (MCT-11 and MCT-12) based on the Mann-Whitney U statistical test. Figure 5 indicates dissolved oxygen concentrations were significantly lower at MCT-12 than MCT-11.

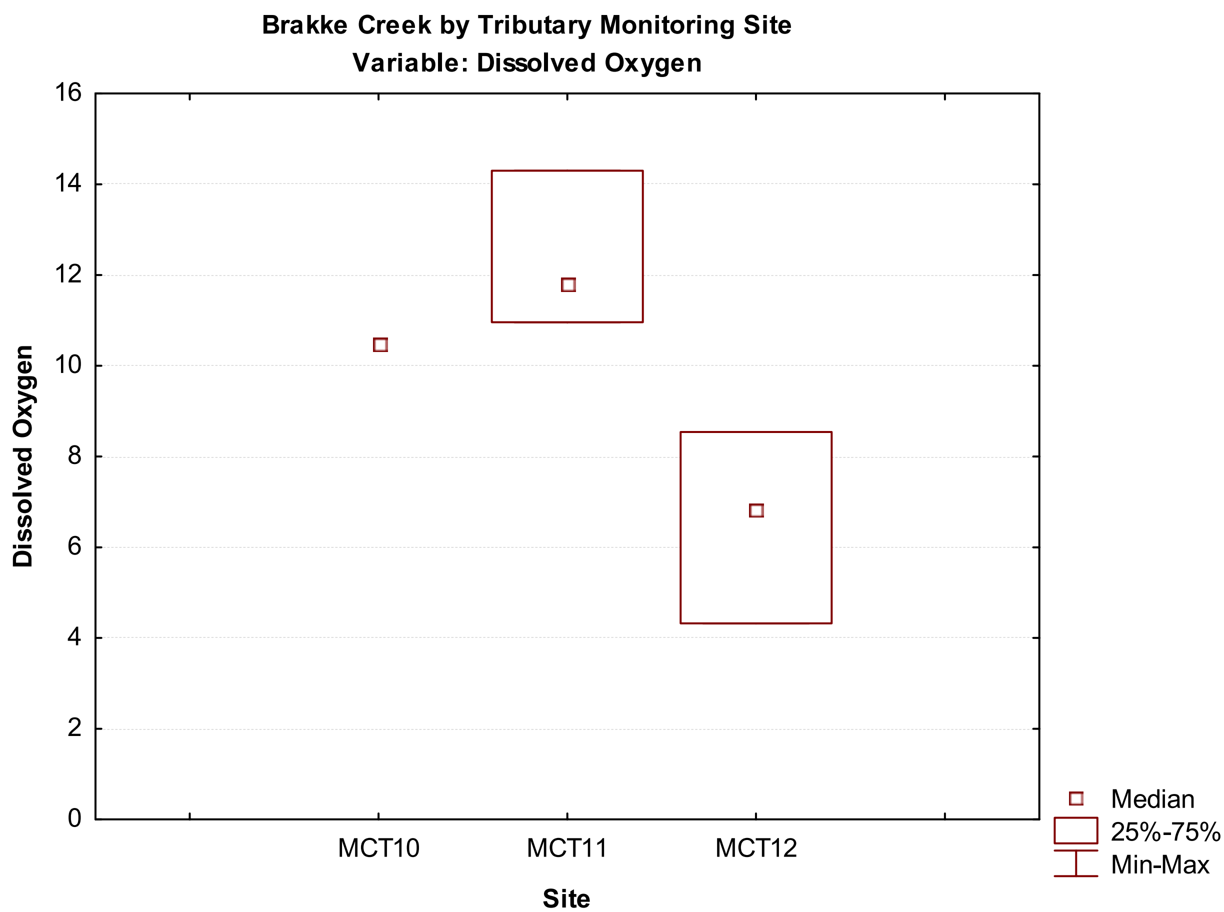


Figure 5. Median, quartile and range for dissolved oxygen concentrations by tributary monitoring site for Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

Table 9 shows seasonal tributary average dissolved oxygen concentrations by tributary monitoring site for tributary monitoring sites during the project. Seasonal average oxygen levels were lowest (averaged 5.6 mg/L) at MCT-12 (Brakke Creek, east tributary) and were the highest at MCT-11(Brakke Creek, west tributary) in the spring of 2001. The significantly lower dissolved oxygen at MCT-12 was attributed to significantly lower tributary flow which was 6.9 percent of the total spring flow into Brakke Dam (Table 10).

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 the Brakke Creek were not extreme in any tributary sample. The relatively high alkalinity concentrations in the unnamed tributary work to buffer dramatic pH changes. Lower pH values are normally observed during increased decomposition of organic matter.

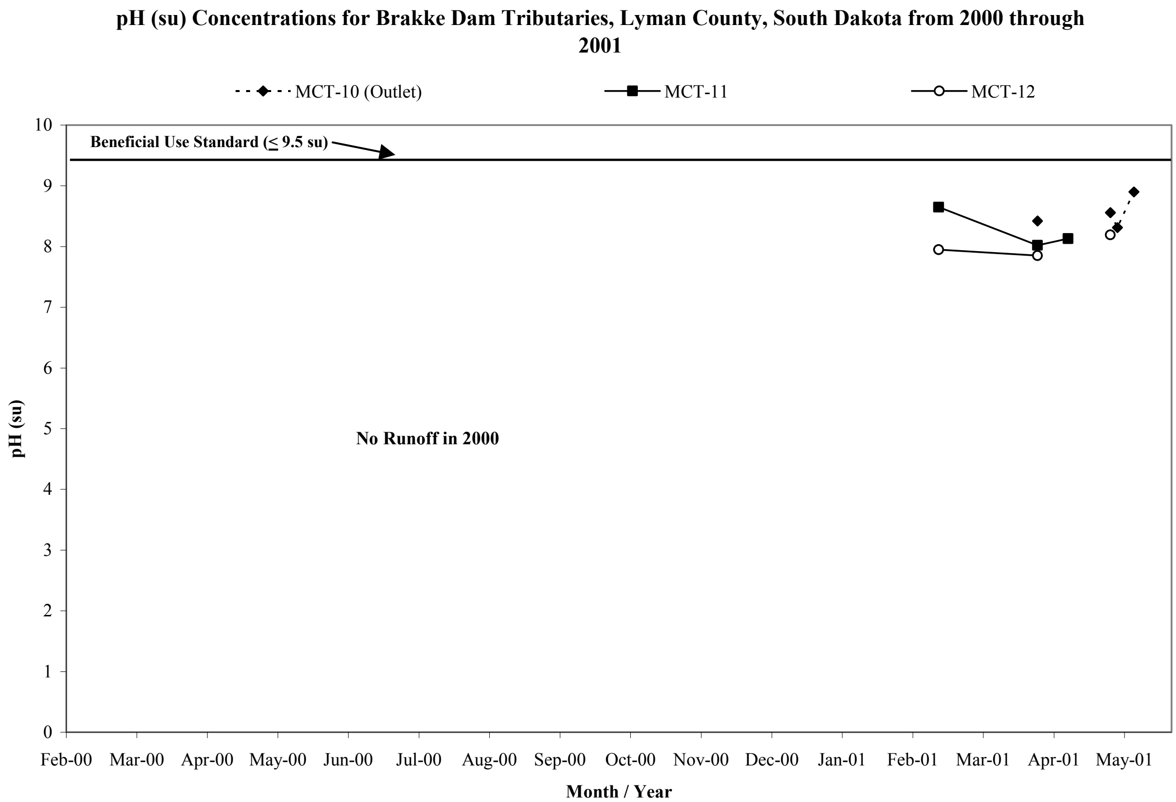


Figure 6. Monthly pH values for Brakke Dam tributaries, Lyman County, South Dakota from 2000 through 2001.

The pH concentrations in the Brakke Creek had a maximum pH of 8.90 su and a minimum pH of 7.85 su (Figure 6). Table 9 lists seasonal maximum pH concentrations by tributary sampling site. The highest concentrations were in the spring of 2001 at MCT-10 (Brakke Dam outlet).

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). Specific conductivity is conductivity adjusted to temperature (25º C) and is reported in micro-Siemens/centimeter ($\mu S/cm^{-1}$).

Specific conductivity values in Brakke Dam tributary monitoring sites (MCT-10, MCT-11 and MCT-12) were below the beneficial use standard for conductivity (Figure 7). Medicine Creek is listed in the 2002 South Dakota Total Maximum Daily Load Waterbody List (303(d) List) as impaired for conductivity and Total Dissolved Solids (TDS). Current data indicate that Brakke Creek (a tributary of Medicine Creek) appears not to contribute increased TDS concentrations and conductivity values to Medicine Creek.

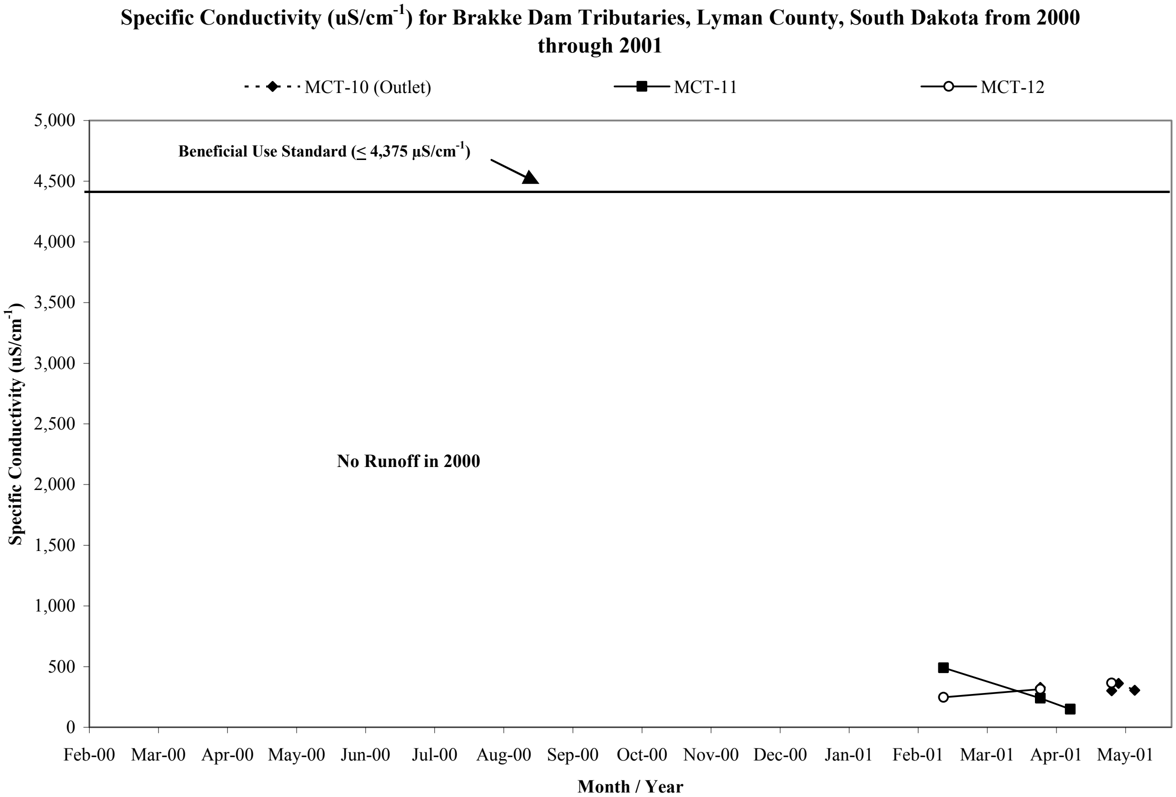


Figure 7. Monthly specific conductivity values for Brakke Dam tributaries, Lyman County, South Dakota from 2000 through 2001.

Total Alkalinity

Alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7 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 11. Estimated total alkalinity loading per year by site as modeled by FLUX for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	7,481	91.4	**100,018**	**13.4**
Total Gauged Load to Brakke Dam	**MCT-12**	3,264	8.6	**17,665**	**5.41**
Total Loading to Brakke Dam		10,745	100.0	**117,683**	**10.9**
Total Gauged Load to Medicine Creek	**MCT-10**	11,288	100.0	**105,524**	**9.3**
Brakke Dam Reduction Coefficient*	**1.12**				

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

The average alkalinity in Brakke Creek entering Brakke Dam was 89.2 mg/L, while the outlet of Brakke Dam averaged 119 mg/L reentering Brakke Creek. The minimum alkalinity concentration was 11 mg/L and was collected at site MCT-11 on March 13, 2001 (Appendix C). The maximum alkalinity sample was 183 mg/L collected at site MCT-12 on May 13, 2001. Seasonally, Brakke Creek average alkalinity concentrations were higher in the spring for MCT-12 (Table 9); MCT-10 (Brakke Dam outlet) only flowed in the spring of 2001. Alkalinity concentrations were not significantly different between tributary monitoring sites (Table 4).

Total alkalinity loading to Brakke Dam by site was highest at site MCT-11 with 100,018 kg/year or approximately 84.9 percent of the total alkalinity load from 91.4 percent of the flow (Figure 8 and Table 11). As with concentration data, alkalinity loading between monitoring sites were not significantly different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-11 (13.4 kg/acre) sub-watershed (Table 11).

MCT-10 (Brakke Dam outlet to Brakke Creek) reduced/modified Brakke Creek alkalinity loading to Medicine Creek (reduction coefficient) by approximately 1.12 times or 12,159 kg.

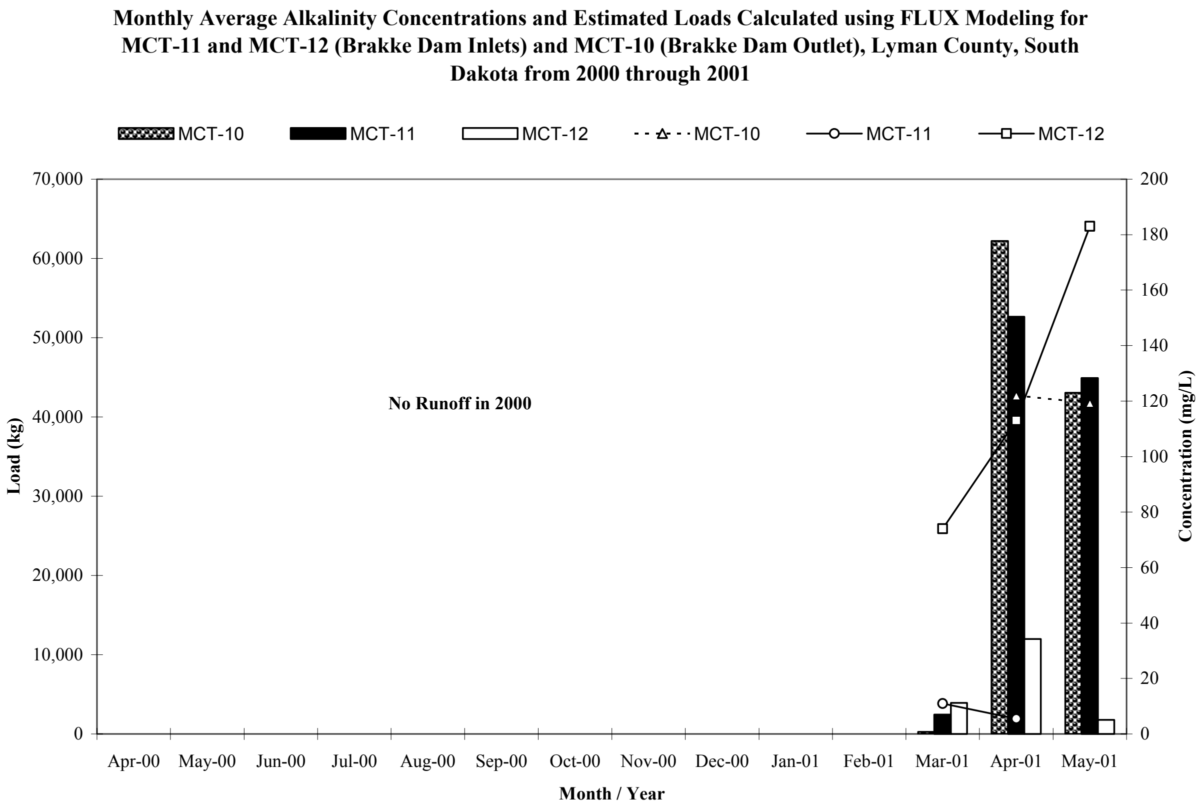


Figure 8. Monthly average total alkalinity concentrations and estimated loads by tributary to Brakke Dam and Medicine Creek from Brakke tributaries and Brakke outlet, Lyman County, South Dakota in 2000 and 2001.

Solids

Total solids are 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. 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 total solids concentrations in Brakke Creek had a median of 254 mg/L (mean 245 mg/L) with a maximum of 401 mg/L and a minimum of 63 mg/L. Total dissolved solids concentrations had a median of 216 mg/L (mean 202 mg/L) with a maximum of 303 mg/L and a minimum concentration of 56 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. Seasonal averages for total and dissolved solids concentrations were highest in the spring at MCT-12 (Table 9).

Total solids concentrations in Brakke Creek were not statistically different between tributary monitoring sites; however, total dissolved solids were significantly lower at MCT-11 (west tributary) than MCT-10 and MCT-12 (Table 4 and Figure 11). This maybe attributed to the hydrologic loading at MCT-11 which received significantly more water (91.4 percent of the total hydrologic load (Table 10)) diluting total dissolved solids concentrations.

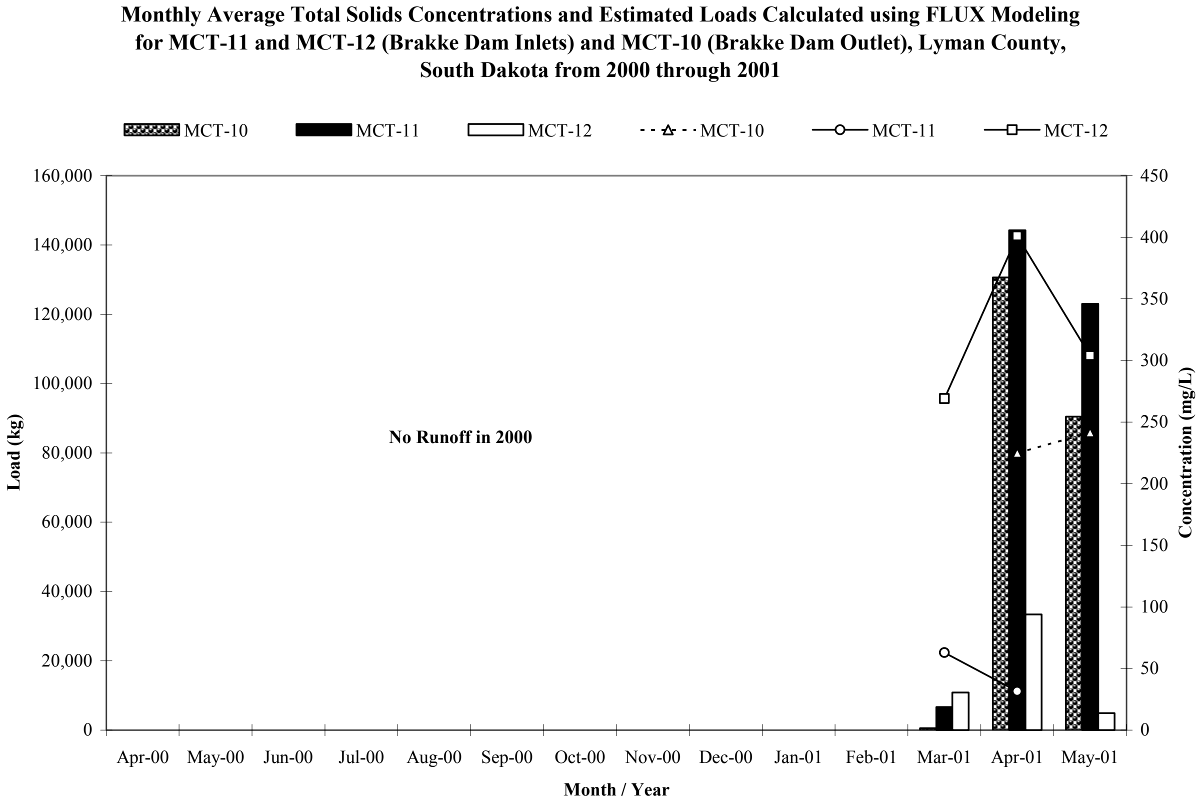


Figure 9. Monthly average total solids concentrations and estimated loads as modeled by FLUX to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 and 2001.

Table 12. Estimated total solids loading per year by site as modeled by FLUX for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	7,481	91.4	**273,988**	**36.6**
Total Gauged Load to Brakke Dam	**MCT-12**	3,264	8.6	**49,163**	**15.1**
Total Loading to Brakke Dam		10,745	100.0	**323,151**	**30.1**
Total Gauged Load to Medicine Creek	**MCT-10**	11,288	100.0	**221,706**	**19.6**
Brakke Dam Reduction Coefficient*	**1.46**				

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

Because of the volume percentage of water at MCT-11 (91.4 percent), the total solids loading by site was also highest at site MCT-11 with 273,988 kg/year (Table 12). Total dissolved solids loadings were also the highest at site MCT-11 with 202,450 kg/year (Table 13). Sub-watershed export coefficients (kilograms/acre) were also highest in the MCT-11 sub-watershed for total solids (36.6 kg/acre) and 27.1 kg/acre for total dissolved solids. Total solids and total dissolved solids loading were not significantly different between tributary monitoring sites (Table 4). The highest loading of both total and dissolved solids to Brakke Dam (MCT-11 and MCT-12) occurred in April 2001 (Figure 9 and Figure 10).

Table 13. Estimated total dissolved solids loading per year by site as modeled by FLUX for Brakke Creek from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**202,450**	**27.1**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**38,045**	**11.7**
Total Loading to Brakke Dam		**10,745**	100.0	**240,495**	**22.4**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**197,950**	**17.5**
Brakke Dam Reduction Coefficient*	**1.21**				

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

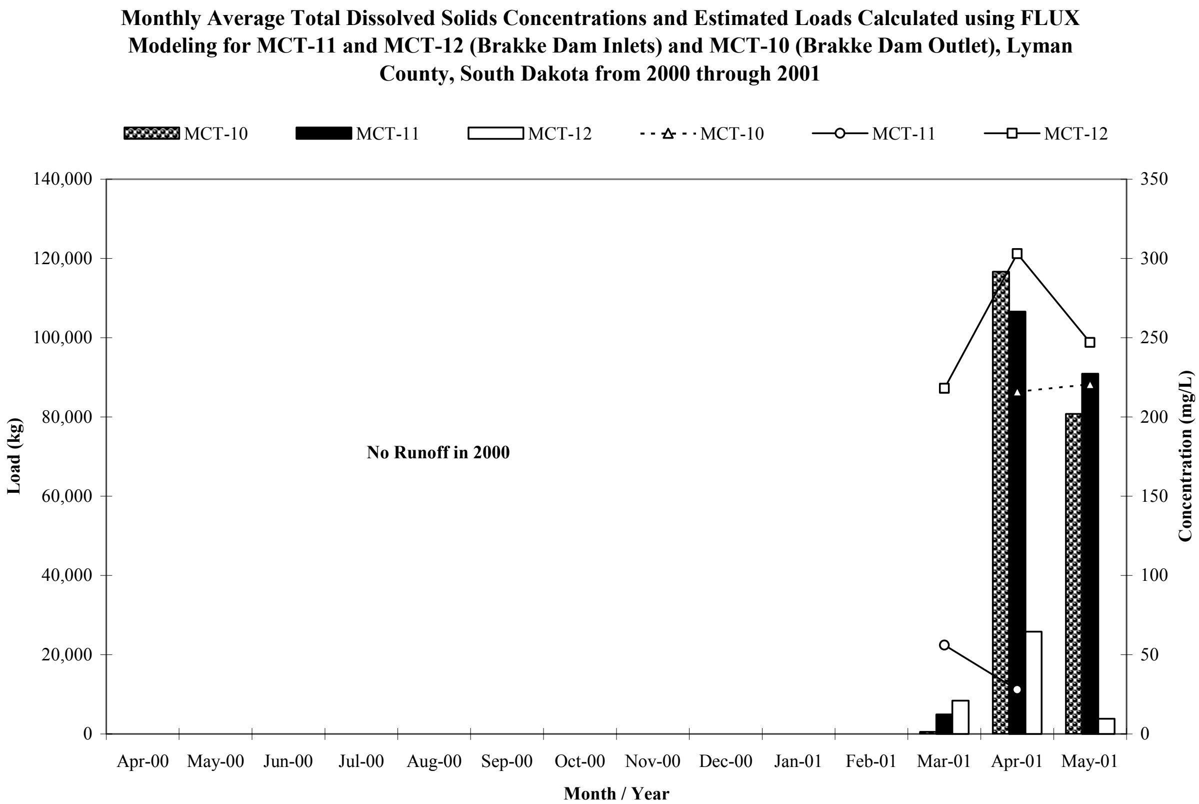


Figure 10. Monthly average total dissolved solids concentrations and estimated loads by tributary to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

Brakke Dam reduces/modifies Brakke Creek total solids loading to Medicine Creek (reduction coefficient) by approximately 1.46 times or 101,445 kg and total dissolved solids loading was reduced/modified by approximately 1.21 times or 42,545 kg (Table 12 and Table 13).

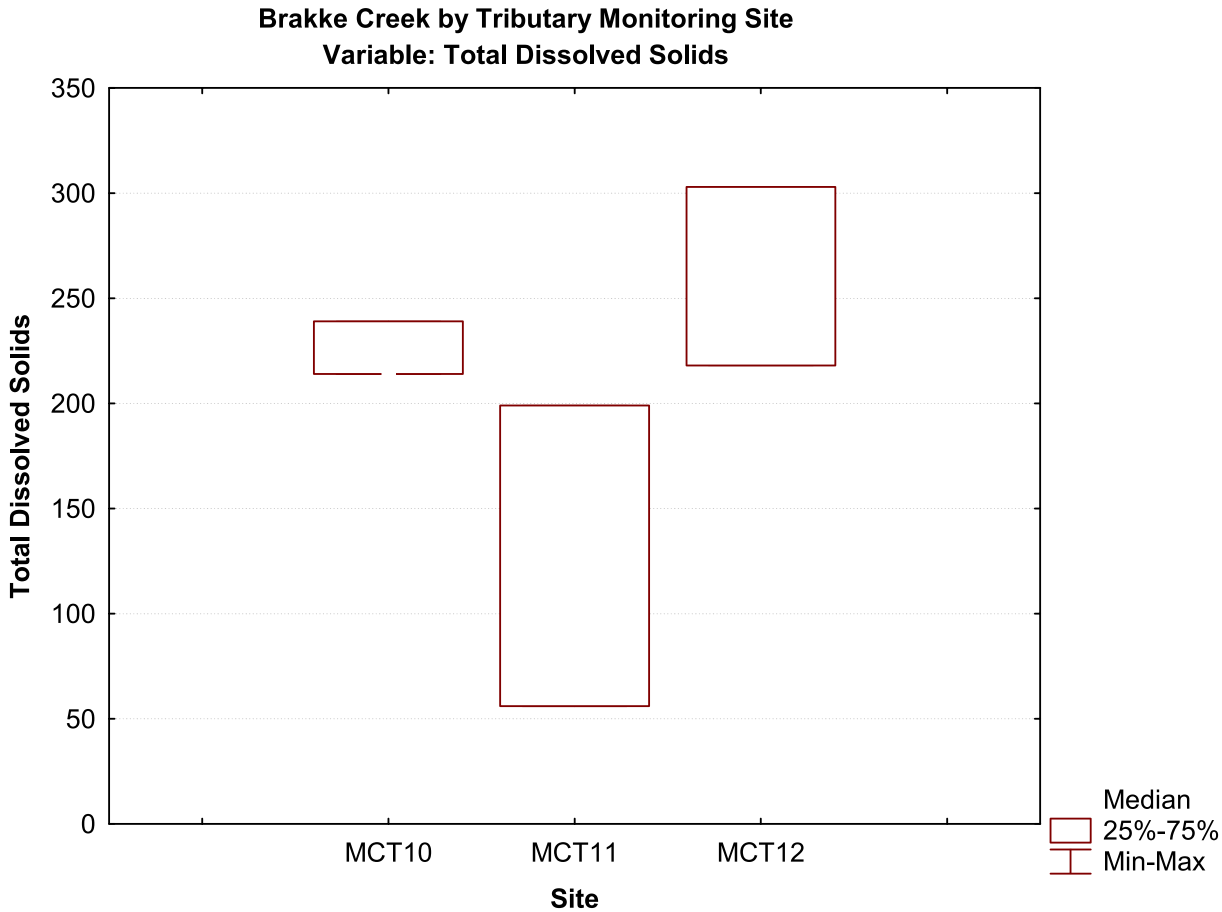


Figure 11. Median, quartile and range for total dissolved solids concentrations by tributary monitoring site for Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

The total suspended solids concentrations in Brakke Creek had a median of 29 mg/L (mean 42 mg/L) with a maximum of 102 mg/L and a minimum of 7.0 mg/L. Volatile total suspended solids concentrations had a median of 3 mg/L (mean 3 mg/L) with a maximum of 12 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 solids concentrations peaked in March for MCT-11, April for MCT-12 and May for MCT-10. Volatile total suspended solids concentrations peaked in March at MCT-11 and April for MCT-10 and MCT-12 (Figure 12 and Figure 13). Table 9 indicates that seasonal averages for total suspended solids and volatile total suspended solids had higher concentrations at MCT-12 in the spring of 2001 (78 mg/L and 8 mg/L, respectively).

Table 14. Estimated total suspended solids loading per year by site, as modeled by FLUX, for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**71,538**	**9.6**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**11,118**	**3.4**
Total Loading to Brakke Dam		**10,745**	100.0	**82,656**	**7.7**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**22,938**	**2.0**
Brakke Dam Reduction Coefficient*	**3.60**				

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

As with total solids and total dissolved solids, the volume percentage of water at MCT-11 (91.4 percent) was attributed to increased total suspended solids and volatile total suspended solids loading in Brakke Creek at MCT-11.

Total suspended solids loading by site was highest at site MCT-11 with 71,538 kg/year (Table 14). Volatile total suspended solids loadings were also the highest at site MCT-11 with 4,546 kg/year (Table 15). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-11 sub-watershed (9.6 kg/acre) for total suspended solids and 0.6 kg/acre at MCT-11 for volatile total suspended solids (Table 14 and Table 15). Total suspended and volatile total suspended solids loads were not significantly different between tributary monitoring sites (Table 4). The highest loading of both total suspended solids and volatile total suspended solids to Brakke Dam was from MCT-11 and occurred in April 2001 (Figure 12 and Figure 13).

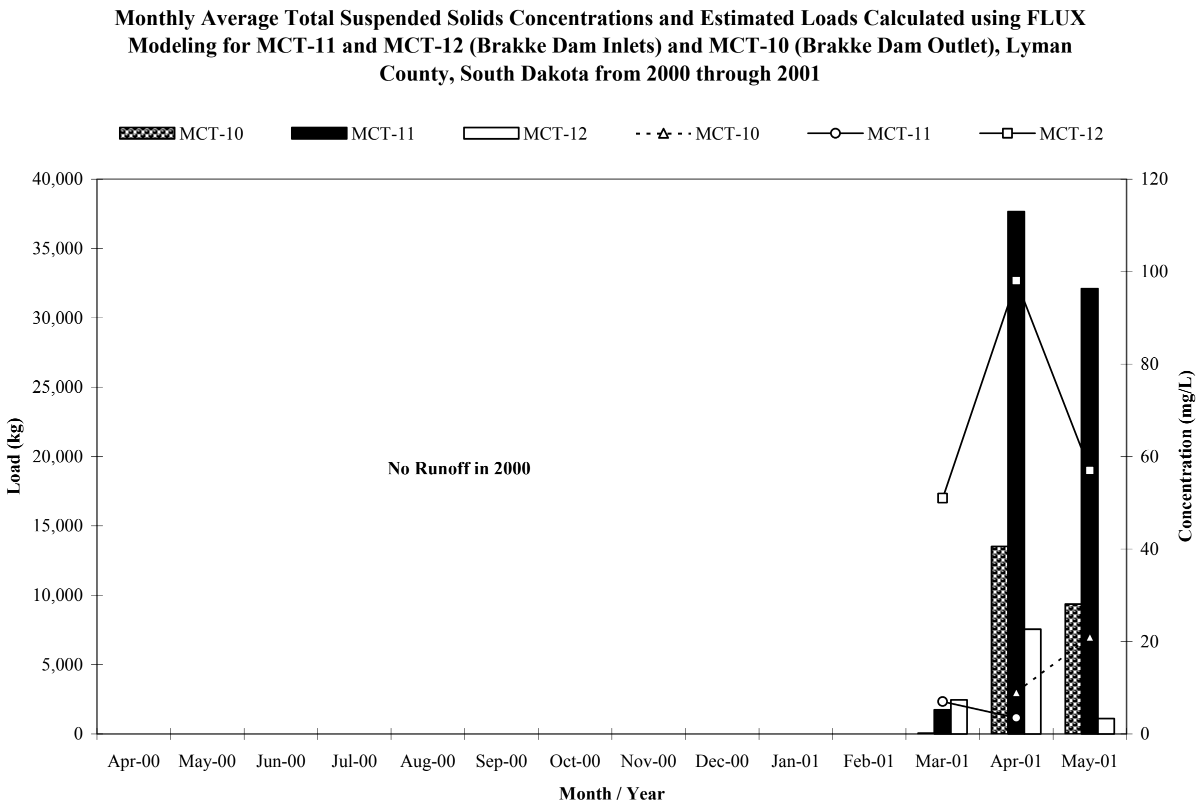


Figure 12. Monthly average total suspended solids concentrations and estimated loads by tributary to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

Brakke Dam dramatically reduced/modifies total suspended solids loading to Medicine Creek (reduction coefficient) by approximately 3.60 times or 59,718 kg and reduced/modifies volatile total suspended solids loading to Medicine Creek by approximately 3.25 times or 3,961 kg (Table 14 and Table 15).

Table 15. Estimated volatile total suspended solids loading per year by site, as modeled by FLUX, for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**4,546**	**0.6**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**1,172**	**0.4**
Total Loading to Brakke Dam		**10,745**	100.0	**5,718**	**0.5**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**1,757**	**0.2**
Brakke Dam Reduction Coefficient*	**3.25**				

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

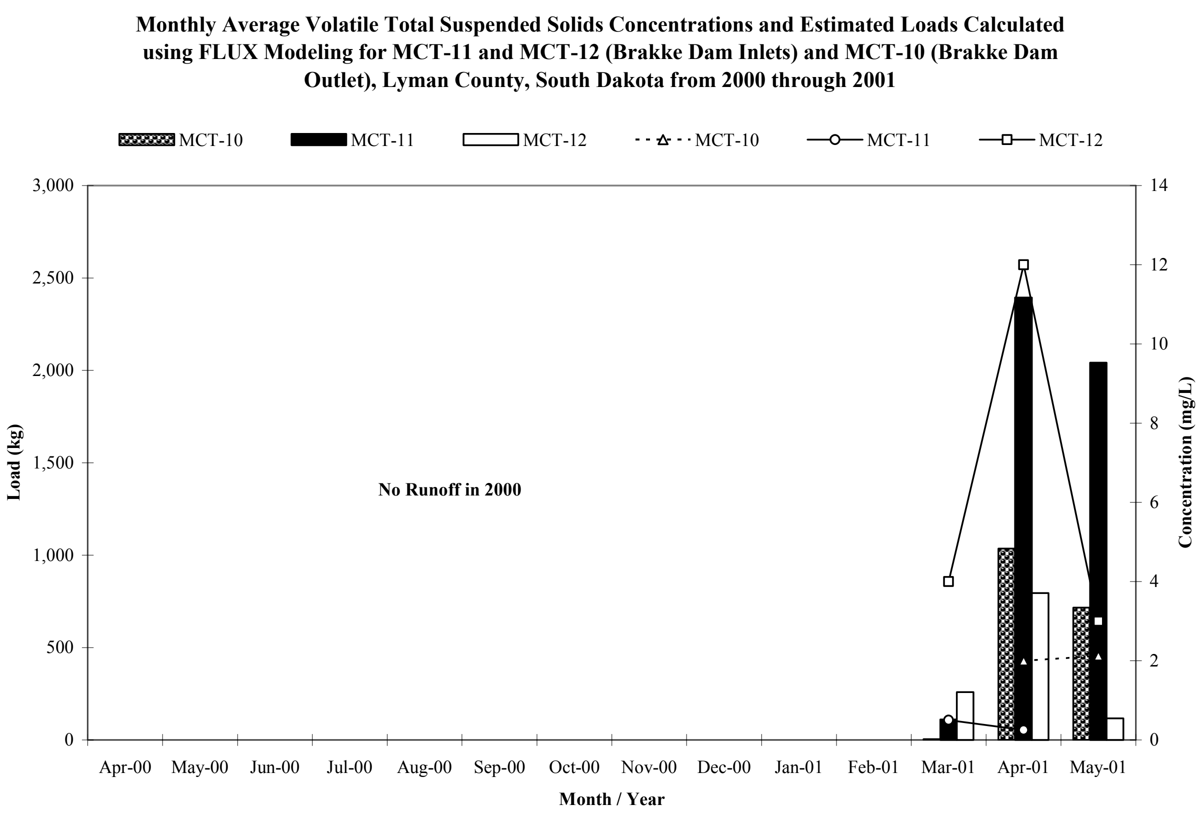


Figure 13. Monthly average volatile total suspended solids concentrations and estimated loads by tributary to Brakke Dam and Medicine Creek from , Lyman County, South Dakota from 2000 through 2001.

Decreasing sediment (erosion) inputs from Brakke 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 Brakke 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 Brakke Dam.

Sub-watersheds that should be targeted for sediment (erosion) mitigation, based on delivered loads from Brakke Creek, are presented in priority ranking in Table 16:

Table 16. Brakke Creek watershed mitigation priority sub-watersheds for sediment (total suspended solids), based on the 2000 through 2001 watershed assessment.

Priority Ranking	Sub-watershed	Total Suspended Solids Export Coefficient (kg/acre)	Total Suspended Solids Kilograms Delivered
1	MCT-11	9.6	71,538
2	MCT-12	3.4	11,118

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 waste, decaying organic matter or bacterial conversion of other nitrogen compounds.

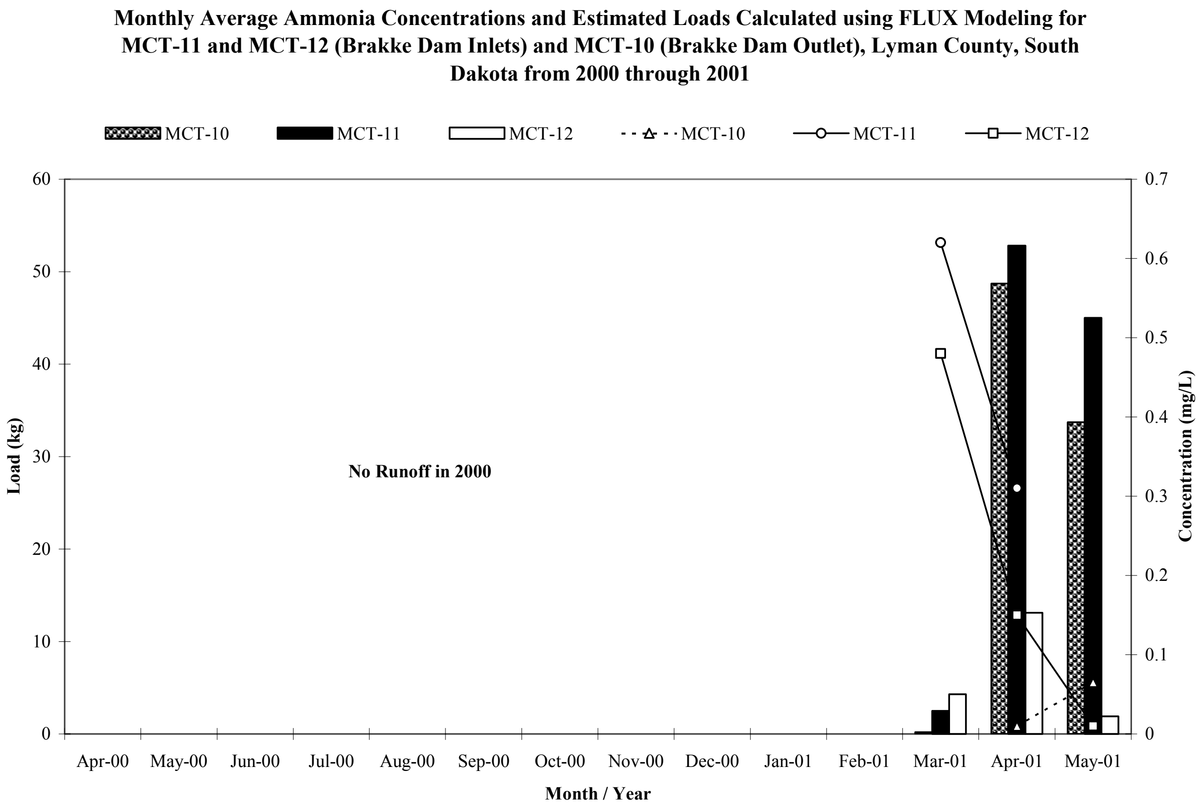


Figure 14. Monthly average ammonia concentrations and estimated loads to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

The median ammonia concentration in Brakke Creek tributaries was 0.06 mg/L with a mean of 0.16 mg/L. The standard deviation was 0.22 mg/L which indicates a large variation in sample concentrations. Ammonia concentrations were high in March, declined in April and again in May for MCT-11 and MCT-12 (Brakke Dam inlet) and increased from April to May at Brakke Dam outlet MCT-10 (Figure 14). Ammonia concentrations between sampling sites were not significantly different (Table 4). Seasonally the highest concentrations of ammonia occurred in the winter of 2001 at MCT-11 west tributary (0.62 mg/L). Average spring concentrations at both sampling sites were above laboratory detection limits (Table 9).

Table 17. Ammonia loading per year by site for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**100**	**0.013**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**19**	**0.006**
Total Loading to Brakke Dam		**10,745**	100.0	**119**	**0.011**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**83**	**0.007**
Brakke Dam Reduction Coefficient*	**1.43**				

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

Ammonia loading by sampling site and sub-watershed export coefficients (kilograms/acre) were highest at site MCT-11, 100 kg/year and 0.013 kg/acre, respectively (Table 17). Ammonia loading between sampling sites was not significantly different (Table 4). Like most parameters, peak ammonia loading occurred in April 2001 at MCT-11 (Figure 14).

Brakke Dam reduced/modified Brakke Creek ammonia loading to Medicine Creek (reduction coefficient) by approximately 1.43 times or 36 kg (Table 17).

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.

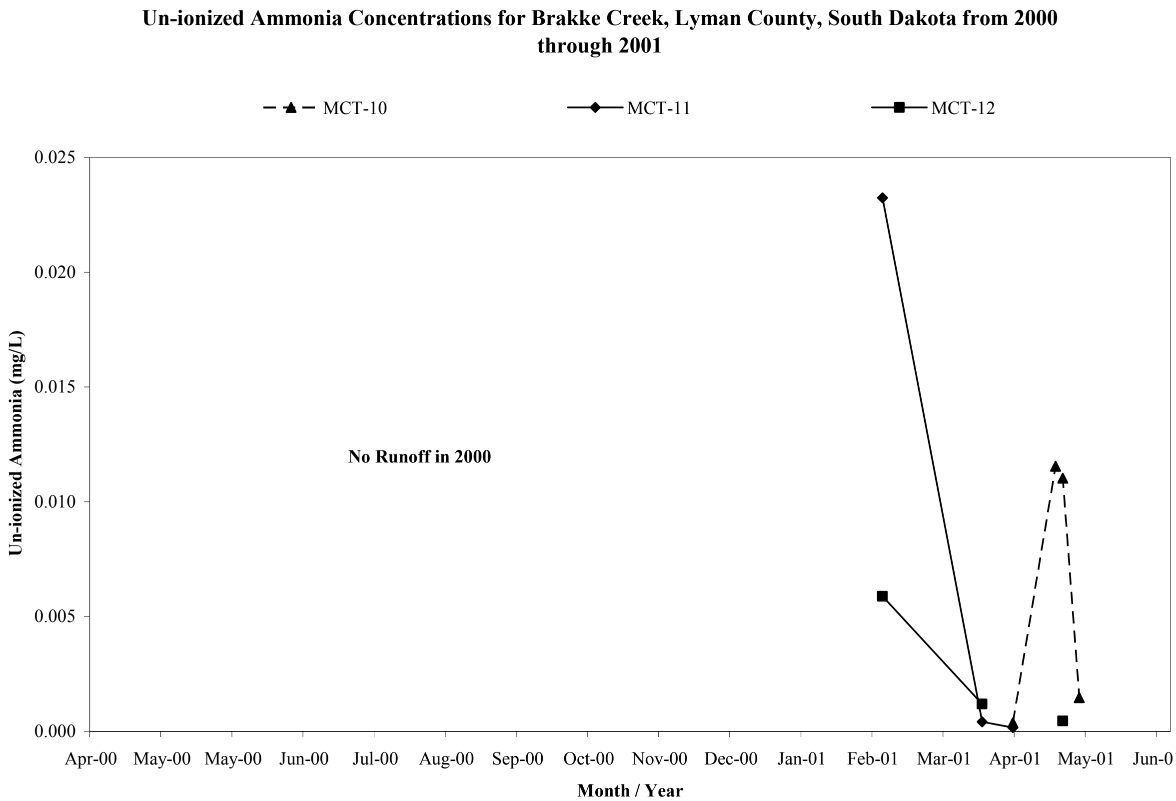


Figure 15. Un-ionized ammonia concentrations to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

No violations in un-ionized ammonia were observed in Brakke Creek during this study. The median un-ionized ammonia concentration for Brakke Creek was 0.00133mg/L (mean, 0.00610). The maximum concentration was 0.02324 mg/L and the minimum concentration was 0.00017 mg/L. Un-ionized ammonia concentrations peaked on March 13, 2001 at MCT-11 west tributary of Brakke Creek (Figure 15 and Appendix C).

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.

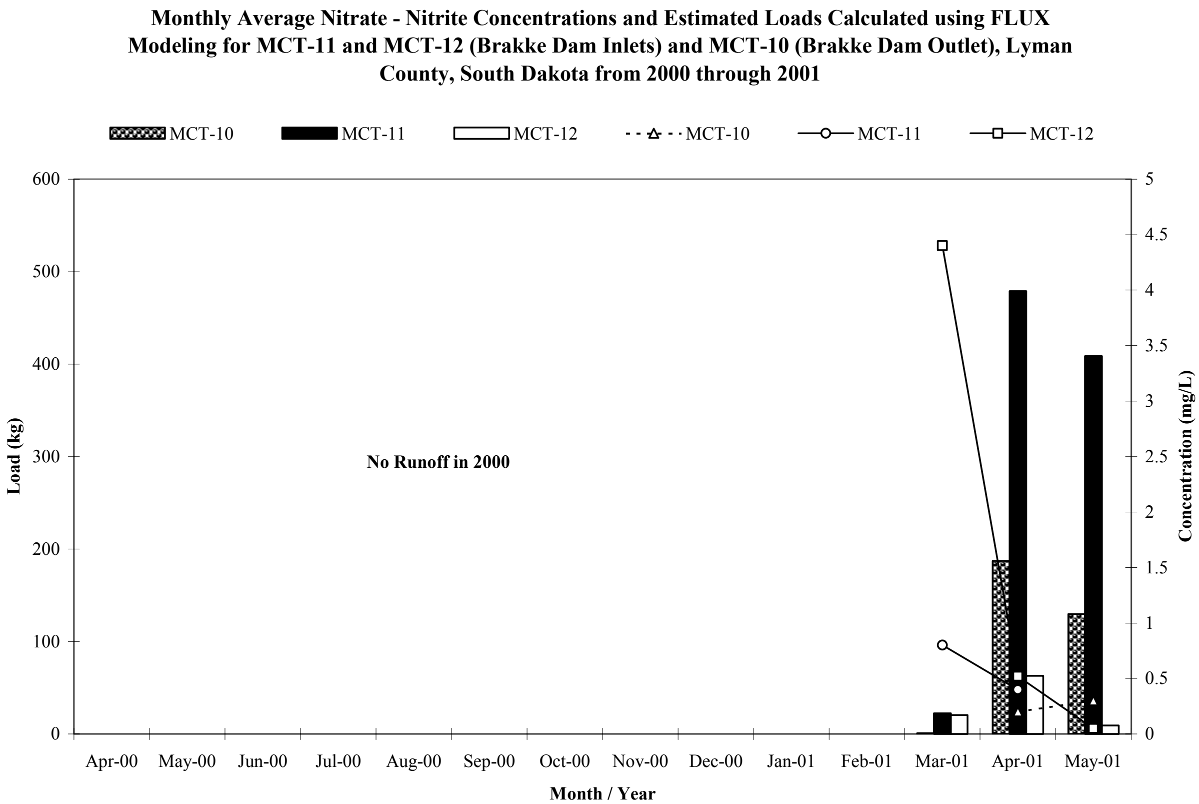


Figure 16. Monthly average nitrate-nitrite concentrations and estimated loads to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

The median nitrate-nitrite concentration for Brakke Creek was 0.45 mg/L (mean, 0.83 mg/L) during the project. The maximum concentration of nitrate-nitrite was 4.40 mg/L on March 19, 2001 at MCT-12 east tributary and a minimum of 0.10 mg/L (laboratory detection limit) in one sample collected on May 13, 2001 at MCT-12 (Appendix C). Nitrate-nitrite concentrations between sampling sites were not significantly different (Table 4). Seasonally, average nitrate-nitrite concentrations were elevated in the winter of 2001 at 4.40 mg/L (Table 9).

Nitrate-nitrite loading by site was highest at site MCT-11 at 910 kg (Table 18). Nitrate-nitrite loading between sampling sites was not significantly different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-11 sub-watershed at 0.12 kg/acre.

Brakke Dam reduced/modified Brakke Creek nitrate-nitrite loading to Medicine Creek (reduction coefficient) by approximately 3.15 times or 685 kg (Table 18).

Soils in the Medicine Creek watershed, of which the Brakke 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 (Kuck et al., 2004).

Current data indicated no elevated nitrate-nitrite concentrations in the Brakke Dam watershed, suggesting the Brakke Dam portion of the Medicine Creek watershed does not contribute elevated nitrate-nitrite concentrations to Medicine Creek.

Table 18. Nitrate-nitrite loading per year by site for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**910**	**0.12**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**93**	**0.03**
Total Loading to Brakke Dam		**10,745**	100.0	**1,003**	**0.09**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**318**	**0.03**
Brakke Dam Reduction Coefficient*	**3.15**				

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

Total Kjeldahl Nitrogen

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

The median TKN concentration in Brakke Creek was 0.85mg/L (mean, 1.16 mg/L) with a maximum concentration of 2.17 mg/L and a minimum of 0.37 mg/L. Total Kjeldahl Nitrogen concentrations between sampling sites were not significantly different (Table 4). Seasonal TKN concentrations were highest in west tributary of Brakke Creek (MCT-11) during the winter of 2001 (Table 9).

Table 19. Total Kjeldahl Nitrogen loading per year by site for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**959**	**0.13**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**256**	**0.08**
Total Loading to Brakke Dam		**10,745**	100.0	**1,215**	**0.11**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**707**	**0.06**
Brakke Dam Reduction Coefficient*	**1.72**				

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

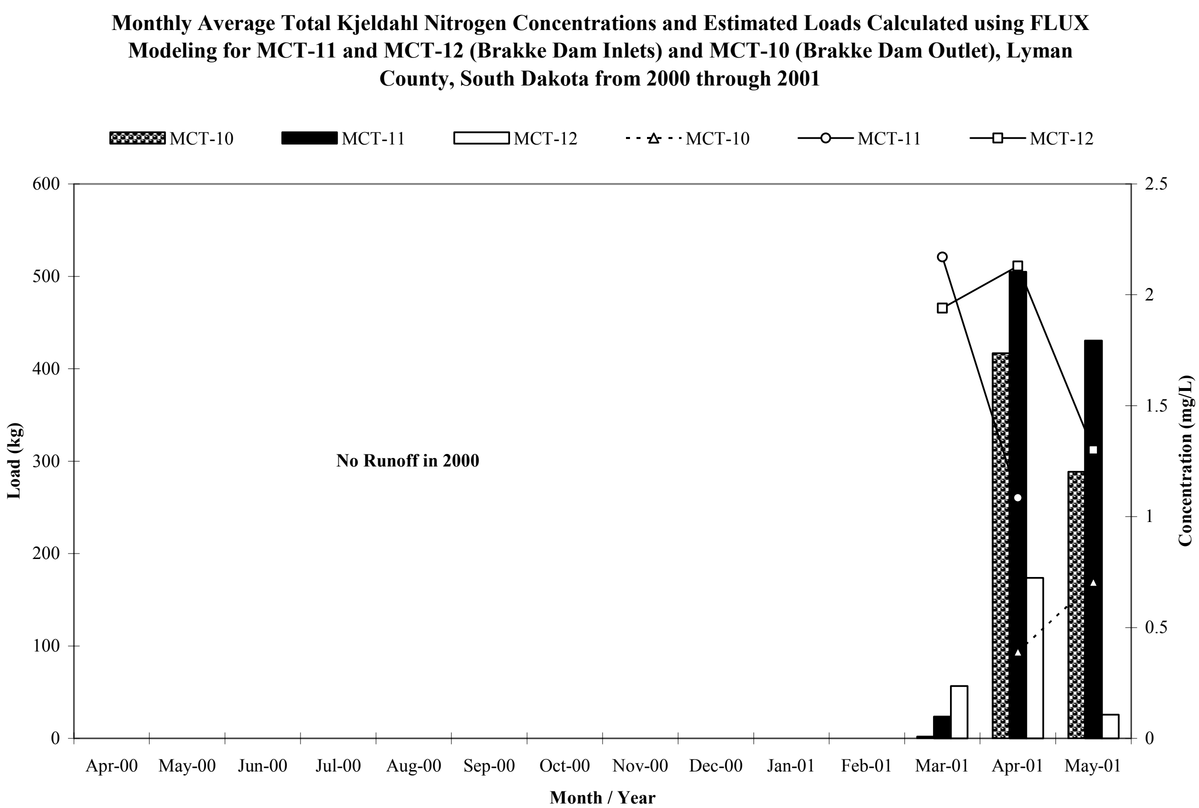


Figure 17. Monthly average Total Kjeldahl Nitrogen concentrations and estimated loads to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

TKN loading by site was highest at site MCT-11 at 959 kg (Table 19). TKN loading between sampling sites was not significantly different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-11 sub-watershed at 0.13 kg/acre.

Brakke Dam dramatically reduced/modified Total Kjeldahl Nitrogen loading to Medicine Creek (reduction coefficient) by approximately 1.72 times or 508 kg (Table 19).

Organic Nitrogen

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

The median organic nitrogen concentrations in Brakke Creek was 0.78 mg/L (mean, 0.97 mg/L) with a maximum of 1.98 mg/L and a minimum concentration of 0.21 mg/L. Since organic nitrogen is calculated from TKN, Figure 17 and Figure 18 are similar. Organic nitrogen concentrations between sampling sites was not significantly different (Table 4). Seasonal averages for organic nitrogen concentrations were highest in the spring at MCT-12 (Table 9).

Table 20. Organic nitrogen loading per year by site for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**859**	**0.11**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**236**	**0.07**
Total Loading to Brakke Dam		**10,745**	100.0	**1,095**	**0.10**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**557**	**0.05**
Brakke Dam Reduction Coefficient*	**1.97**				

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

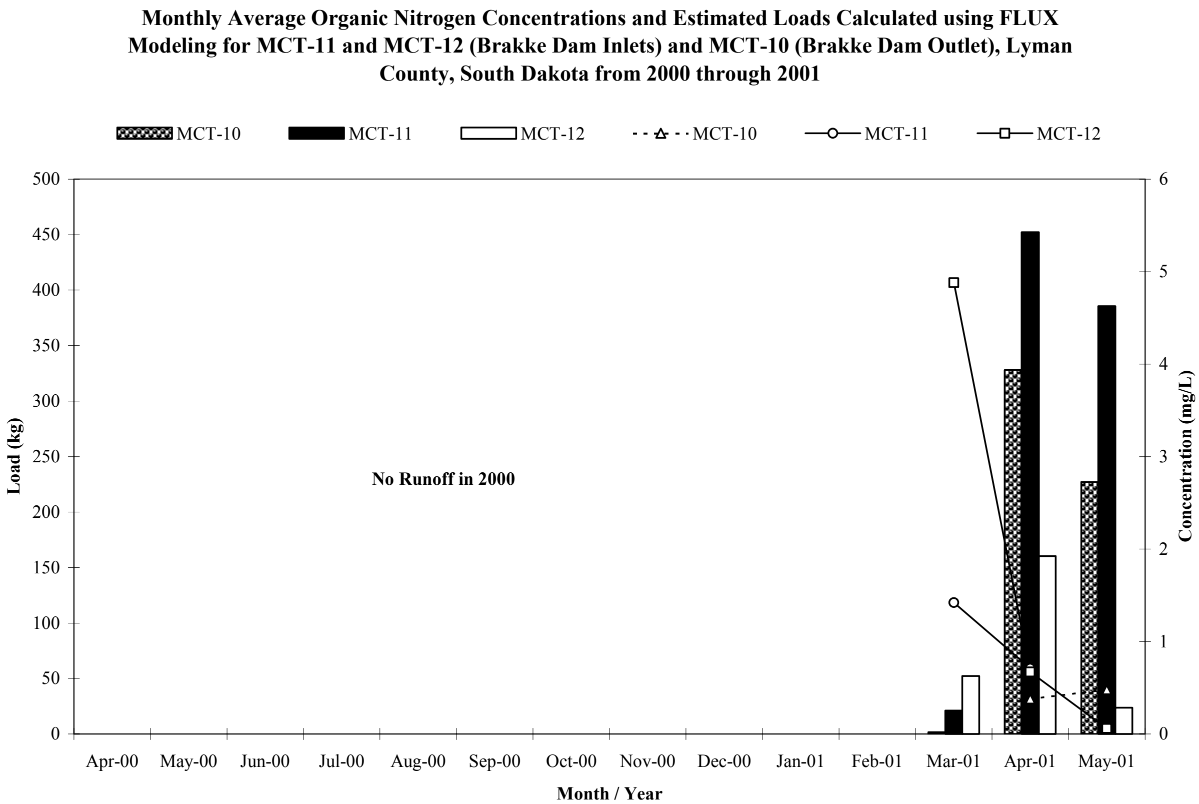


Figure 18. Monthly average organic nitrogen concentrations and estimated loads to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

Organic nitrogen loading by site was highest at site MCT-11 at 859 kg (Table 20). Organic nitrogen loading between sampling sites was not significantly different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-11 sub-watershed at 0.11 kg/acre.

Brakke Dam reduced/modified Brakke Creek organic nitrogen loading to Medicine Creek (reduction coefficient) by approximately 1.97 times or 538 kg (Table 20).

Inorganic Nitrogen

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

The median inorganic nitrogen concentration in Brakke Creek was 0.67 mg/L (mean 1.11 mg/L) with a maximum of 4.88 mg/L and a minimum concentration of 0.06 mg/L. Inorganic nitrogen concentrations between sampling sites were not significantly different (Table 4). Seasonal averages for inorganic nitrogen concentrations were highest in the winter at MCT-12 (Table 9).

Table 21. Inorganic nitrogen loading per year by site for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**1,004**	**0.13**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**112**	**0.03**
Total Loading to Brakke Dam		**10,745**	100.0	**1,116**	**0.10**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**469**	**0.04**
Brakke Dam Reduction Coefficient*	**2.38**				

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

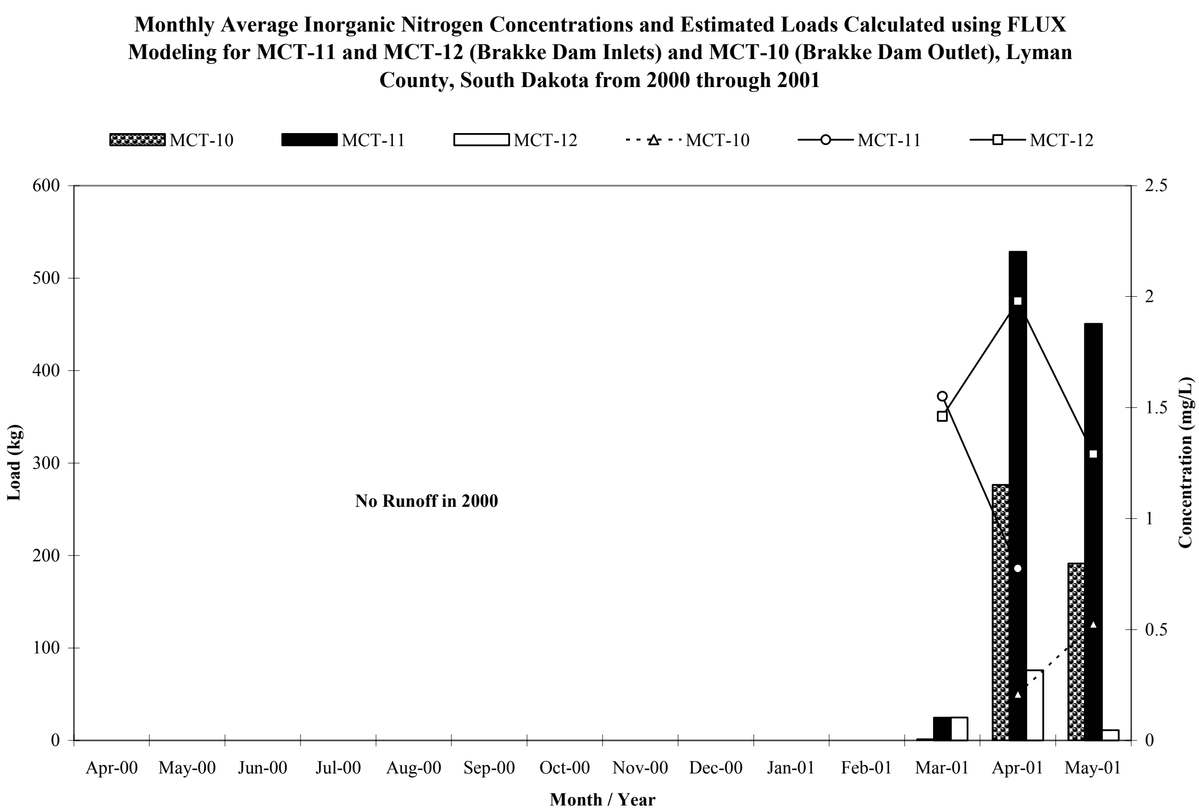


Figure 19. Monthly average inorganic nitrogen concentrations and estimated loads to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

Inorganic nitrogen loading by site was highest at site MCT-11 at 1,004 kg (Table 21) with the greatest monthly inorganic nitrogen loading occurring in April (Figure19).. Sub-watershed export coefficients (kilograms/acre) were also highest in the MCT-11 sub-watershed at 0.13 kg/acre. Organic nitrogen loading between sampling sites was not significantly different (Table 4).

Brakke Dam slightly reduced/modified Brakke Creek inorganic nitrogen loading to Medicine Creek (reduction coefficient) by approximately 2.38 times or 647 kg (Table 21).

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) for biological growth and will be discussed later in this section and in the lake section of this report. The maximum total nitrogen concentration found in Brakke Creek was 6.34 mg/L at MCT-12 on March 19, 2001 (Appendix C). The median concentration for the entire project was 1.35 mg/L (mean 2.08 mg/L) and the standard deviation for total nitrogen was 1.78 mg/L. Total nitrogen concentrations between sampling sites was not significantly different (Table 4). The organic nitrogen fraction (percent of organic nitrogen in total nitrogen (concentrations) ranged from 23.0 percent to 95.6 percent and averaged 48.0 percent, while the inorganic nitrogen fraction ranged from 4.4 percent to 77.0 percent and averaged 52.0 percent. Seasonally, average total nitrogen concentrations were higher in the winter at MCT-12 (Table 9).

Total nitrogen loading by site was highest at site MCT-11 at 1,862 kg (Table 22) with the greatest monthly total nitrogen loading occurring in April (Figure 20).. Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-11 sub-watershed at 0.25 kg/acre. Total nitrogen loading between sampling sites was not significantly different (Table 4).

Brakke Dam reduced/modified Brakke Creek total nitrogen loading to Medicine Creek (reduction coefficient) by approximately 2.16 times or 1,194kg (Table 22).

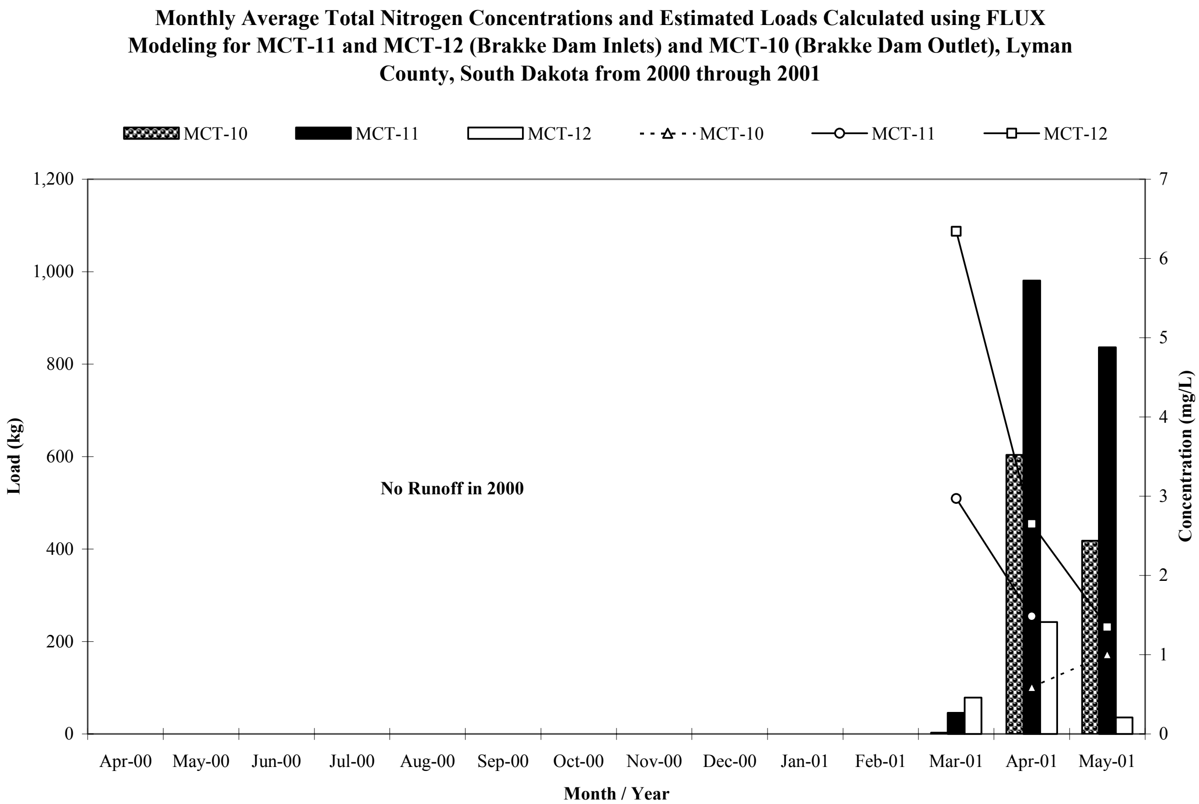


Figure 20. Monthly average total nitrogen concentrations and estimated loads to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

Table 22. Total nitrogen loading per year by site for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**1,862**	**0.25**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**357**	**0.11**
Total Loading to Brakke Dam		**10,745**	100.0	**2,219**	**0.21**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**1,025**	**0.09**
Brakke Dam Reduction Coefficient*	**2.16**				

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

Decreasing nitrogen inputs from Brakke Creek may improve (lower) in-lake TSI values. Reducing nitrogen (especially organic nitrogen) could decrease 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 Brakke Dam. A dramatic reduction in both nitrogen and phosphorus is needed to reduce algal growth in Brakke 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 Brakke 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 Brakke Dam, are presented by priority ranking in Table 23.

Table 23. Brakke Creek watershed mitigation priority sub-watersheds for total nitrogen based on 2000 through 2001 watershed assessment modeling.

Priority Ranking	Sub-watershed	Total Nitrogen Export Coefficient (kg/acre)	Total Nitrogen Kilograms Delivered
1	MCT-11	0.25	1,862
2	MCT-12	0.11	357

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 Brakke 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 Brakke 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 Brakke Creek.

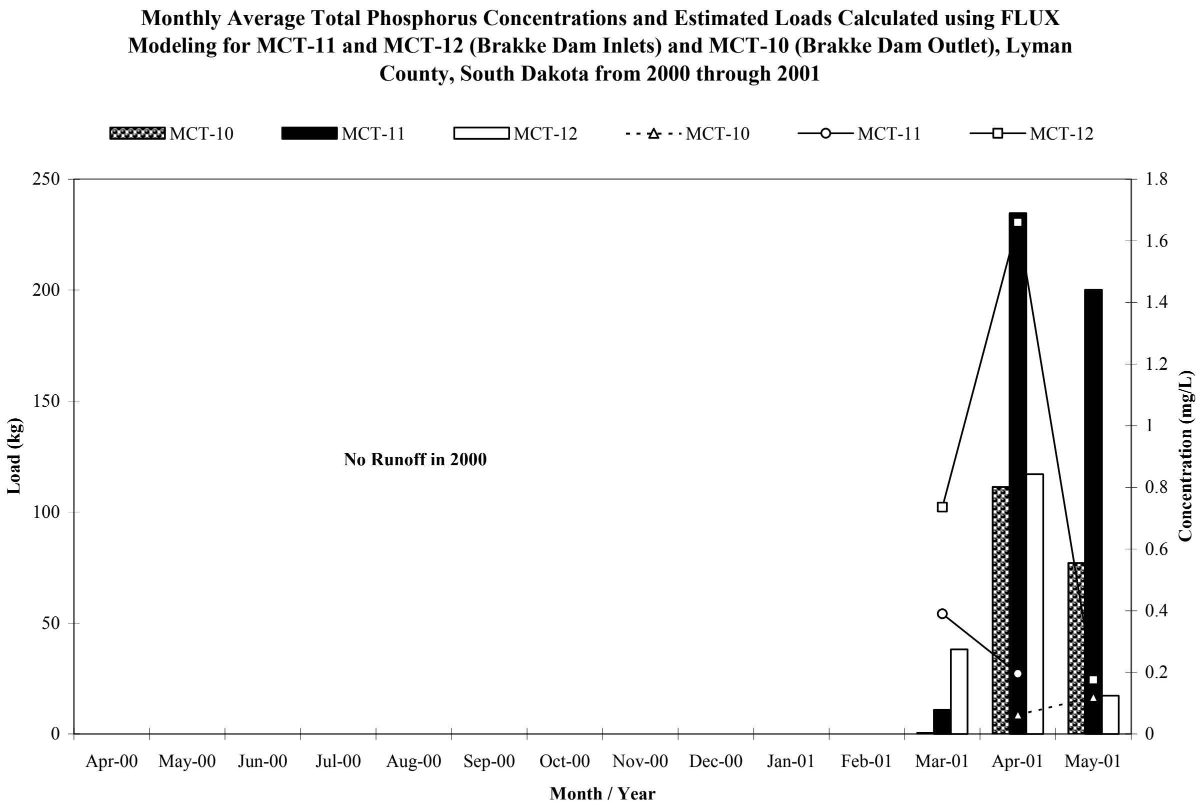


Figure 21. Monthly average total phosphorus concentrations and estimated loads to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

The median total phosphorus concentration for Brakke Creek was 0.235mg/L (mean, 0.441 mg/L) during this study. The maximum concentration of total phosphorus was 1.660 mg/L on April 25, 2001 at MCT-12 and a minimum of 0.062 mg/L at MCT-10 (Brakke Dam outlet) on April 10, 2000 (Appendix C). Total phosphorus concentrations between sampling sites were not significantly different (Table 4). Since algae/periphyton only need 0.02 mg/L of phosphorus to produce algal blooms in lakes (Wetzel, 2001), Brakke Creek average delivery concentration was 20.0 times the phosphorus needed to produce algal blooms in Brakke Dam. Seasonally, average total phosphorus concentrations were elevated in the spring of 2001 at 0.918 mg/L at site MCT-12 (Table 9). Total phosphorus concentrations between sampling sites was not significantly different (Table 4).

Table 24. Total phosphorus loading per year by site for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**446**	**0.06**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**172**	**0.05**
Total Loading to Brakke Dam		**10,745**	100.0	**618**	**0.06**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**189**	**0.02**
Brakke Dam Reduction Coefficient*	**3.27**				

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

Total phosphorus loading by site was highest at site MCT-11 with 446 kg/year (Table 24). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-11 sub-watershed (0.06 kg/acre). Total phosphorus loading between sampling sites were not significantly different (Table 4). Monthly total phosphorus loading was similar to most other parameter observations in Brakke Creek. The greatest monthly total phosphorus loading occurred in April (Figure 21).

Brakke Dam dramatically reduced/modified Brakke Creek total phosphorus loading to Medicine Creek (reduction coefficient) by approximately 3.27 times or 429 kg (Table 24). This reduction suggests that phosphorus (total and dissolved) was sorbed on to particles and settled out, delayed through phosphorus residence time in Brakke Dam (0.175 years or 63.9 days) or was utilized in biological processes for biomass production in Brakke Dam

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

Decreasing total phosphorus inputs from the Brakke Creek and could improve or 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 elevated TSI values observed in Brakke Dam.

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 Brakke Dam and are presented in Table 25.

Table 25. Brakke 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-11	0.06	446
2	MCT-12	0.05	172

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 Brakke Creek was 0.174 mg/L (mean, 0.331 mg/L). The maximum concentration of total dissolved phosphorus was 1.320 mg/L on April 25, 2001 at MCT-12 and a minimum of 0.015 mg/L at MCT-10 on April 10, 2001 (Appendix C). Total dissolved phosphorus concentrations between sampling sites was not significantly different (Table 4). During this study, the percentage of total dissolved phosphorus to total phosphorus ranged from 24.2 percent in the summer to 88.5 percent in spring and averaged 74.3 percent over the project. Seasonally, total dissolved phosphorus concentrations were elevated in the spring of 2001 with 0.711 mg/L at MCT-11 (Table 9).

Table 26. Total dissolved phosphorus loading per year by site for Brakke 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)
Total Gauged Load to Brakke Dam	**MCT-11**	**7,481**	91.4	**292**	**0.039**
Total Gauged Load to Brakke Dam	**MCT-12**	**3,264**	8.6	**136**	**0.041**
Total Loading to Brakke Dam		**10,745**	100.0	**428**	**0.040**
Total Gauged Load to Medicine Creek	**MCT-10**	**11,288**	100.0	**146**	**0.013**
Brakke Dam Reduction Coefficient*	**2.93**				

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

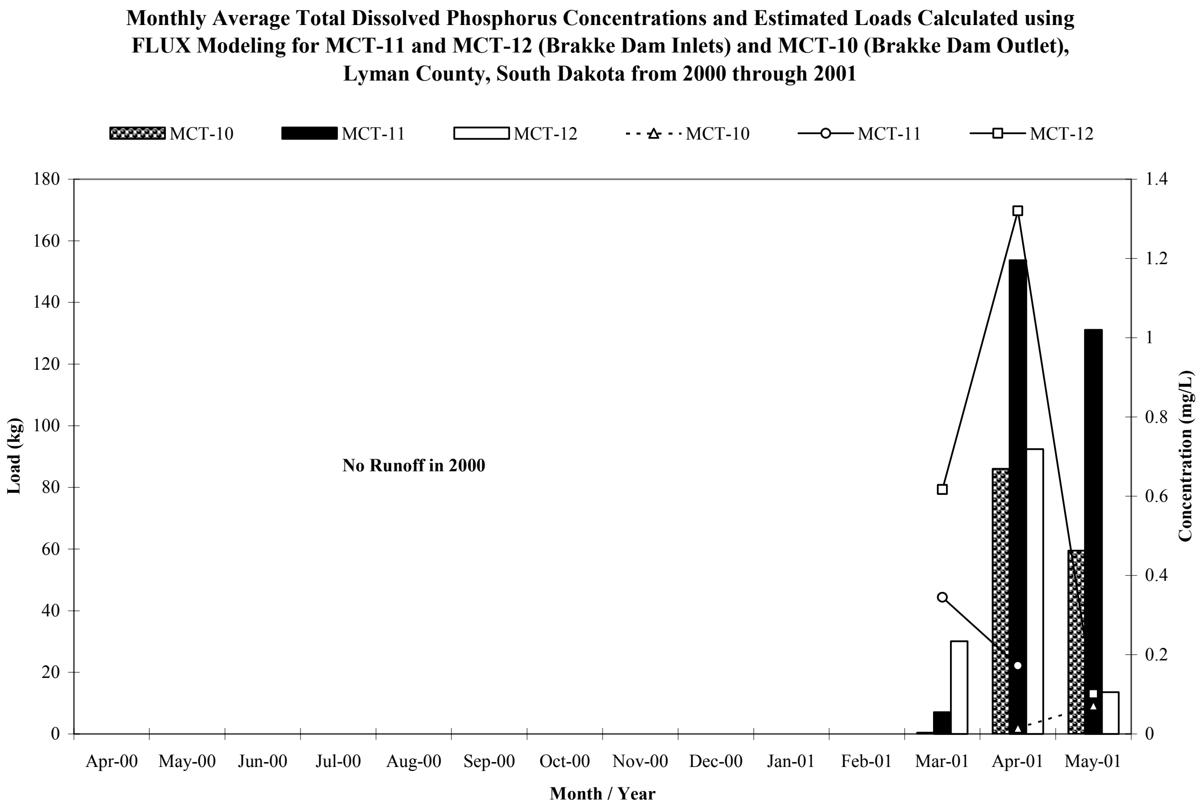


Figure 22. Monthly average total dissolved phosphorus concentrations and estimated loads to Brakke Dam and Medicine Creek from Brakke Creek, Lyman County, South Dakota from 2000 through 2001.

Total dissolved phosphorus loading by site was highest at site MCT-11 with 292 kg/year (Table 26). Sub-watershed export coefficients (kilograms/acre) were highest (0.041 kg/acre) at MCT-12 (Table 26). Total phosphorus loading between sampling sites was not significantly different (Table 4). Again, monthly total dissolved phosphorus loading was similar to most other parameter observations in Brakke Creek, with the greatest monthly total phosphorus loading occurring in April 2001 (Figure 22).

Brakke Dam dramatically reduced/modified Brakke Creek total dissolved phosphorus loading to Medicine Creek (reduction coefficient) by approximately 2.93 times or 282 kg (Table 26).

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 seem to lessen fecal coliform concentrations although nutrient concentrations 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.

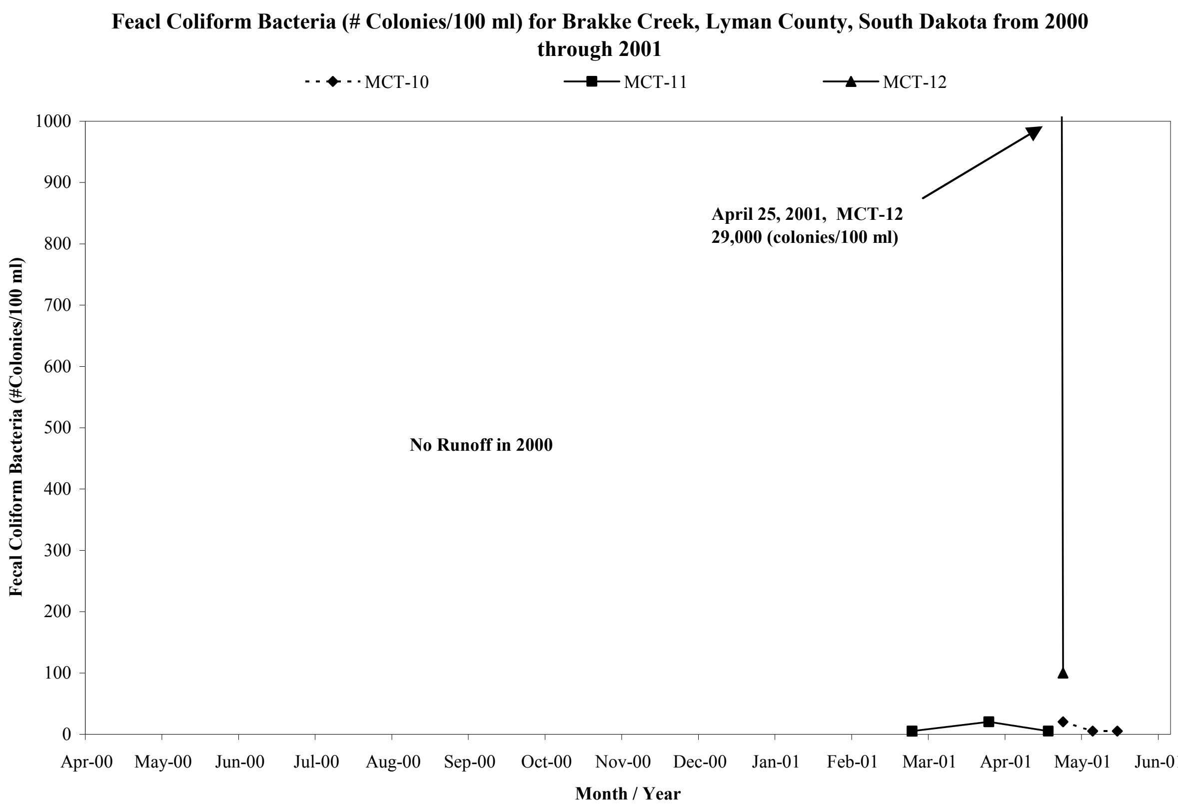


Figure 23. Monthly fecal coliform concentrations (# colonies/100 ml) to Brakke Dam and Medicine Creek from , Lyman County, South Dakota in 2000 and 2001.

Table 8 identifies one elevated fecal coliform sample collected in mid to late April of 2001 in Brakke Creek. Although no standards apply, elevated fecal coliform counts are not healthy or desirable.

The median fecal coliform count (concentration) for Brakke Creek was 5colonies/100 ml (mean 3,240 colonies/100 ml). The maximum concentration of total phosphorus was 29,000 colonies/100 ml on April 25, 2001 at MCT-12 and a minimum of < 10 colonies/100 ml at MCT-10, MCT-11 and MCT-12 on various dates (Appendix C). Fecal coliform bacteria counts were not significantly different between sampling sites ($H_{0.05\ (2,\ N=10)} = 2.42$, $p>0.05$). Seasonally, fecal coliform concentrations were elevated in the spring at MCT-12 with 14,550 colonies/100 ml (Table 9). 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 46 and Table 32). This indicates that fecal decay rate, sunlight and in-lake dilution affect tributary fecal coliform loading to Brakke Dam.

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).

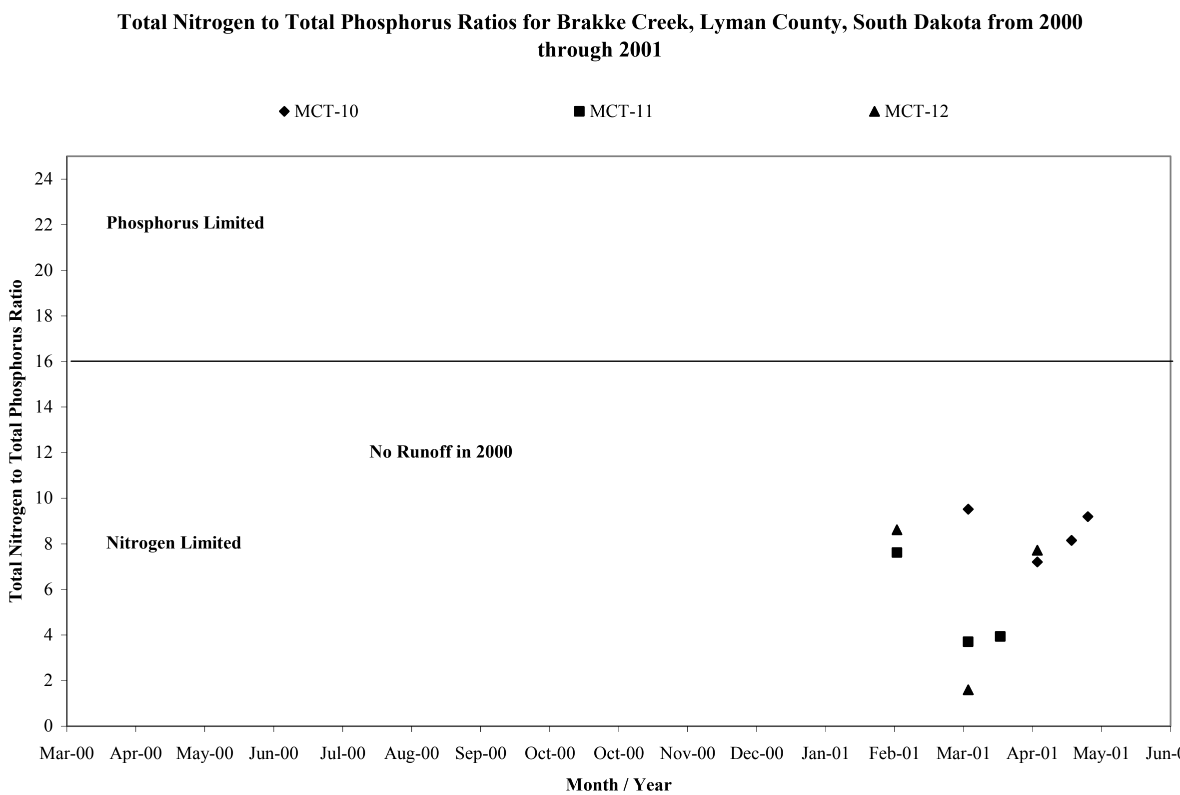


Figure 24. Total nitrogen-to-total phosphorus ratios based on concentrations at MCT-10, MCT-11 and MCT-12 for Brakke Creek, Lyman County, South Dakota in 2000 and 2001.

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. Even if the in-lake total nitrogen-to-total phosphorus convention is used on tributary data (10:1), would still be nitrogen-limited.

Nitrogen and phosphorus ratios were calculated for all tributary samples (10 samples). Concentrations data (ratios) from MCT-11 and MCT-12 influence Brakke Dam directly while ratios from MCT-10 influence Medicine Creek. Individual ratios for MCT-10, MCT-11 and MCT-12 are shown in Figure 24. Total nitrogen-to-total phosphorus ratios were not significantly different between sampling sites. Over the project, tributary total nitrogen-to-total phosphorus ratios tended to be slightly nitrogen limited.

Average seasonal tributary total nitrogen-to-total phosphorus ratios were generally lower and in the spring. Most tributary total nitrogen-to-total phosphorus ratios (both individually and seasonally) indicate that the Brakke Creek system in the Brakke Dam watershed is nitrogen-limited (Figure 24 and Table 9). Based on the criteria previously proposed for this watershed, metabolic activity and community structure based on nutrient limitations may have been a factor in Brakke Creek during portions of the year due to nitrogen limitation (indicating excess phosphorus in the watershed).

In-lake Methods

Brakke Dam is a 52.6 ha (130 acre) impoundment in Lyman County, South Dakota. Two in-lake sample locations were chosen for collecting nutrient, biological and sediment data from Brakke Dam during the study. The locations of the in-lake sampling sites are shown in Figure 25. A sample set consisted of one surface and one bottom sample collected from each site (BL-1 and BL-2) each month. These samples were used to analyze seasonal water quality trends over time.

Chlorophyll *a* samples were used with total phosphorus and Secchi disk data to evaluate the trophic status in Brakke Dam (Carlson, 1977).

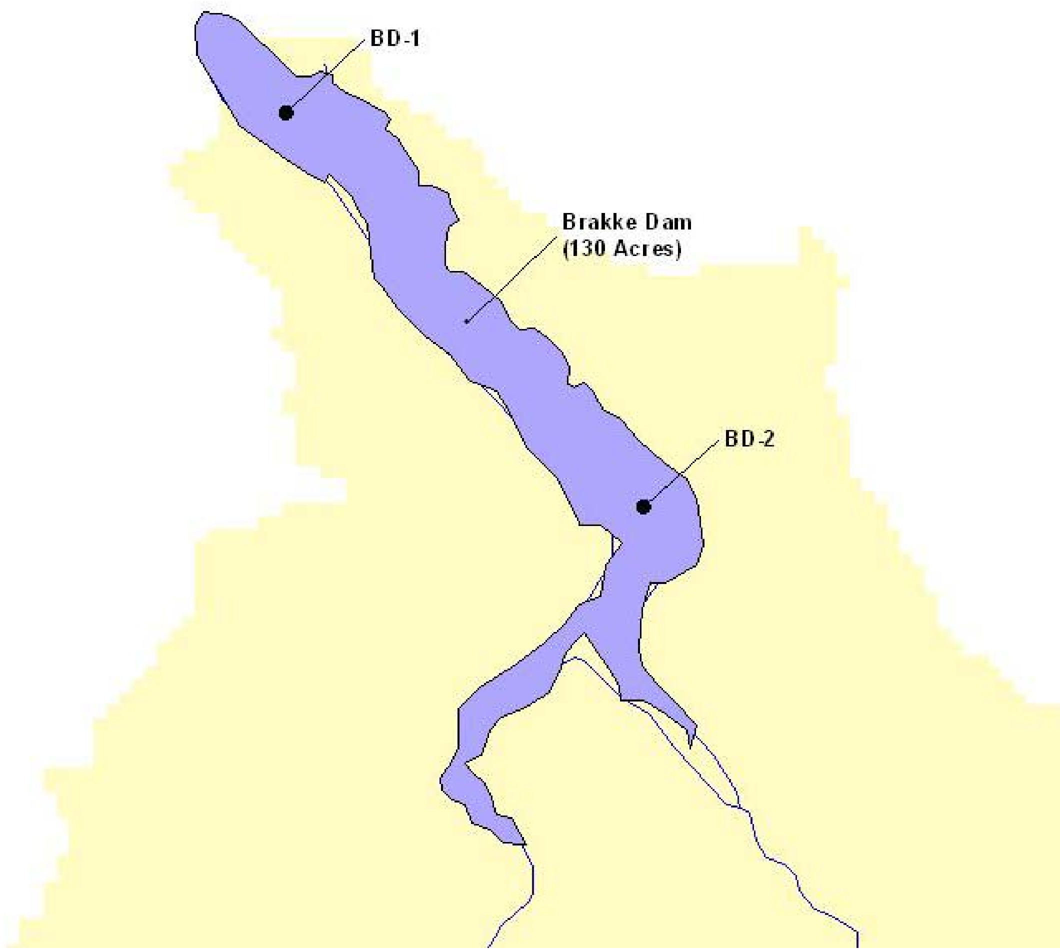


Figure 25. Brakke Dam in-lake sampling sites for 2000 and 2001.

In-lake Water Quality Sampling

Samples collected at each in-lake site were taken according to South Dakota's EPA-approved *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 http://www.state.sd.us/denr.

Table 27. In-lake physical, chemical and biological parameters analyzed in Brakke 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 SD DENR staff and Aquatic Analysts with enumeration results entered into a SD DENR database to calculate biovolume.

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 both surface concentration and surface and bottom data for all parameters are provided in Table 28.

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

	Surface Concentration				Surface vs. Bottom			
Parameter	**(N) BD-1**	**(N) BD-2**	**Mann-Whitney (U)**	**p-value**	**(N) Surface**	**(N) Bottom**	**Mann-Whitney (U)**	**p-value**
Water Temperature	11	11	55.50	0.743	22	8	72.00	0.453
Dissolved Oxygen	11	11	59.00	0.922	20	8	64.00	0.416
pH	10	10	45.00	0.308	22	8	77.50	0.622
Conductivity	11	11	48.50	0.910	20	6	54.50	0.738
Secchi Depth	9	9	38.00	0.824	-	-	-	-
Fecal Coliform	11	11	54.00	0.559	22	8	87.00	0.963
Alkalinity	11	11	51.00	0.532	22	8	86.00	0.925
Total Solids	11	11	59.50	0.948	22	8	77.50	0.622
Total Dissolved Solids	11	11	58.00	0.869	22	8	86.00	0.925
Total Suspended Solids	11	11	57.50	0.844	22	8	71.00	0.425
Volatile Total Suspended Solids	11	11	43.00	0.244	22	8	73.00	0.482
Ammonia	11	11	50.50	0.473	22	8	77.50	0.622
Un-ionized Ammonia	11	11	46.00	0.341	-	-	-	-
Nitrate-Nitrite	11	11	57.50	0.836	22	8	85.00	0.888
Total Kjeldahl Nitrogen	11	11	46.50	0.358	22	8	82.50	0.796
Organic Nitrogen	11	11	52.00	0.576	22	8	83.50	0.833
Inorganic Nitrogen	11	11	53.50	0.637	22	8	80.50	0.725
Total Nitrogen	11	11	47.50	0.393	22	8	85.00	0.888
Total Phosphorus	11	11	53.50	0.646	22	8	69.00	0.373
Total Dissolved Phosphorus	11	11	53.50	0.644	22	8	82.00	0.778
Chlorophyll-*a* (µg/L)	8	6	22.00	0.796	22	8	85.00	0.888
Phosphorus TSI	11	11	53.50	0.646	-	-	-	-
Chlorophyll-*a* TSI	8	6	22.00	0.796	-	-	-	-
Secchi TSI	9	9	37.50	0.789	-	-	-	-
Total Nitrogen-to-Total Phosphorus Ratio	11	11	55.00	0.718	-	-	-	-

Shaded = significantly different between sampling sites ($p<0.05$).
- = not analyzed in bottom samples

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.

Brakke 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).

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 Brakke Dam, Lyman County, South Dakota.

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

*** = See Table 28 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 30 lists the most stringent water quality parameters for Brakke Dam. Three of the seventeen parameters (un-disassociated hydrogen sulfide, total petroleum hydrocarbon and oil and grease) listed for Brakke 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 Brakke Dam based on beneficial use classifications.

Water Body	Beneficial Uses	Parameter	Standard Value
Brakke 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 $\mu S/cm^{-1}$
		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 $\mu S/cm^{-1}$ or ≤ 4,000 $\mu S/cm^{-1}$ 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.

Brakke Dam Water Quality Exceedances

No in-lake South Dakota surface water quality standards were exceeded in Brakke Dam during the project (Appendix D).

Seasonal In-lake Water Quality

Typically, water quality parameters will vary with season due to changes in temperature, precipitation and agricultural practices. Thirty in-lake water quality samples were collected during the project (22 surface and 8 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, two samples in the spring of 2000 and six in the spring of 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 small 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, Brakke Dam did stratify from December 2000 through March 2001 (Appendix E). Average concentrations of in-lake sampling sites and sampling parameters by season and are listed in Table 32.

In-lake dissolved oxygen concentrations were highest in the winter due to cooler water temperatures (cooler water can hold more oxygen) and increased algal densities. Dissolved oxygen profiles (Appendix E) indicated some limited short term stratification (BD-1 (February and March) and BD-2 (July 2000))

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

Total solids and total dissolved solids average concentrations were highest in the spring of 2001 at BD-2 in Brakke Dam. Average total suspended solids were highest at BD-1 in the summer of 2000 and volatile total suspended solids concentrations were highest in the fall of 2000 for both sampling sites (Table 32).

Average total nitrogen, Total Kjeldahl Nitrogen (TKN) and organic nitrogen concentrations were highest in the summer of 2000 at BD-1. Nitrate-nitrite nitrogen concentrations were highest in Brakke Dam during the summer of 2001 at both in-lake sampling sites (Table 32).

Ammonia concentrations were highest at BD-1 in the spring of 2001. Un-ionized ammonia (NH_4-OH) is the fraction of ammonia that is toxic to aquatic organisms. Sources for high in-lake ammonia concentrations could be tributary loading, livestock wading in the lake, animal feeding areas, decomposition of organic matter, or runoff from applied manure (fertilizer). Seasonally, the highest un-ionized ammonia fractions were highest in the spring of 2001 at BD-2.

Average total phosphorus and total dissolved phosphorus concentrations were highest in the spring of 2001 at BD-2 (Table 32).

Both total phosphorus and Secchi average Trophic State Index (TSI) values were highest in the summer of 2000 at BD-1, while chlorophyll-*a* TSI was highest in the fall of 2000 at BD-2 (Table 32).

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

Data	Spring 2000				Summer 2000				Fall 2000				Winter 2001				Spring 2001			
	Sample Count	BD-1	Sample Count	BD-2	Sample Count	BD-1	Sample Count	BD-2	Sample Count	BD-1	Sample Count	BD-2	Sample Count	BD-1	Sample Count	BD-2	Sample Count	BD-1	Sample Count	BD-2
Water Temperature (ºC)	1	16.0	1	16.0	3	23.0	3	23.3	2	17.4	2	16.5	2	4.0	2	3.7	3	10.3	3	10.4
Dissolved Oxygen (mg/L)	1	10.6	1	10.8	3	6.8	3	6.9	2	5.4	2	5.4	2	11.5	2	11.7	3	9.4	3	9.8
pH (su)	1	7.84	1	8.52	3	8.29	3	8.37	2	8.73	2	8.68	2	8.27	2	8.25	3	8.11	3	8.25
Conductivity (µS/cm3)	-	-	-	-	3	325	3	324	2	288	2	289	2	412	2	419	3	361	3	360
Secchi Depth (m)	1	0.94	1	1.10	3	0.42	3	0.44	2	0.45	2	0.49	1	0.76	1	0.64	2	0.44	2	0.41
Fecal Coliform (# colonies/100 ml)	1	5	1	10	3	7	3	15	2	8	2	5	2	5	2	5	3	5	3	5
Alkalinity (mg/L)	1	140	1	140	3	135	3	134	2	124	2	125	2	132	2	153	3	138	3	138
Total Solids (mg/L)	1	221	1	217	3	249	3	242	2	232	2	227	2	220	2	253	3	260	3	262
Total Dissolved Solids (mg/L)	1	217	1	212	3	221	3	220	2	212	2	210	2	215	2	249	3	251	3	251
Total Suspended Solids (mg/L)	1	4	1	5	3	28	3	22	2	21	2	18	2	5	2	5	3	8	3	11
Volatile Total Suspended Solids (mg/L)	1	1	1	2	3	5	3	5	2	8	2	8	2	1	2	2	3	1	3	3
Ammonia (mg/L)	1	0.01	1	0.01	3	0.04	3	0.02	2	0.01	2	0.01	2	0.10	2	0.10	3	0.14	3	0.09
Un-ionized Ammonia (mg/L)	1	0.00020	1	0.00089	3	0.00330	3	0.00195	2	0.00151	2	0.00130	2	0.00200	2	0.00175	3	0.00418	3	0.00769
Nitrate-Nitrite (mg/L)	1	0.05	1	0.05	3	0.12	3	0.08	2	0.05	2	0.05	2	0.15	2	0.15	3	0.20	3	0.20
Total Kjeldahl Nitrogen (mg/L)	1	0.56	1	0.74	3	0.89	3	0.49	2	0.84	2	0.73	2	0.71	2	0.79	3	0.73	3	0.76
Organic Nitrogen (mg/L)	1	0.55	1	0.73	3	0.85	3	0.47	2	0.83	2	0.72	2	0.62	2	0.69	3	0.59	3	0.66
Inorganic Nitrogen (mg/L)	1	0.06	1	0.06	3	0.16	3	0.10	2	0.06	2	0.06	2	0.25	2	0.25	3	0.34	3	0.29
Total Nitrogen (mg/L)	1	0.61	1	0.79	3	1.01	3	0.57	2	0.89	2	0.78	2	0.86	2	0.94	3	0.93	3	0.96
Total Phosphorus (mg/L)	1	0.030	1	0.038	3	0.088	3	0.075	2	0.077	2	0.073	2	0.030	2	0.033	3	0.082	3	0.088
Total Dissolved Phosphorus (mg/L)	1	0.005	1	0.006	3	0.021	3	0.018	2	0.030	2	0.028	2	0.019	2	0.016	3	0.043	3	0.044
Chlorophyll-*a* (µg/L)	1	5.87	1	4.75	1	19.84	3	15.29	1	21.20	1	36.09	2	4.95	-	-	3	12.18	1	3.73
Phosphorus TSI	1	53.22	1	56.63	3	68.79	3	66.44	2	66.79	2	65.92	2	52.62	2	54.36	3	65.46	3	65.06
Chlorophyll-*a* TSI	1	56.97	1	54.89	1	68.91	3	66.26	1	69.56	1	74.78	2	50.09	-	-	3	60.28	1	52.51
Secchi TSI	1	60.82	1	58.66	3	73.35	3	72.18	2	71.54	2	70.47	1	63.92	1	66.44	2	72.21	2	72.21
Total Nitrogen-to-Total Phosphorus Ratio	1	20.33	1	20.79	3	11.35	3	7.71	2	11.65	2	10.95	2	30.01	2	29.01	3	14.75	3	15.65

[1] = A one (1) in the sample count column indicates actual value and not an average
[2] = Highlighted areas are the seasons that recorded the highest concentrations or values for a given parameter.

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.

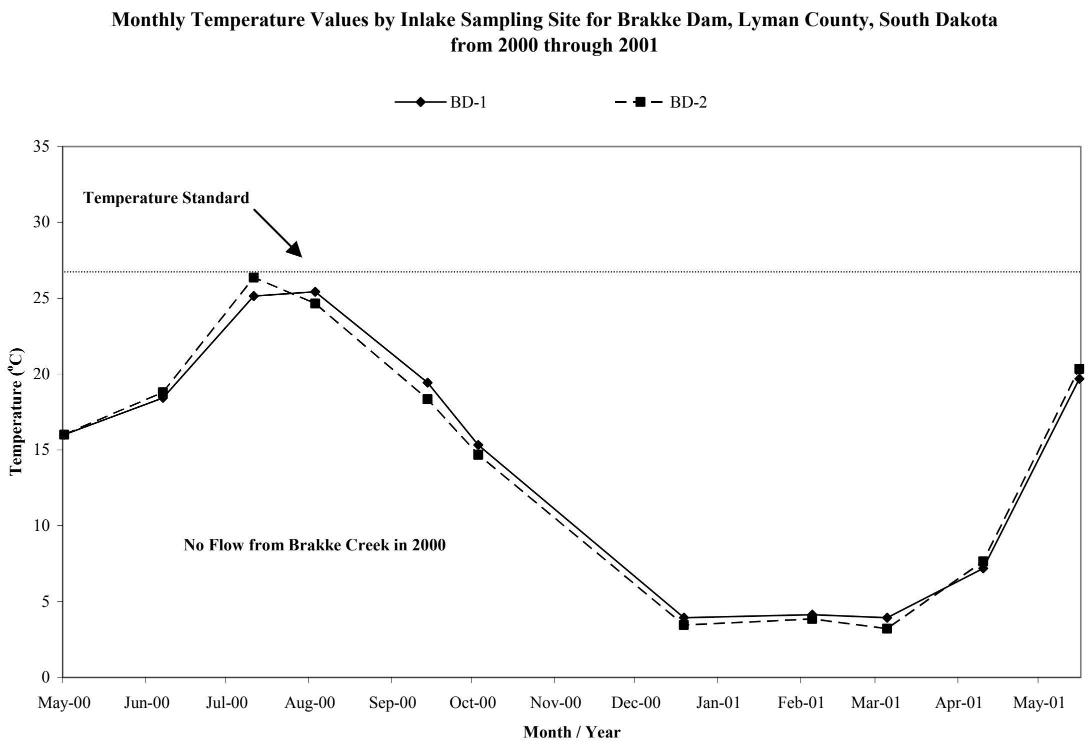


Figure 26. Monthly Surface water temperatures by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

The median surface water temperature in Brakke Dam over the sampling period was 16.0º C (mean 14.4° C). Figure 26 shows surface water temperatures throughout the project period for both in-lake sampling sites. No significant differences were detected between sampling sites (Table 28). The maximum surface water temperature measured during the sampling season was 26.4° C taken in mid-July 11, 2000.

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.

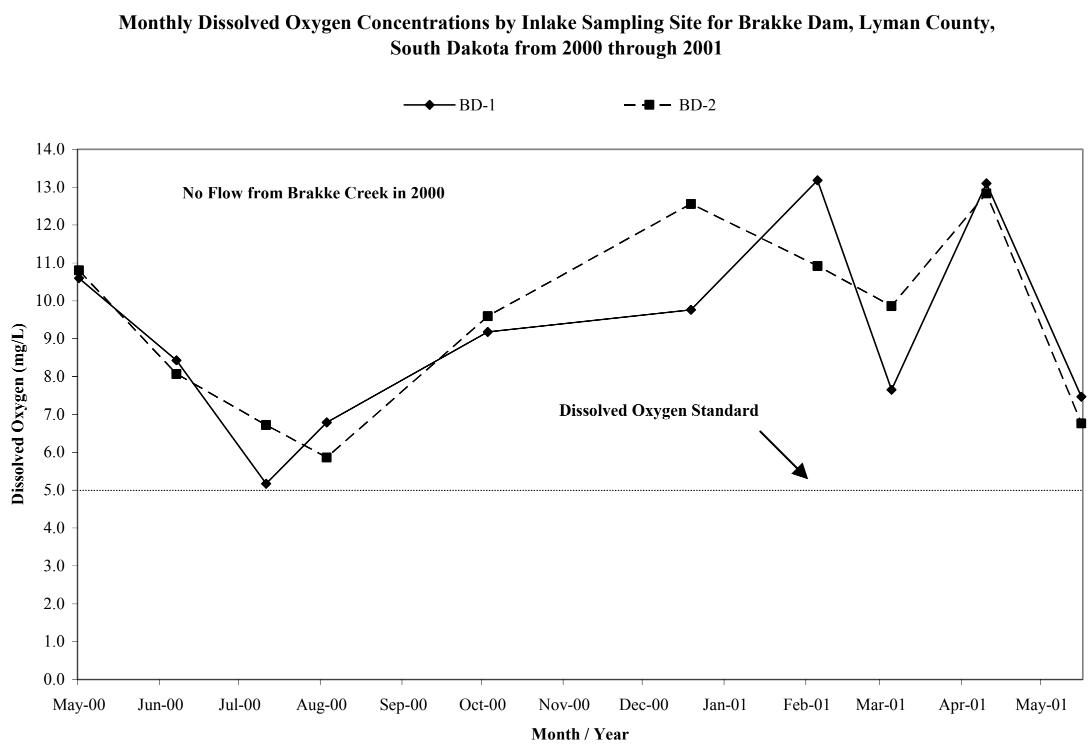


Figure 27. Monthly surface dissolved oxygen concentrations by sampling site for Brakke Dam, Lyman County, South Dakota in 2000 and 2001.

Surface water dissolved oxygen median was 8.8mg/L (mean 8.5 mg/L) over the duration of the study. On average, dissolved oxygen concentration were lower in the summer of 2000 at both in-lake sampling sites (Figure 27) and were attributed to increased water temperatures (Figure 26). The maximum surface-water oxygen concentration in Brakke Dam was 13.2 mg/L. That sample was collected at BD-1 on February 5, 2001. Typically, as much oxygen as is produced by photosynthesis in a day, is used in respiration, or 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).

Oxygen stratification was observed in the water column from December 2000 through March 2001 at both in-lake monitoring sites. Surface water dissolved oxygen samples were not significantly different between sites or between surface and bottom dissolved oxygen concentrations (Table 28). Appendix E has all dissolved oxygen profiles collected in Brakke Dam from 2000 through 2001.

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).

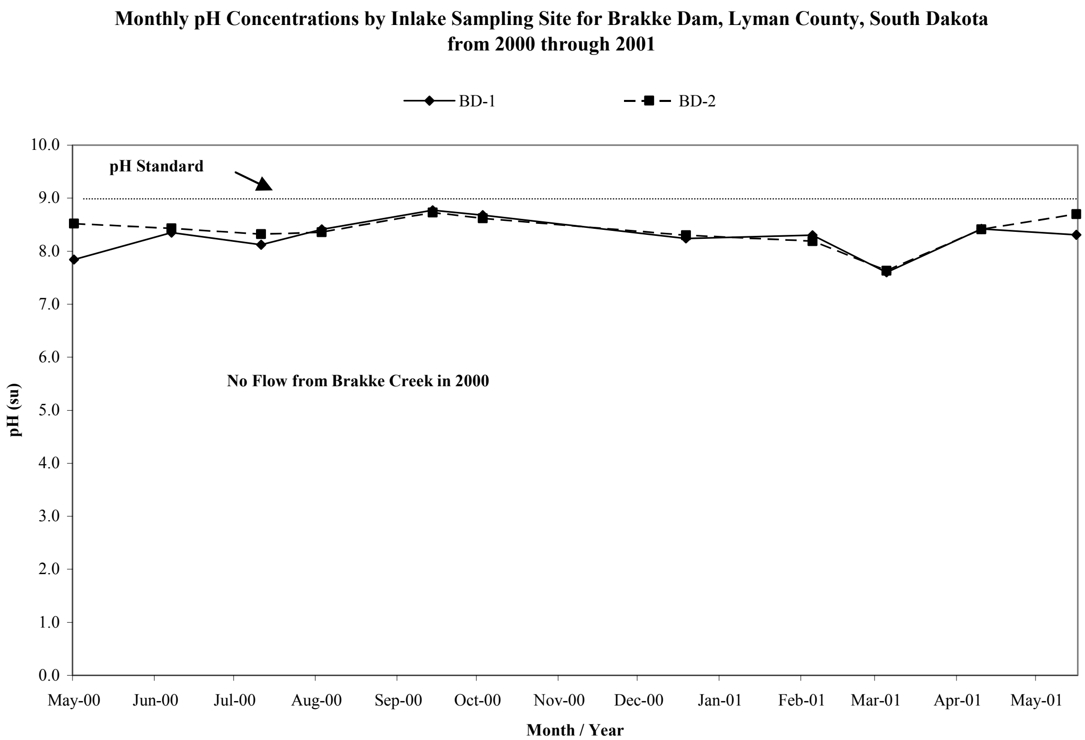


Figure 28. Monthly surface pH concentrations by date and sampling site for Brakke Dam Lyman County, South Dakota from 2000 through 2001.

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 7.60 su to 8.77 su (Figure 28) and had a median of 8.35 su (mean, 8.33). In-lake pH concentrations were not significantly different between sites or between surface and bottom pH concentrations at in-lake sampling site (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 (25º C) and is reported in micro-Siemens/centimeter ($\mu S/cm^{-1}$).

In-lake specific conductivity values in Brakke Dam directly affect tributary monitoring site MCT-10 (Brakke Dam outlet) and Medicine Creek. In-lake conductivity values were below the beneficial use standards (beneficial uses 4, 7, 8 and 9) for Brakke Dam (Figure 29 and Table 31). Medicine Creek is listed in the 2002 South Dakota Total Maximum Daily Load Waterbody List (303(d) List) as impaired for conductivity and Total Dissolved Solids (TDS).

The median in-lake surface water specific conductivity for Brakke Dam over the sampling period was 329.5 $\mu S/cm^{-1}$ (mean, 346.3 $\mu S/cm^{-1}$). Figure 29 shows surface water conductivity values throughout the project period for both in-lake sampling sites. No significant differences were detected between sampling sites (Table 28). The maximum surface water specific conductivity measured during the sampling season was 449.0 $\mu S/cm^{-1}$ taken in early March 2001 at BD-1.

In-lake water quality standards for specific conductivity is $\leq$ 7,000 $\mu mhos/cm^{-1}$ ($\mu S/cm^{-1}$). Data indicate that Brakke Dam appears not to contribute to increased TDS concentrations and conductivity values to Brakke Dam outfall or Medicine Creek

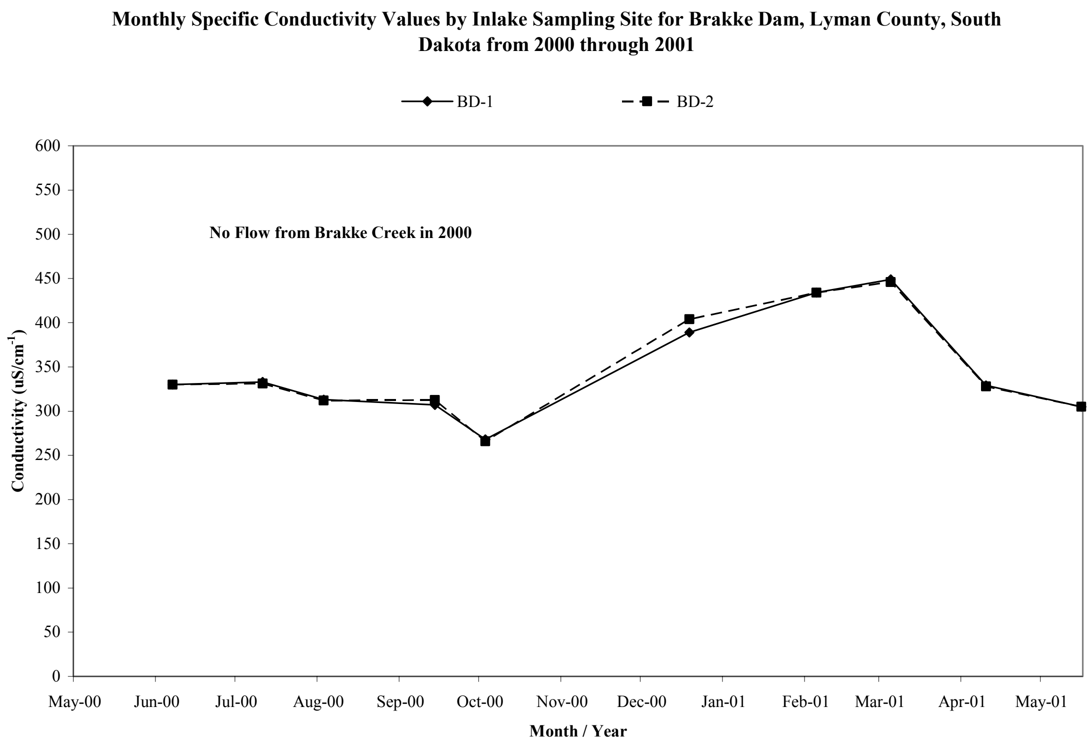


Figure 29. Monthly specific conductivity values for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

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.

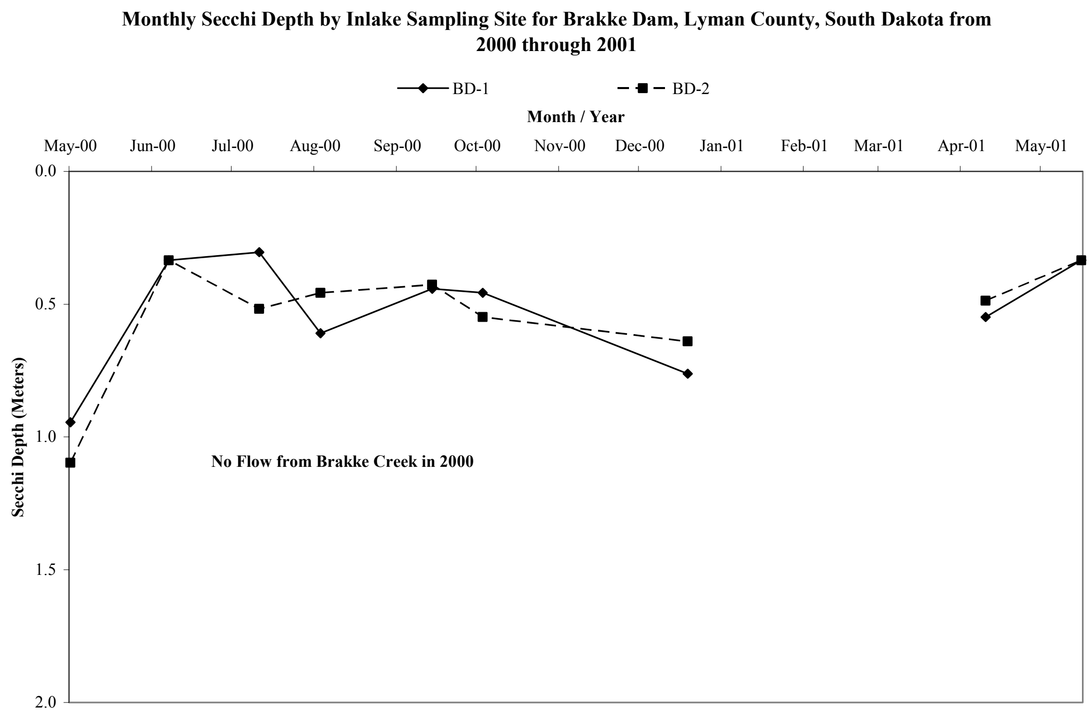


Figure 30. Monthly Secchi depth by date and sampling site for Brakke Dam, Lyman County, South Dakota in 2000 through 2001.

Figure 30 shows lower (shallow) Secchi depth readings in summer of 2000, especially at site BL-1. The highest (deepest) Secchi disk reading was 1.10 meters (3.6 feet) at BD-2 in May of 2000. The median seasonal Secchi depth during the project was 0.47 m (1.55 feet); (mean, 0.53 m (1.75 feet)). Secchi transparency between sampling sites were not significantly different in Brakke Dam (Table 28). Since Secchi transparency depth is one parameter used in measuring trophic state, Secchi TSI values between sites were also not significantly different (Table 28).

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 Brakke Dam was 130 mg/L with a median of 135 mg/L. The maximum alkalinity concentration (176.0 mg/L) was collected at BD-2 in March of 2001 while the minimum alkalinity concentration (108.0 mg/L) was collected at BD-1 in February of 2001.

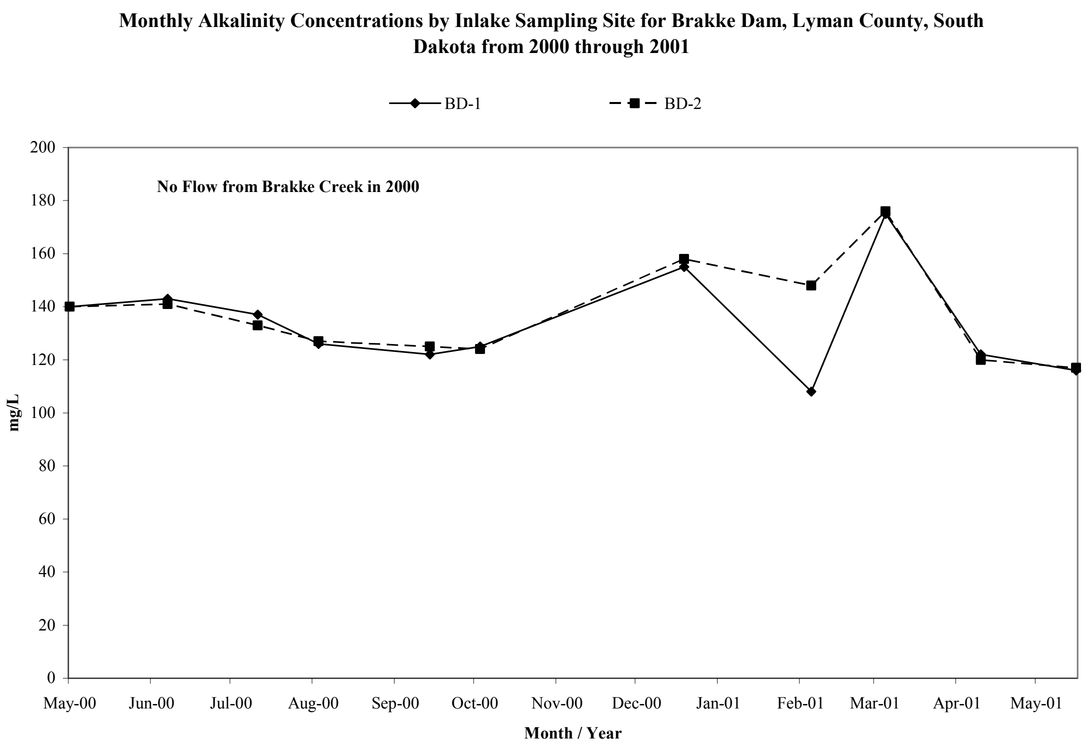


Figure 31. Monthly surface alkalinity concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Generally, alkalinity concentrations were consistent throughout the sampling period (Figure 31) and were not statistically significant between BD-1 and BD-2 (Table 28). Seasonally, the highest average concentration occurred in the winter of 2001 (average 153 mg/L) at BD-2.

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 500º C muffle furnace).

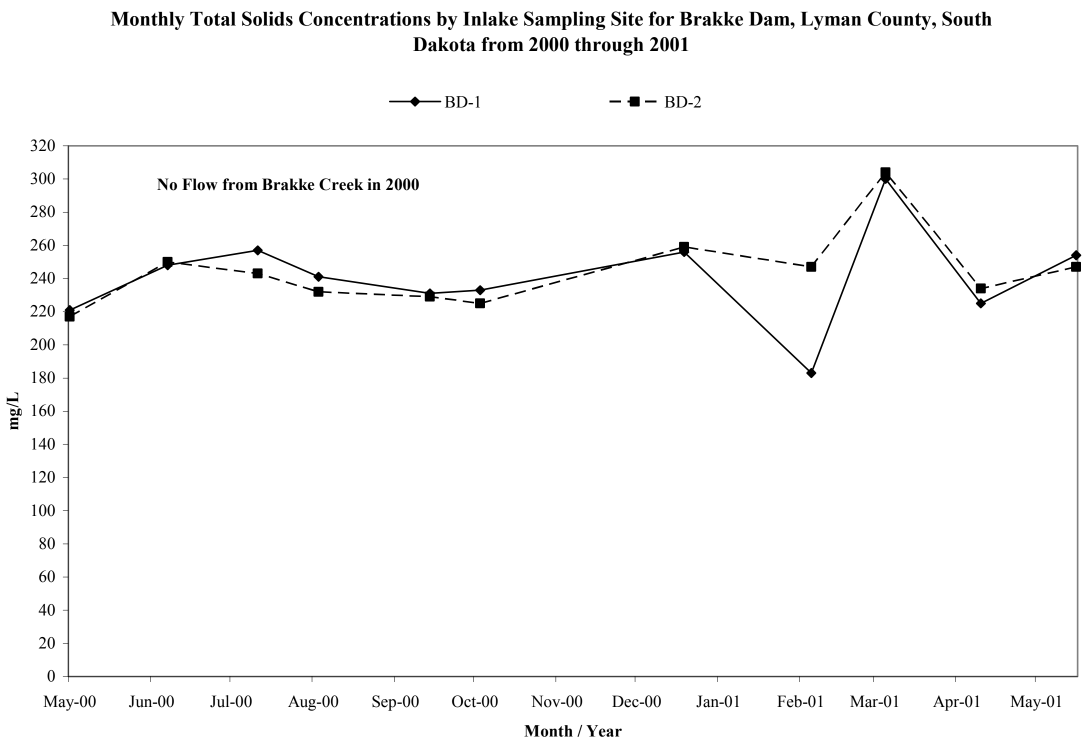


Figure 32. Monthly surface total solids concentration by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Total solids concentrations in Brakke Dam had a median of 242.0 mg/L (mean, 242 mg/L) with a maximum of 304.0 mg/L and a minimum of 183.0 mg/L. Generally, total solids concentrations were lower in the late spring and gradually peaked in late winter (Figure 32). Seasonal averages for total solids concentrations were highest in the winter of 2001 at BL-2 (Table 32). Total solids concentrations were not significantly different between in-lake sampling sites (Table 28).

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.

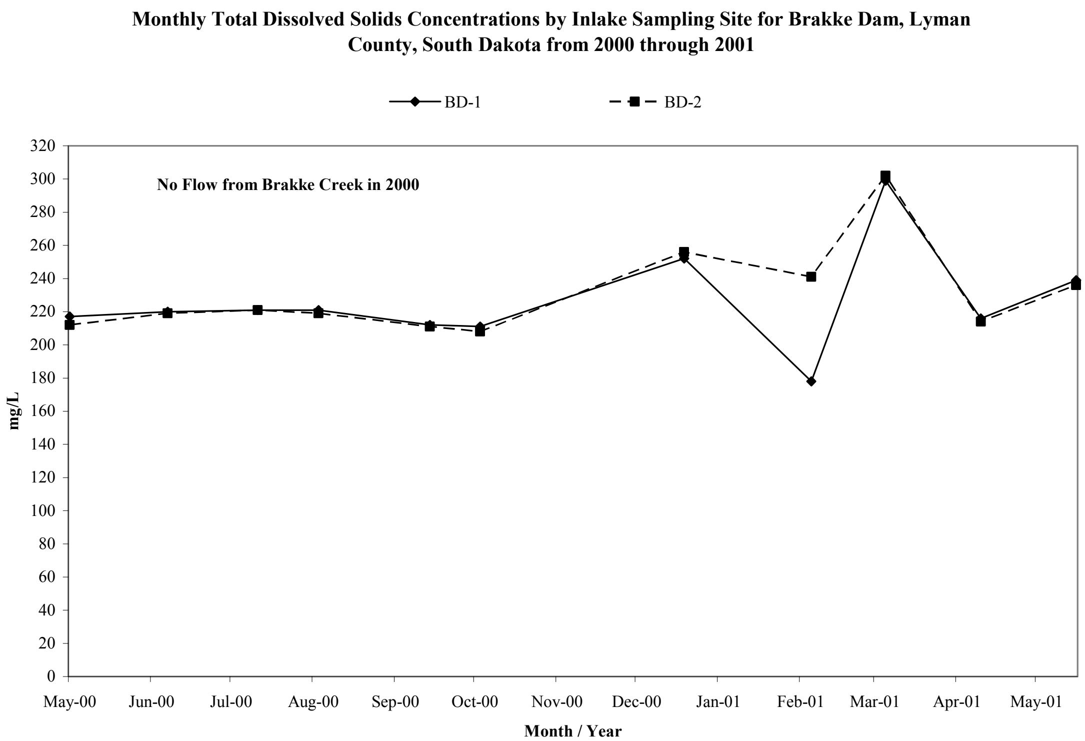


Figure 33. Monthly surface total dissolved solids concentration by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Total dissolved solids concentrations in Brakke Dam had a median of 219 mg/L (mean 228 mg/L) with a maximum of 302.0 mg/L and a minimum of 178.0 mg/L. Similar to total solids, total dissolved solids concentrations were lower in the late spring and summer and gradually peaked in the winter (Figure 33). Total dissolved solids concentrations comprised between 86.0 percent and 99.7 percent of total solids concentrations. Total dissolved solids concentrations between BD-1 and BD-2 were not significantly different (Table 28).

Medicine Creek, of which Brakke Dam and its watershed is a part, is listed on the 303(d) list for surface waters quality standards violations in specific conductivity and total dissolved solids concentrations. Surface waters quality standards for total dissolved solids in Brakke Dam are ≤ 4,375 mg/L.

During this study, in-lake total dissolved solids concentrations were well below the standard and do not appear to be a problem in this portion of the Medicine Creek watershed.

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.

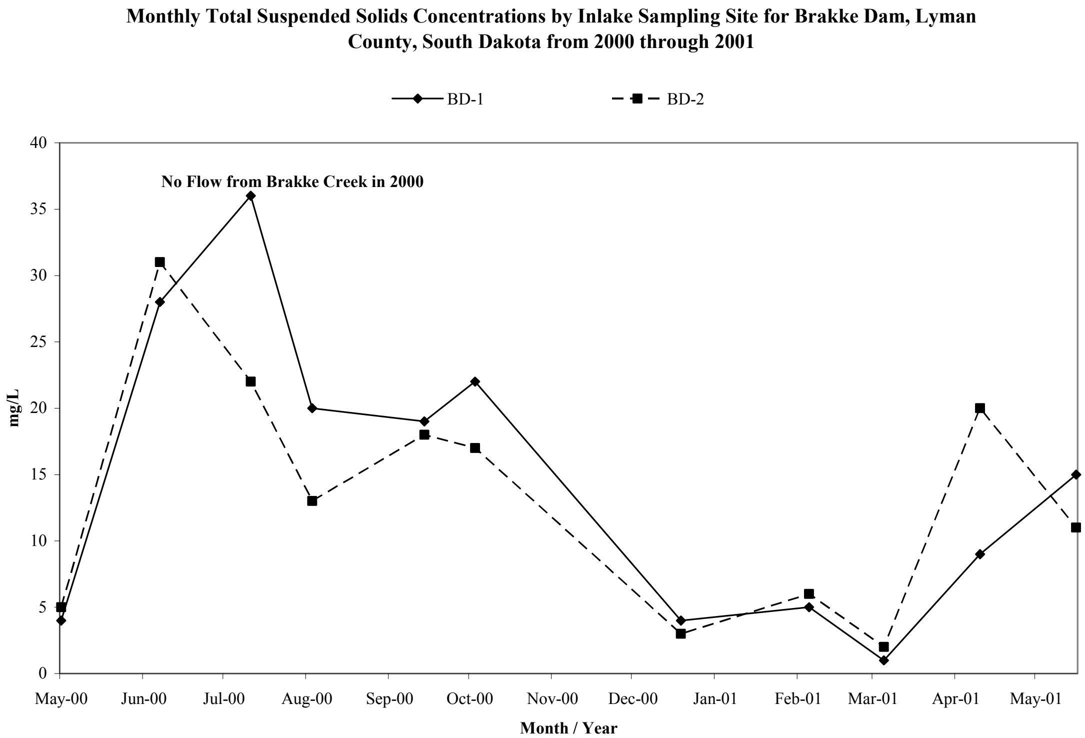


Figure 34. Monthly surface total suspended solids concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

The median total suspended solids concentration in Brakke Dam was 14 mg/L (mean, 14 mg/L) with a maximum of 36.0 mg/L and a minimum of 1.0 mg/L. Seasonal averages for total suspended solids concentrations were highest in the summer of 2000 at BD-1 (Table 32). The surface sample with the highest total suspended solids concentration was collected in July 11, 2000 at BL-1 (Appendix D). Total suspended solids concentrations between in-lake sampling sites were not significantly different (Table 28) during this study (Figure 34).

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.

The median Volatile total suspended solids concentration was 2.0 mg/L (mean 4 mg/L) with a maximum of 11.0 mg/L and a minimum concentration of < 1.0 mg/L. Seasonal average volatile total suspended solids concentrations were highest in the summer of 2000 and the fall of 2000 at both in-lake sampling sites (Table 32). The maximum surface water concentrations of volatile total suspended solids were collected in July 11, 2000 (Figure 35). No significant differences were detected between in-lake sampling sites (Table 28).

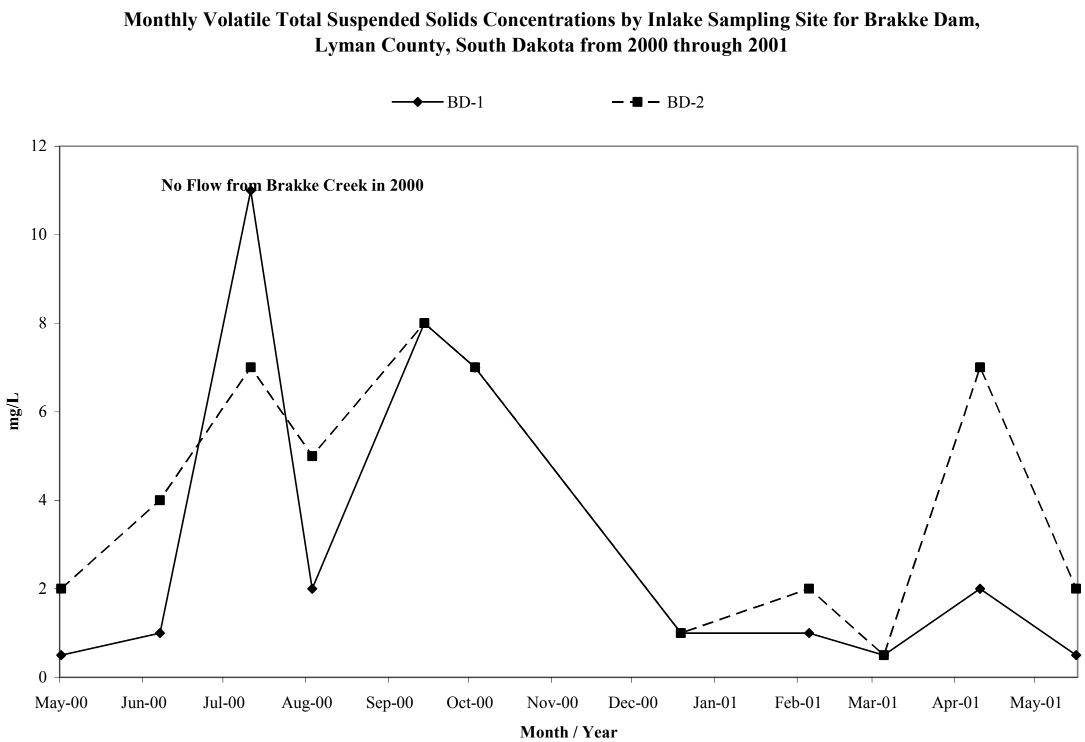


Figure 35. Monthly surface volatile total suspended solids concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

The percentage of volatile total suspended solids in total suspended solids by site ranged widely. BD-1 percent volatile suspended solids ranged from 3.3 percent to 50.0 percent and in-lake sampling site BD-2 ranged from 12.9 percent to 44.4 percent.

Total suspended solids and volatile total suspended solids affect Secchi transparency and chlorophyll-*a* concentrations, respectively. Brakke Dam is currently listed on the 2002 303(d) list (impaired waterbody list) and the current assessment data support the listing and indicate elevated (Trophic State Index) TSI values (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.

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 Brakke Dam comes from Brakke Creek loadings, runoff from ungauged areas of the watershed, wildlife and/or livestock (cattle) with direct access to the lake, decaying organic matter and bacterial conversion of other nitrogen compounds.

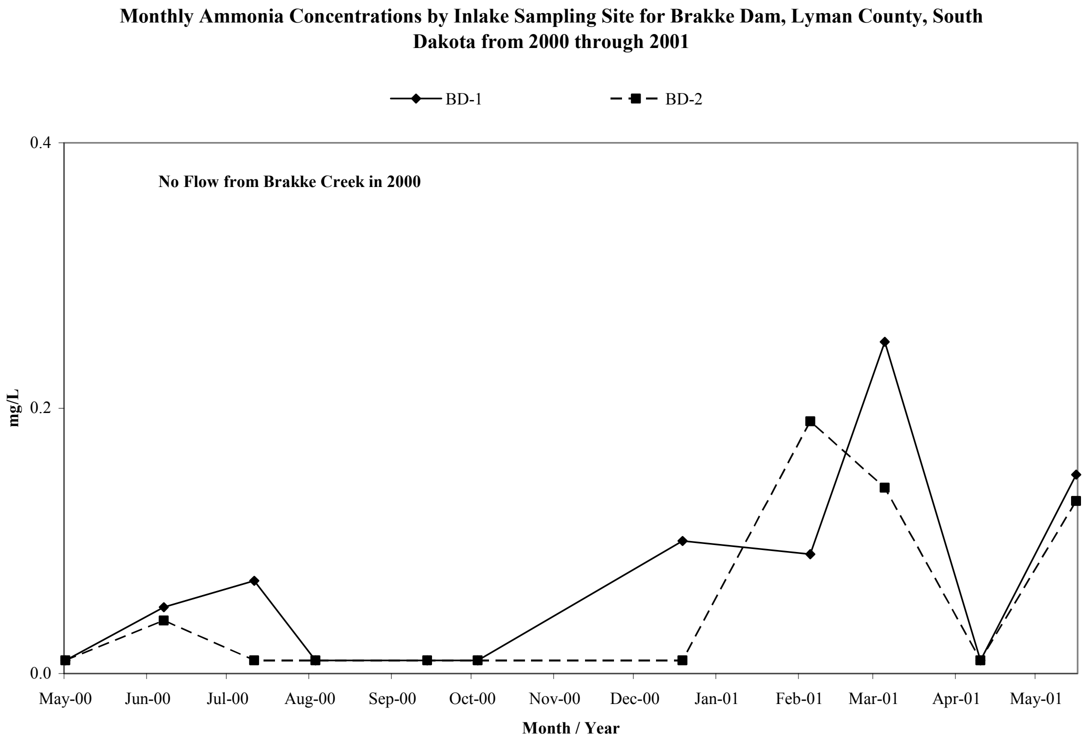


Figure 36. Monthly ammonia concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota in 1999.

The median concentration of ammonia in Brakke Dam was 0.01 mg/L with a mean of 0.06 mg/L. Fifty-two percent of all surface samples collected at Brakke Dam were at or below laboratory detection limits. On average, ammonia concentrations were lower in 2000 (with no tributary runoff) than 2001 (Figure 36). Seasonal concentrations were highest in the spring of 2001 (average 0.14 mg/L) at BD-1 (Table 32). No significant differences in ammonia concentrations were detected between BD-1 and BD-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

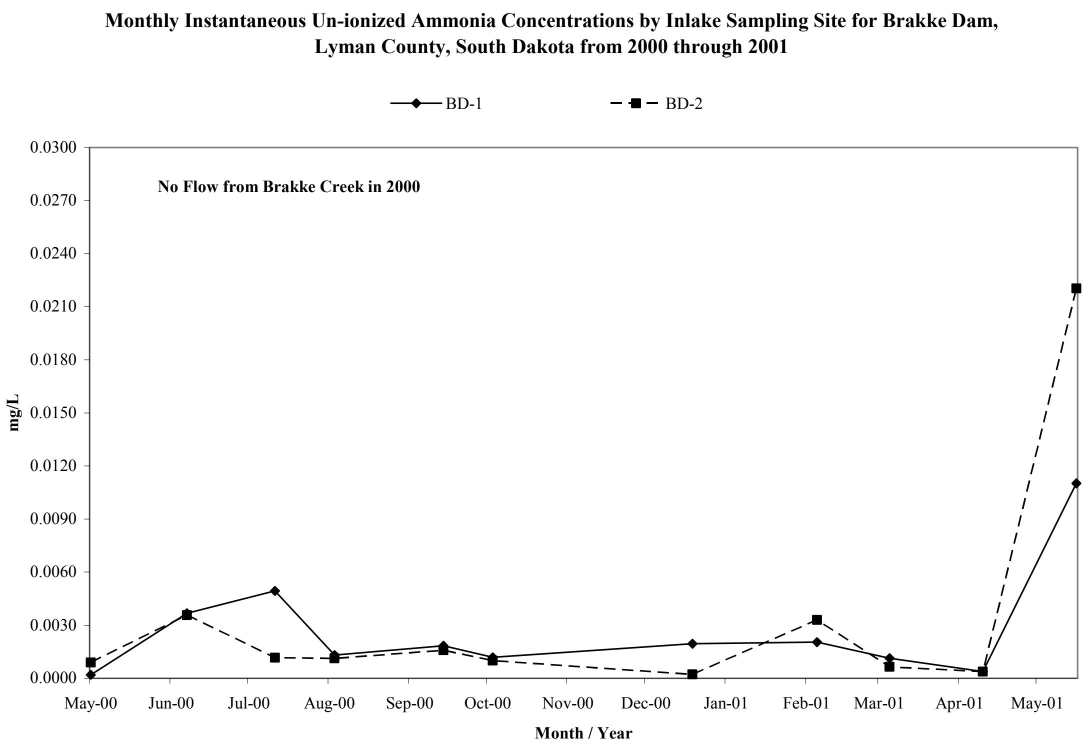


Figure 37. Monthly instantaneous un-ionized ammonia concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

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 Brakke Dam was 0.0012 mg/L (mean, 0.0030 mg/L). The maximum concentration was 0.0220 mg/L and a minimum concentration of 0.0002 mg/L. Un-ionized ammonia concentrations (mg/L) peaked in the spring of 2001 at BL-1 and BD-2 (Figure 37). The concentrations of un-ionized ammonia at Brakke Dam were not significantly different between in-lake sampling sites from 2000 through 2001 (Table 28).

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.

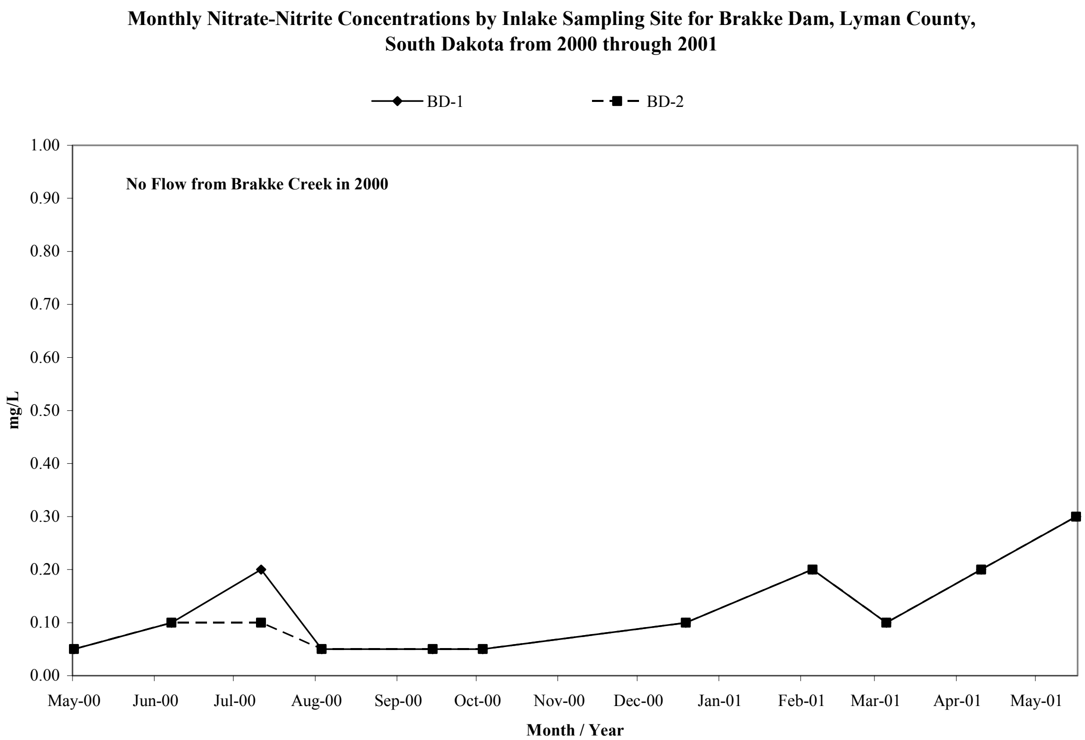


Figure 38. Monthly surface nitrate-nitrite concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

The median nitrate-nitrite concentration for Brakke Dam was 0.10 mg/L (median, 0.12 mg/L), with a maximum of 0.3 mg/L and a minimum concentration of < 0.1 mg/L. Monthly average nitrate–nitrite concentrations were relatively steady during the 2000 sampling season with no input from Brakke Creek and reduced lake levels (evaporative loss). Nitrate–nitrite concentrations peaked in the spring of 2001 at 0.30 mg/L at BD-1 and BD-2 in May (Figure 38 and 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 no input from Brakke Creek in 2000 and inflow occurring during ice out, this situation may have been masked in Brakke Dam during the study. Nitrate-nitrite and ammonia make up the inorganic portion of total nitrogen. No significant differences in nitrate–nitrite concentrations were detected between in-lake sampling sites (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.

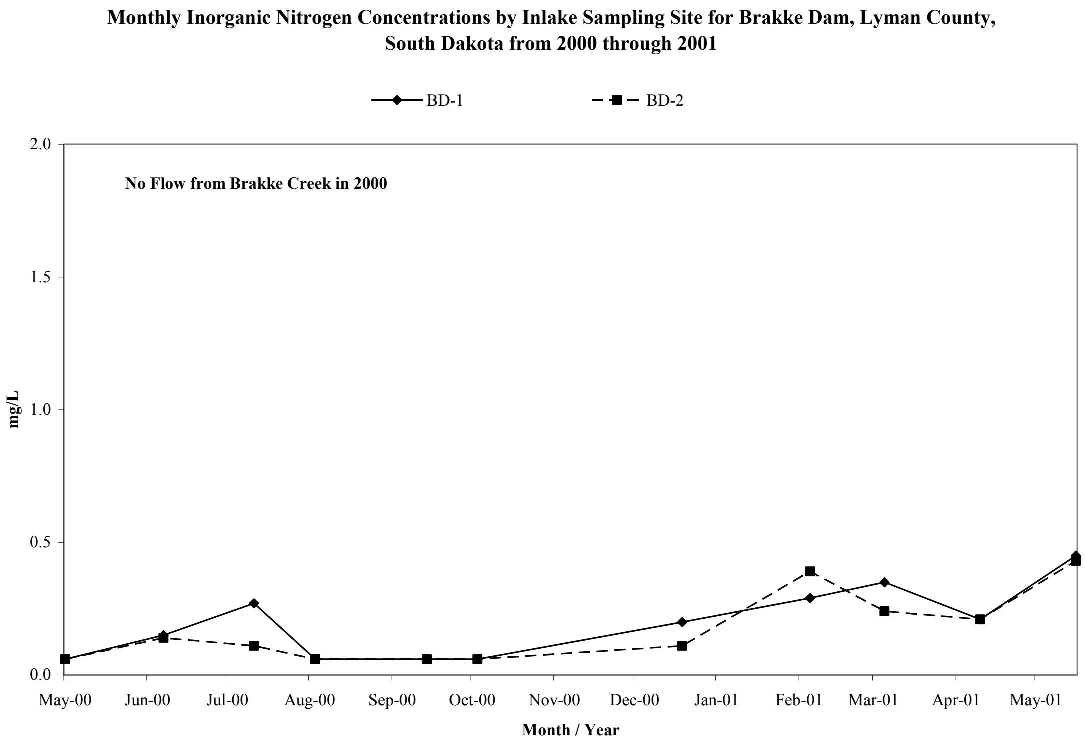


Figure 39. Monthly surface inorganic nitrogen concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Inorganic nitrogen concentrations in Brakke Dam had a median of 0.14 mg/L (mean, 0.18 mg/L) with a maximum of 0.45 mg/L and a minimum concentration of 0.06 mg/L. Inorganic nitrogen concentrations peaked in the spring of 2001 (Figure 39) and are similar to the nitrate-nitrite graph (Figure 38), because as mentioned above, inorganic nitrogen incorporates nitrate-nitrite in the calculation. Inorganic nitrogen concentrations between sampling sites were not significantly different (Table 28). Seasonal averages for inorganic nitrogen concentrations were highest in the spring of 2001 at BD-1 (Table 32).

Total Kjeldahl Nitrogen

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

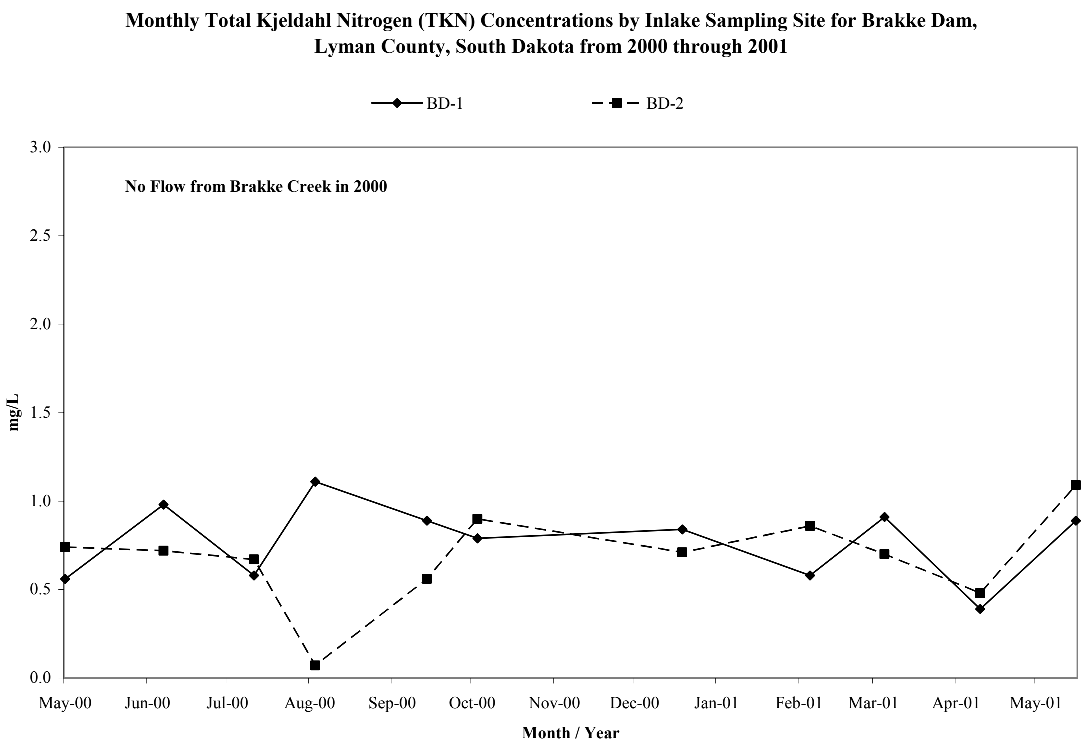


Figure 40. Monthly surface Total Kjeldahl Nitrogen (TKN) concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

The median and mean TKN concentration was 0.73 mg/L and 0.73 mg/L, respectively. Monthly average TKN concentrations were relatively steady during the project, even during the 2000 sampling season with no input from Brakke Creek (Figure 40). Seasonally, average TKN concentrations were highest in the summer of 2000 at BD-1 (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 42. Organic nitrogen percentages (percent organic nitrogen in TKN) ranged from 72.5 percent to 99.1 percent and averaged 91.7 percent. The lowest organic percentage was in March 2001 at BD-1 (72.5 percent).

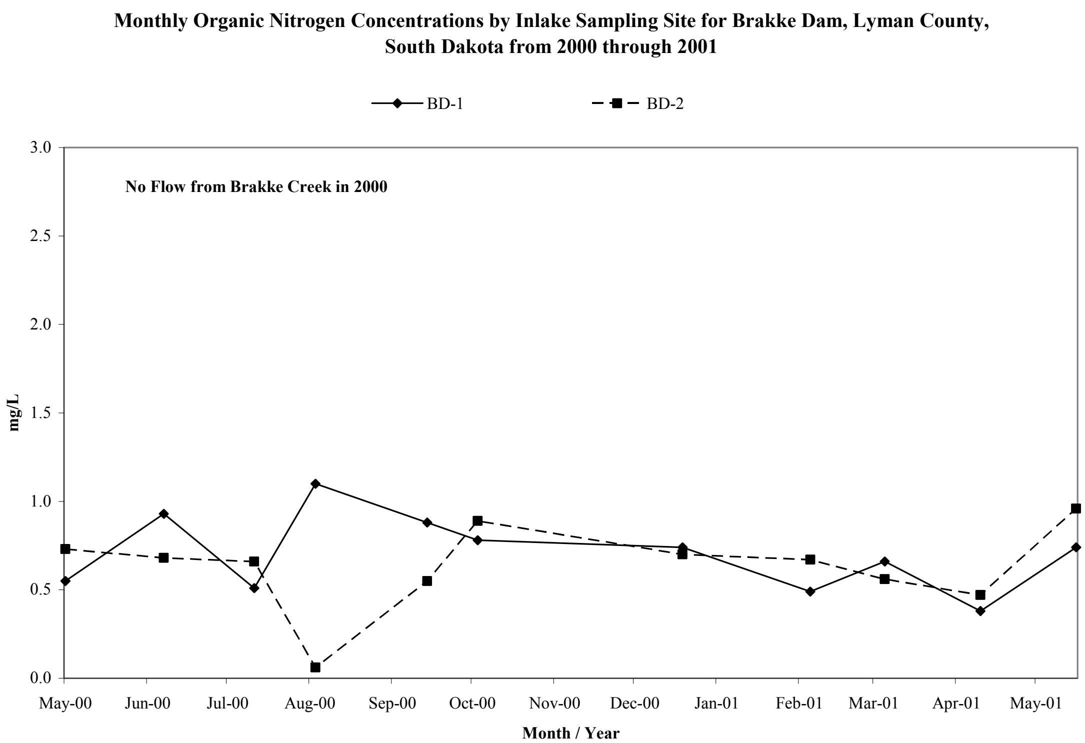


Figure 41. Monthly surface organic nitrogen concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

The median organic nitrogen concentration for Brakke Dam was 0.67 mg/L (mean 0.67 mg/L), with a maximum of 1.10 mg/L and a minimum concentration of 0.06 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 summer of 2000 and are similar to the TKN graph (Figure 40), because organic nitrogen incorporates TKN in the calculation (Figure 41). No significant differences in organic nitrogen concentrations were detected between in-lake sampling sites (Table 28).

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. The median total nitrogen concentration for Brakke Dam was 0.81 mg/L (mean 0.85 mg/L), with a maximum of 1.39 mg/L and a minimum concentration of 0.12 mg/L. Seasonally, average total nitrogen concentrations for Brakke Dam were highest in the summer of 2000 at BD-1 (Table 32); however, the highest in-lake concentrations of total nitrogen occurred at both in-lake sampling sites (Figure 42). No significant differences in total nitrogen concentrations were detected between in-lake sampling sites (Table 28).

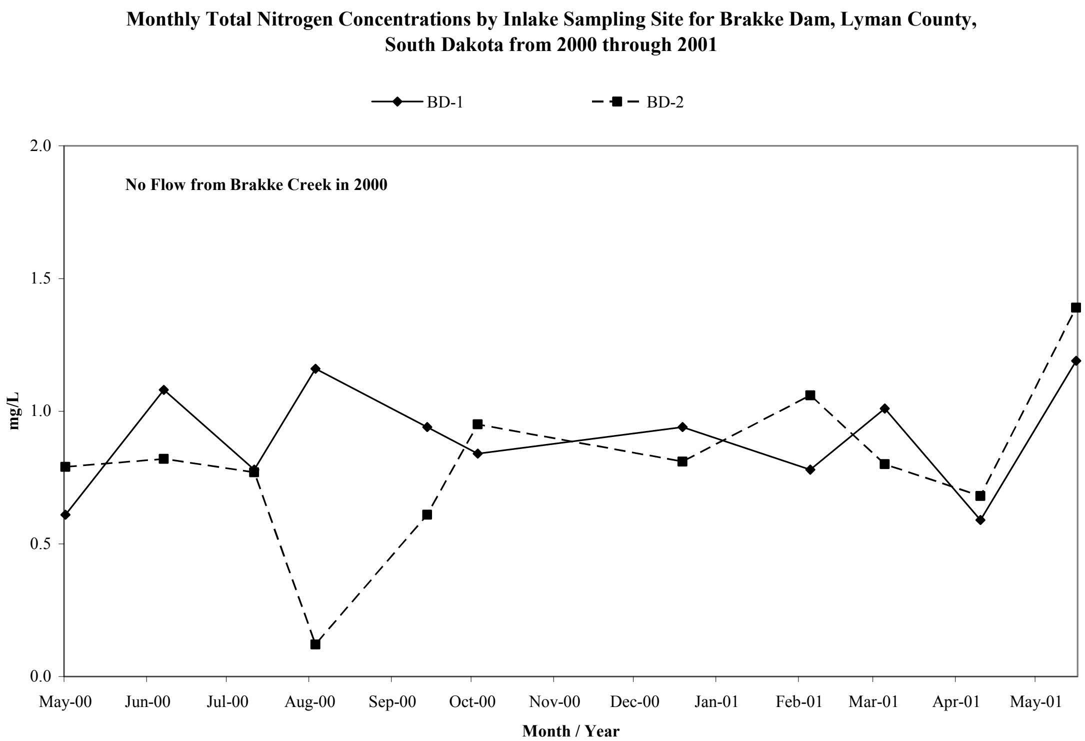


Figure 42. Monthly total nitrogen concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota in 2000 and 2001.

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).

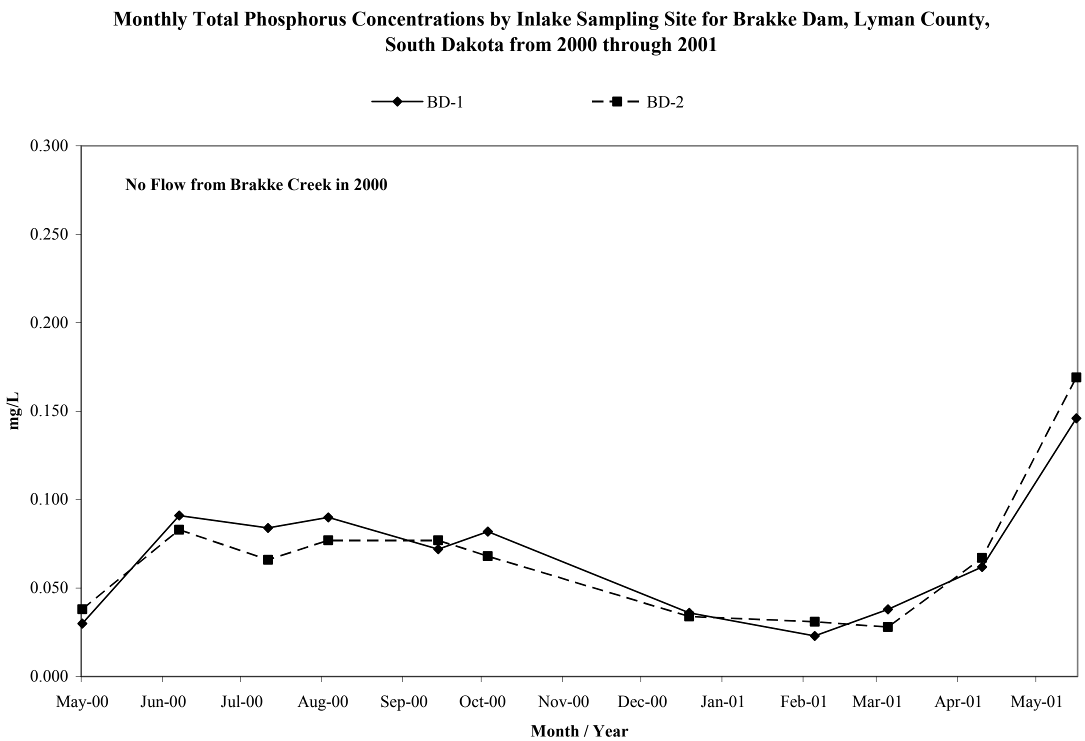


Figure 43. Monthly surface total phosphorus concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

The median concentration of total phosphorus throughout the study period was 0.067 mg/L (mean 0.068 mg/L). The maximum sample concentration was collected at BD-2 in May of 2001 (0.169 mg/L) (Figure 43). No significant differences in total phosphorus concentrations were detected between in-lake sampling sites (Table 28).

Seasonally, average total phosphorus concentrations were lower in the fall of 2000 and winter of 2001(Figure 43 and Table 32). Runoff from Brakke Creek appeared to influence in-lake total phosphorus concentrations in the spring 2001 (Figure 43 and Figure 44).

On average, Brakke Dam had 3.4 times more total phosphorus than the amount needed to cause algal blooms ((0.02 mg/L) Wetzel, 1983). Similarly, Byre Lake and Fate Dam had excess total phosphorus concentrations, 2.8 and 4.6 times respectively (Smith 2003 and Smith 2004). During this study, monthly in-lake total phosphorus was generally limited until the spring of 2001(Figure 51). The highest densities of algae occurred in the falloff 2000 and spring of 2001 (April) with flagellated algae blooms (Figure 52, Figure 67, Figure 68 and Table 39). 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 of increased tributary loading (including internal loads) over time should promote better water quality.

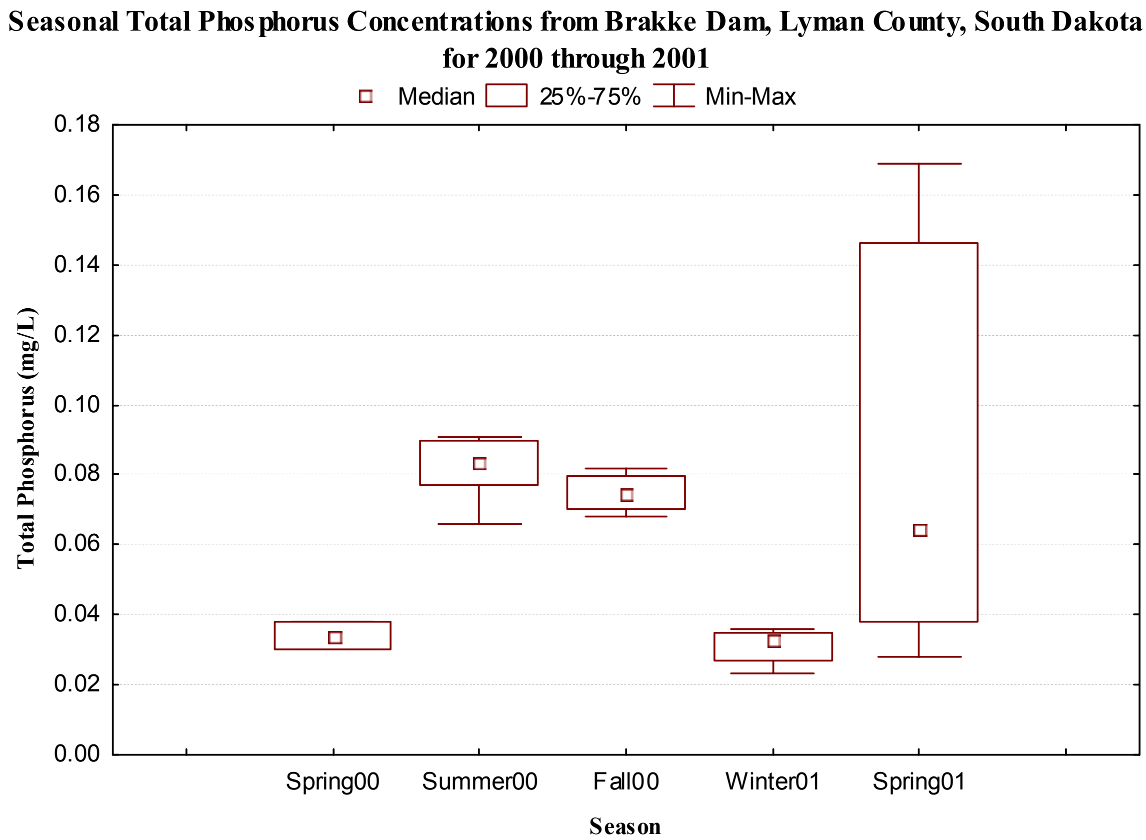


Figure 44. Seasonal statistics of in-lake total phosphorus concentrations from Brakke Dam, Lyman County, South Dakota for 2000 through 2001.

Significant total phosphorus loading from Brakke Creek occurred from late March through May 2001 (Figure 21 and Table 24) and contributed to peak in-lake total phosphorus concentrations in May 2001 (Figure 43). Increased in-lake concentrations were from both tributary and internal loading of total phosphorus in 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 during this time.

Data indicate that a reduction in total phosphorus is needed in the watershed and in Brakke Dam to meet designated beneficial uses based on reference lake criteria for ecoregion 43. At a minimum, in-lake Trophic State Index (TSI) values indicate that a 79.1 percent reduction in tributary total phosphorus loading is needed to generate mean in-lake TSI values to meet current ecoregion targeted designated beneficial uses based on reference lake criteria for ecoregion 43. Every effort should be made to improve current management practices to control and reduce sediment and nutrient runoff in the Brakke Dam watershed.

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 Brakke Dam.

Generally, increased total suspended solids concentrations decrease concentrations of available total dissolved phosphorus; however, during this study total suspended solids showed almost no relationship to total dissolved phosphorus (R^2=0.007). The overall average percent phosphorus that was dissolved during the project was 38.3 percent. Percentages of total dissolved phosphorus ranged from 15.1 percent in the summer of 2000 to 77.8 percent in the spring of 2001. The median dissolved phosphorus concentration in Brakke Dam was 0.018 mg/L (mean 0.026 mg/L), with a maximum of 0.110 mg/L and a minimum concentration of 0.005 mg/L. Since algae only need 0.02 mg/L of phosphorus to produce an algal bloom (Wetzel, 1983), Brakke Dam averages 1.3 times the available total dissolved phosphorus needed for algal blooms. No significant differences in total dissolved phosphorus concentrations were detected between in-lake sampling sites (Table 28).

Seasonal average total dissolved phosphorus concentrations were lowest in the spring of 2000 (0.005 mg/L) and increased to the highest average concentration (0.044 mg/L) in the spring of 2001 (Figure 45 and Table 32).

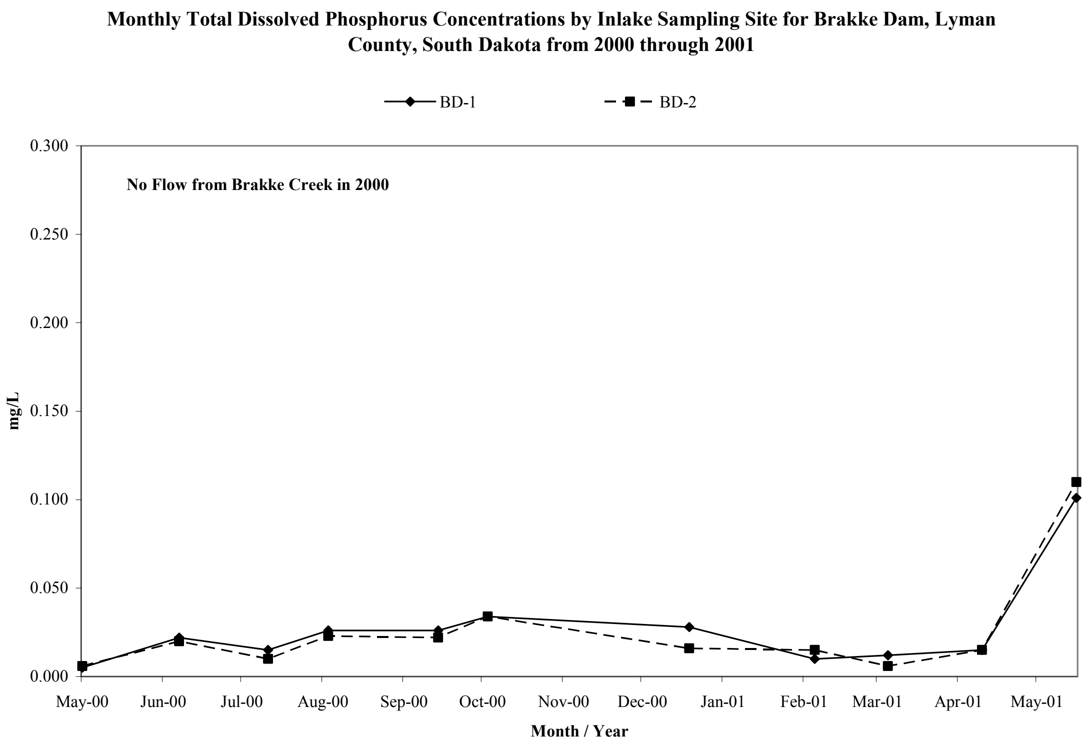


Figure 45. Monthly surface total dissolved phosphorus concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Data indicate that while algal densities in Brakke Dam were relatively high in spring of 2001, those densities did not produce thick floating mats of algae in Brakke Dam. Since no nuisance 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 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.

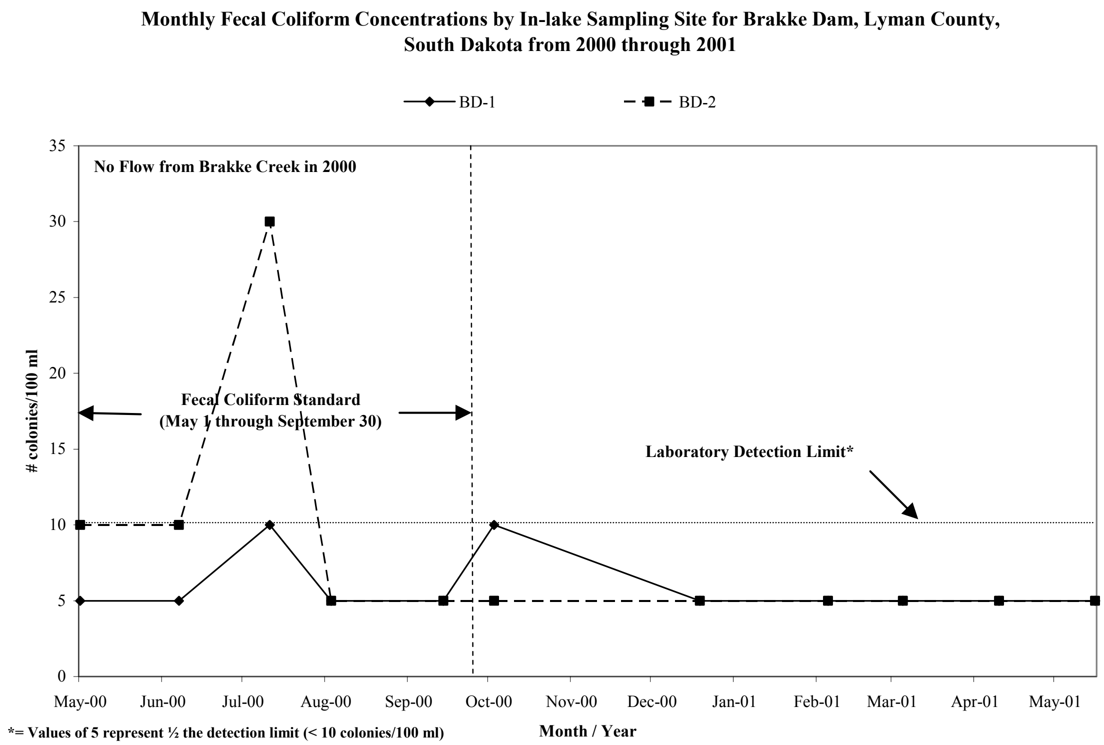


Figure 46. Surface fecal coliform bacteria colonies per 100 milliliters by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

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 22 individual samples collected, 95.5 percent of fecal coliform concentrations were at or below detection limits (Figure 46). The maximum count/concentration (30 colonies/100 ml) was collected in July of 2000 at BD-2. 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 colonies/100 ml (mean, 7 colonies/100 ml). No significant differences in fecal coliform counts were detected between in-lake sampling sites (Table 28).

Fecal coliform samples collected from MCT-12 (Brakke Creek water quality monitoring site) upstream of Brakke Dam had one elevated fecal coliform count in excess of 2,000 colonies/100 ml (Table 8 and Figure 23). Elevated fecal coliform values in April did not translate to elevated in-lake fecal coliform bacteria (Table 8, Figure 23 and Figure 46). This is due in part to increased exposure to sunlight, dilution and hydrologic residence time in Brakke Dam. In-lake fecal coliform concentrations 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. Over all, the chlorophyll-*a* concentrations in Brakke Dam were relatively high (Figure 44).

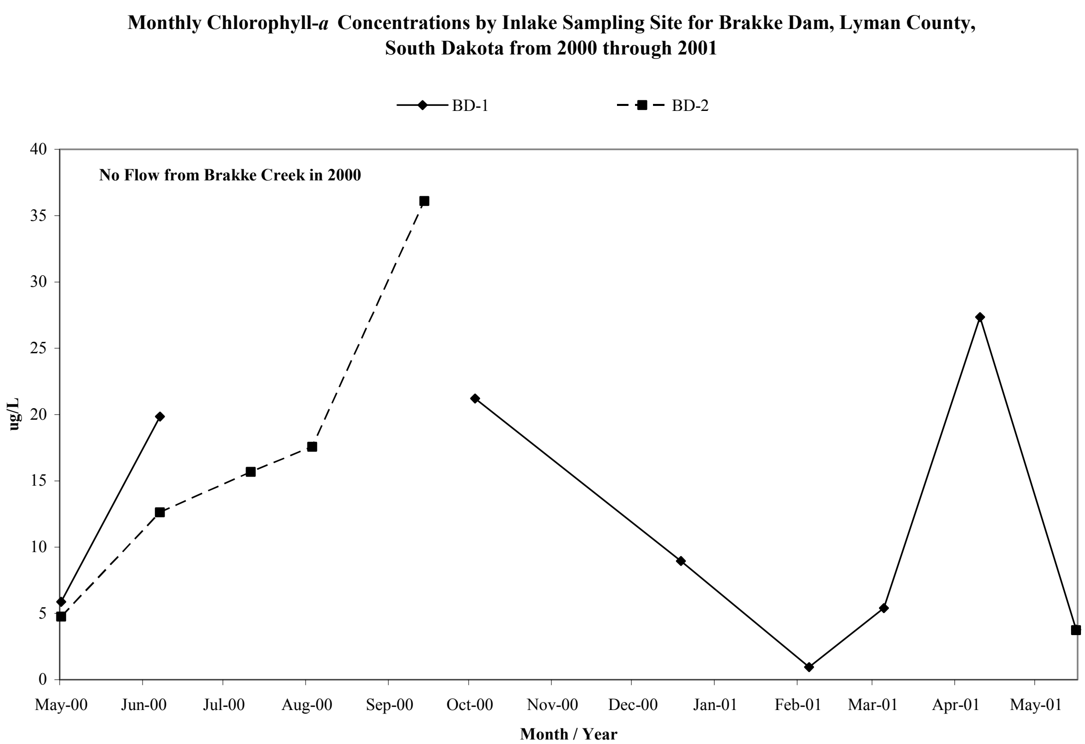


Figure 47. Monthly surface in-lake chlorophyll-*a* concentrations by date and sampling site for Brakke Dam, Lyman County, South Dakota in 1999 and 2000.

The maximum in-lake chlorophyll-*a* concentration (36 µg/L) was collected on September 14, 2000 at BD-2 (Figure 47). The median chlorophyll-*a* concentration for the project was 11 µg/L and a mean concentration of 13 µg/L. Only three samples were collected on various dates at BL-2.

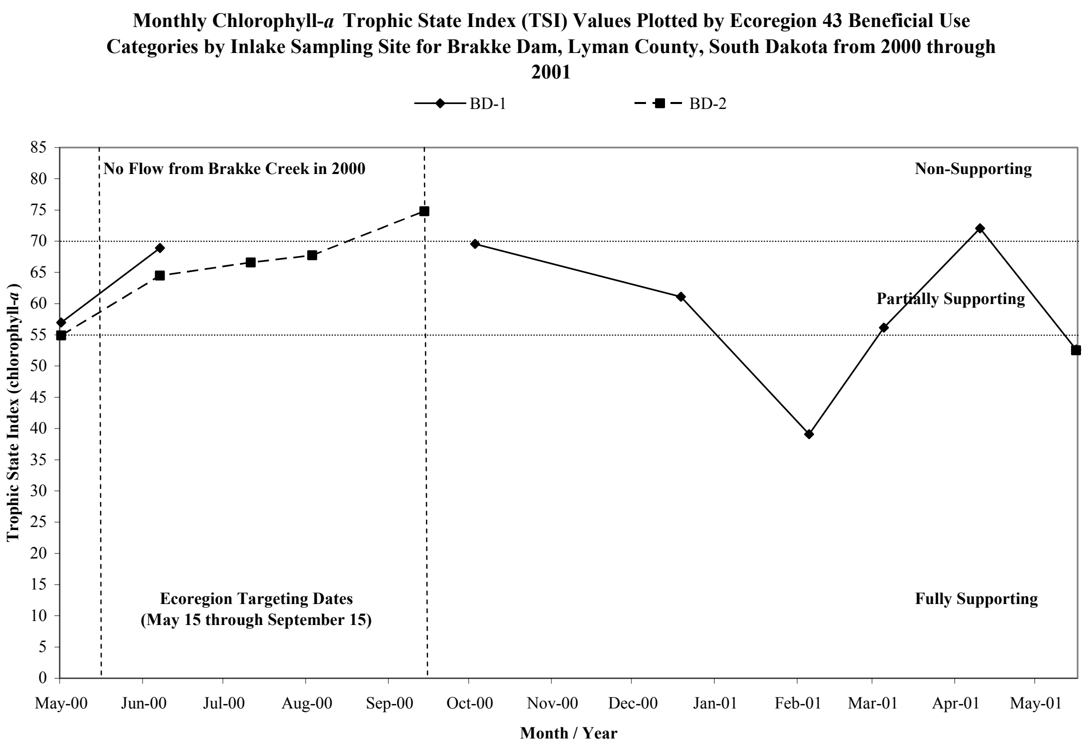


Figure 48. Monthly chlorophyll-*a* Trophic State Index (TSI) by beneficial use support categories, date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

If chlorophyll-*a* was the only parameter used to estimate the trophic status of lakes, Brakke Dam would be rated eutrophic and partially-supporting with an average TSI value of 61.25 (Figure 48 and Figure 49). Figure 48 indicate that two of the fourteen samples analyzed during the project had TSI values were not supporting beneficial uses based on current ecoregional targeting, and using Carlson's trophic categories, six of the fourteen TSI values that were in the hyper-eutrophic range > 65.00 (Figure 49). No significant differences in chlorophyll-*a* concentrations were detected between in-lake sampling sites (Table 28).

Typically, chlorophyll-*a* and total phosphorus have direct relationships. As total phosphorus concentrations increase, so do chlorophyll-*a* concentrations. Each lake usually shows a different relationship because of factors including, but not limited to: nutrient ratios, temperature, light, suspended sediment, and hydrologic residence time.

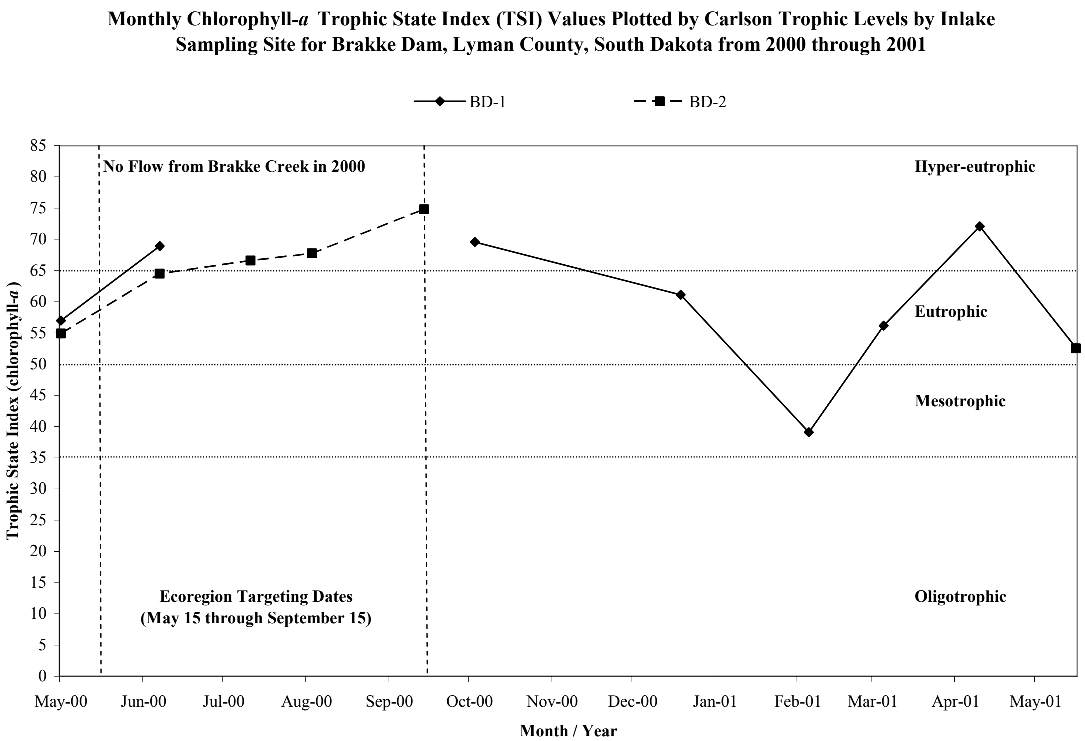


Figure 49. Monthly chlorophyll-*a* Trophic State Index (TSI) by Carlson trophic categories, date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Chlorophyll-*a* and total phosphorus concentrations were transformed using Log $_{(10)}$ to linearize the data. Chlorophyll-*a* samples for the two sites were plotted against total phosphorus concentrations based on ecoregion targeting dates to determine their relationship in Brakke 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 chlorophyll-*a* to total phosphorus relationship was calculated as having a $R^2 = 0.1046$ (Figure 50). This indicates that total phosphorus is a poor predictor of chlorophyll-*a* concentrations in Brakke Dam.

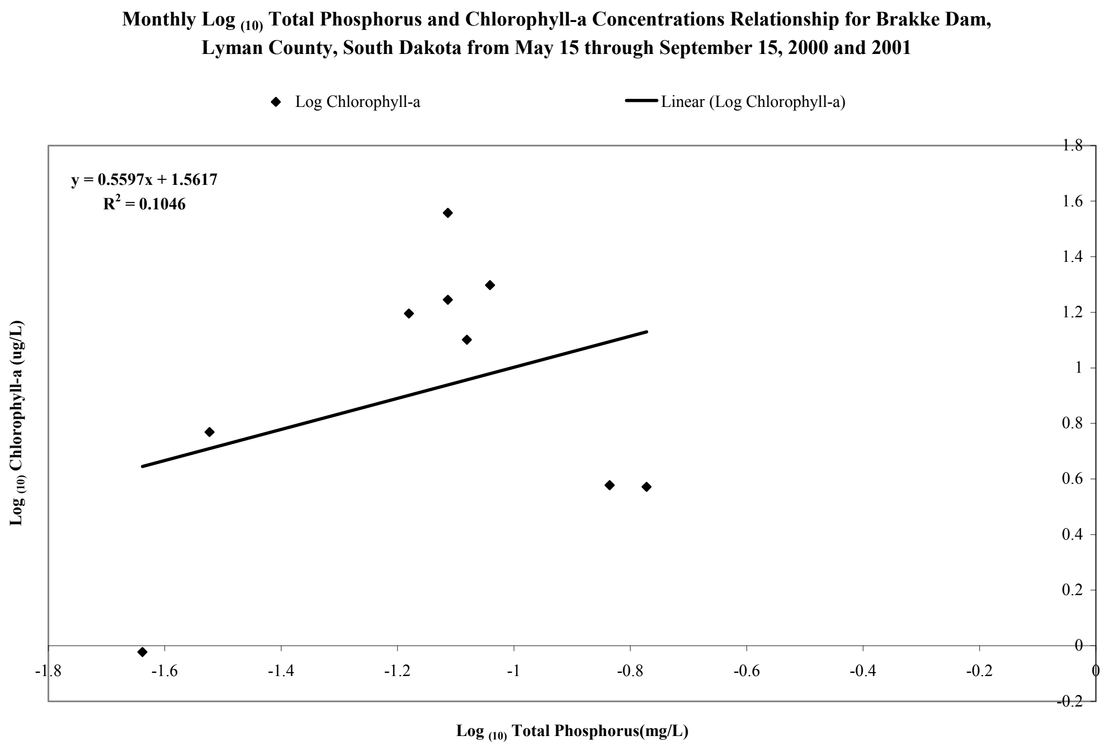


Figure 50. Log (10) chlorophyll-*a* vs. log (10) total phosphorus concentrations relationship by date and in-lake sampling site for Brakke Dam, Lyman County, South Dakota from May 15 through September 15, 2000 through 2001.

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.

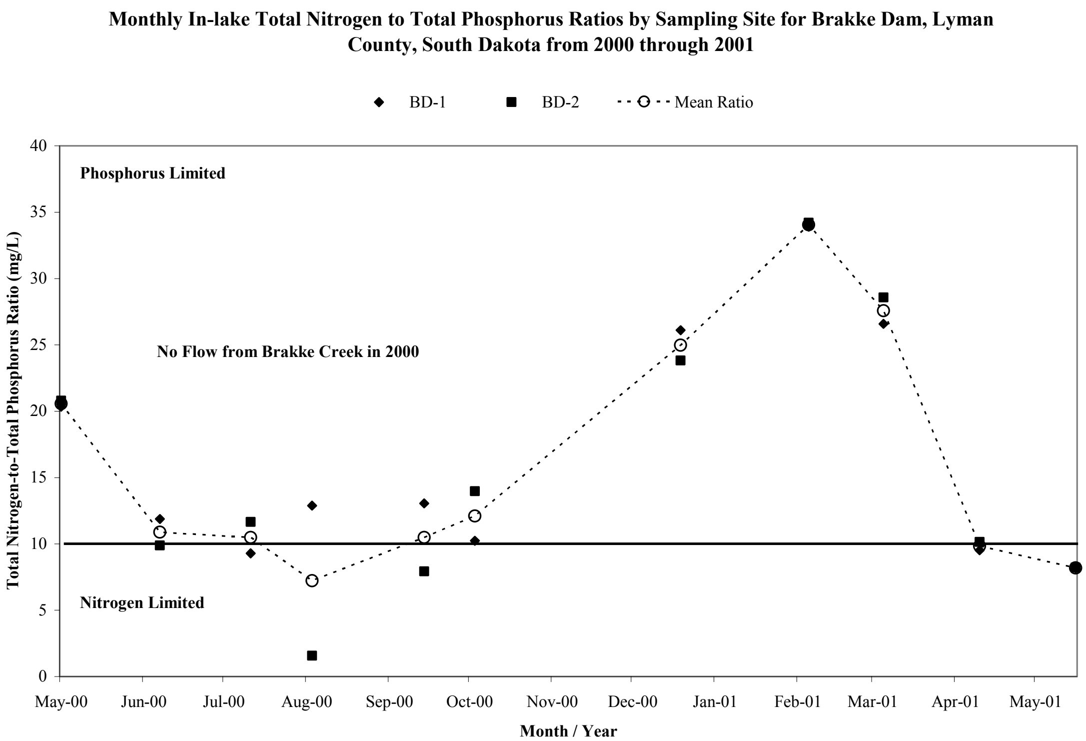


Figure 51. Surface total nitrogen-to-total phosphorus ratios by date and sampling site for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

During the project, Brakke Dam was generally phosphorus-limited (Figure 51). The median total nitrogen-to-total phosphorus ratio in Figure 51 was 12.4:1 (phosphorus-limited above 10) with a mean of 16.0:1. Brakke Dam was slightly nitrogen-limited in August of 2000 and May of 2001 (Figure 51). All total nitrogen to total phosphorus ratios between in-lake sampling sites (BD-1 and BD-2) were not significantly different (Table 28).

As stated earlier, limiting factors can be anything physical or chemical that limits the growth or production of organisms. Generally, total nitrogen to total phosphorus ratios were steady throughout the spring and summer and became phosphorus limited from the late fall 2000 through the winter of 2001. Algal densities (cells/ml) increased September through October of 2000 and March through April 2001 in Brakke Dam (Figure 52).

One compounding factor in algal response to nutrient limitation is the lack of flow from Brakke Creek into Brakke Dam in 2000. During the spring and summer of 2000, algal densities were relatively low and increased dramatically in the fall with relatively steady total nitrogen to total phosphorus ratios. This indicates that during drought conditions in the Brakke Dam watershed, nutrients may not be as limiting as other factors in determining algae population densities.

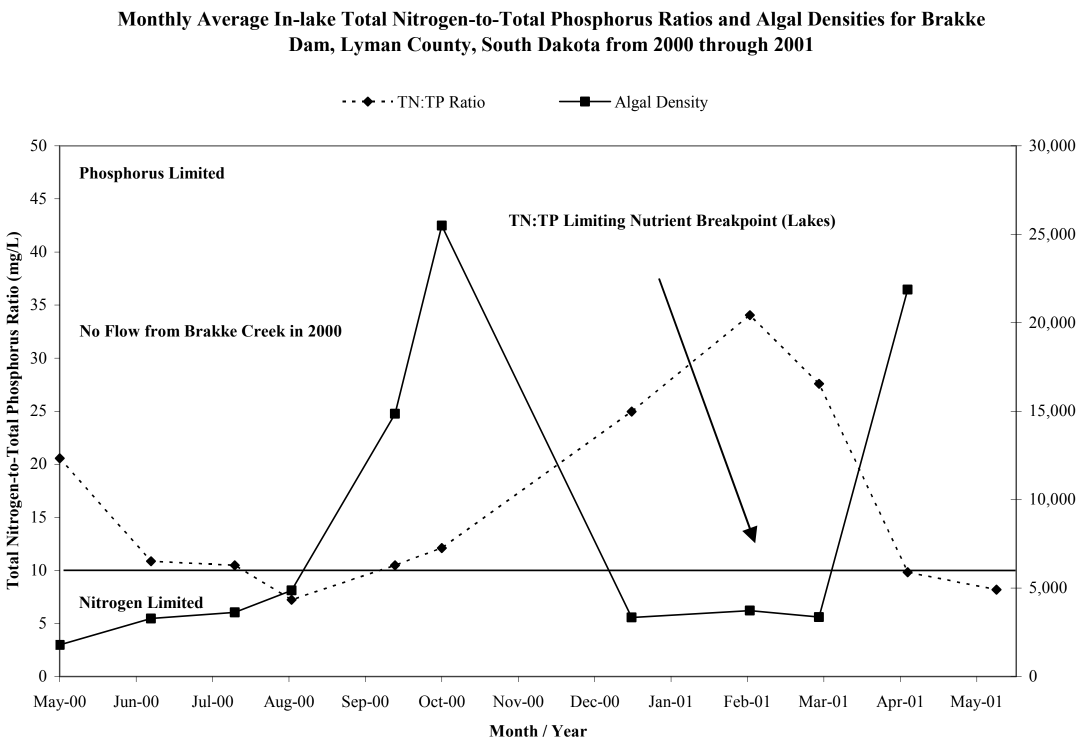


Figure 52. Monthly average surface total nitrogen-to-total phosphorus ratios and algal densities (cells/ml) for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Hydrologic, Sediment and Nutrient Budgets for Brakke Dam

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 Brakke Dam included precipitation, tributary runoff, both gauged and ungauged areas of the watershed. Hydrologic output from Brakke 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. Brakke Dam was 0.75 m (2.47 feet) below spillway height at the beginning of the study and was used as initial volume loss. The initial volume loss totaled 319.77 acre-feet (Table 33). During the study period, water was at or below the level of the spillway 337 days out of 394 days of monitoring (85.5 percent).

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

Tributary	Input (acre-feet)	Tributary	Output (acre-feet)
West Tributary MCT-11	1,184.44	**Outlet Discharge (MCT-10)**	729.81
East Tributary MCT-12	111.06	**Evaporation**	411.67
Rainfall on Brakke Dam	165.75	**Initial Volume Loss**	319.77
Total	**1,461.25**		**1,461.25**

The hydrologic budget for Brakke 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, 1996). One factor never directly measured in Brakke Dam was the total volume of ground water that passed through the lake. Ground water in the area (based on alluvial wells (all are ≥ 30 feet)) is relatively deep and generally of poor drinking water quality. 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 Brakke Dam was MCT-11 at 81.1 percent of the total hydrologic load, followed by rainfall directly on Brakke Dam contributing 11.3 percent. The hydraulic residence is the time between when water enters a reactor (lake) and the same water leaves the reactor. The hydraulic residence time when Brakke Dam is full was estimated at 1.017 years or 371.2 days (calculated using BATHTUB (Walker, 1999)).

Total 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 the data collected from Brakke Creek and the estimated amount from the ungauged portion of the watershed, Brakke Dam received approximately 38.2 m^3 (0.03 acre-foot) of sediment, during this study. The volume of sediment was calculated by dividing the annual kilograms of sediment (82,656 kg) by 2,162.5 kg/m^3 (Stueven and Bren, 1999).

The calculation of total suspended solids at the outlet (MCT-10) found approximately 22,938 kg or 10.6 m^3 (0.009 acre-foot) of sediment leaving Brakke Dam. The amount of suspended solids retained in Brakke Dam during this study was approximately 59,718 kg, which is 27.6 m^3 (0.02 acre-foot) or 72.2 percent of the total of suspended solids loading to the lake (Figure 53). This translates to an overall increase of 0.05 mm in sediment depth over the entire lake during the project.

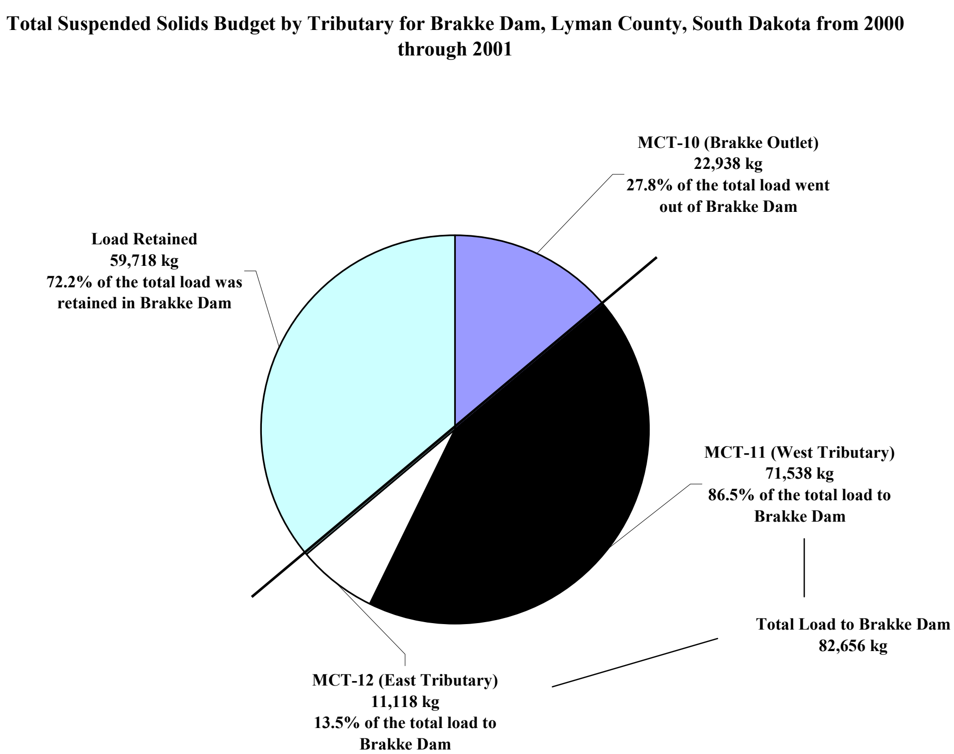


Figure 53. Total suspended solids budget for Brakke Dam, Lyman County, South Dakota by source from 2000 through 2001.

To estimate the average organic portion of total suspended solids leaving Brakke Dam, the total kilograms per year of volatile total suspended solids (VTSS) were divided by total suspended solids to predict the percentage of organic suspended solids. The organic percentage of suspended solids measured at MCT-11 and MCT-12 (Brakke Dam inlets) during the project was

9.1 percent. In comparison, the overall average in-lake percentage of volatile total suspended solids at BD-1 was 21.2 percent while the percentage of volatile total suspended solids at BD-2 was 30.7 percent (Brakke Dam average 25.7 percent). An increase in organic composition of total suspended solids from tributary to in-lake percentages was observed in Brakke Dam. A large portion of this increase may be attributed to in-lake algal populations. The estimated volatile total suspended solids percentage discharged from Brakke Dam (MCT-10) was 7.7 percent. Reducing suspended solids concentrations to Brakke Dam should be beneficial in reducing trophic state indices and the non-supporting (hyper-eutrophic) condition of the lake.

Total Nitrogen Budget

Total nitrogen concentrations are derived by adding TKN concentrations to nitrate–nitrite concentrations. Approximately 1,194 kg (1.3 tons) or 53.8 percent of the total nitrogen load was retained in Brakke Dam during the project. Figure 54 indicates a total nitrogen load of 2,219 kg (2.4 tons) to Brakke Dam. 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, while in-lake ratios were generally phosphorus-limited from 2000 through 2001 (Figure 24 and Figure 51). All forms of nitrogen can eventually be reduced (broken down) and reused for algal growth. Reducing the influx of nitrogen will be beneficial for reducing the hyper-eutrophic (non-supporting) condition found in Brakke Dam.

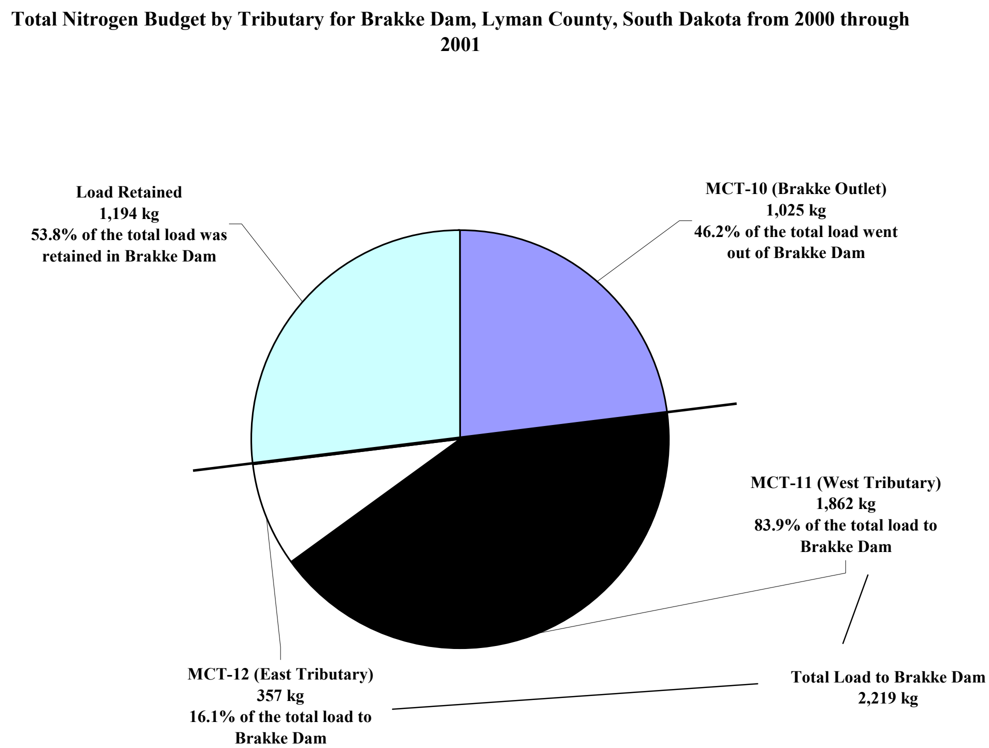


Figure 54. Total nitrogen budget for Brakke Dam, Lyman County, South Dakota by source from 2000 through 2001.

Total Phosphorus Budget

Total phosphorus inputs during the 2000 through 2001 sampling season totaled approximately 618 kg (0.68 tons) to Brakke Dam (Figure 55). 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 Brakke Dam was calculated using BATHTUB (Walker, 1996) and was estimated to be 0.175 years or 63.8 days.

The total load out of Brakke Dam over the spillway (MCT-10) was approximately 189 kg (416.7 pounds). During the 2000 through 2001 sampling season, there was an estimated 429 kg (0.47 tons), or 69.4 percent of the phosphorus entering Brakke Dam stayed and was available to be utilized in the lake. In-lake total phosphorus concentrations of were relatively stable throughout the 2000 (drought) sampling season and increased during tributary runoff, April through May 2001 (Figure 43). Variable total phosphorus concentrations and total nitrogen concentrations contributed to the nutrient limitations (phosphorus) observed in Brakke Dam from 2000 through 2001 (Figure 51).

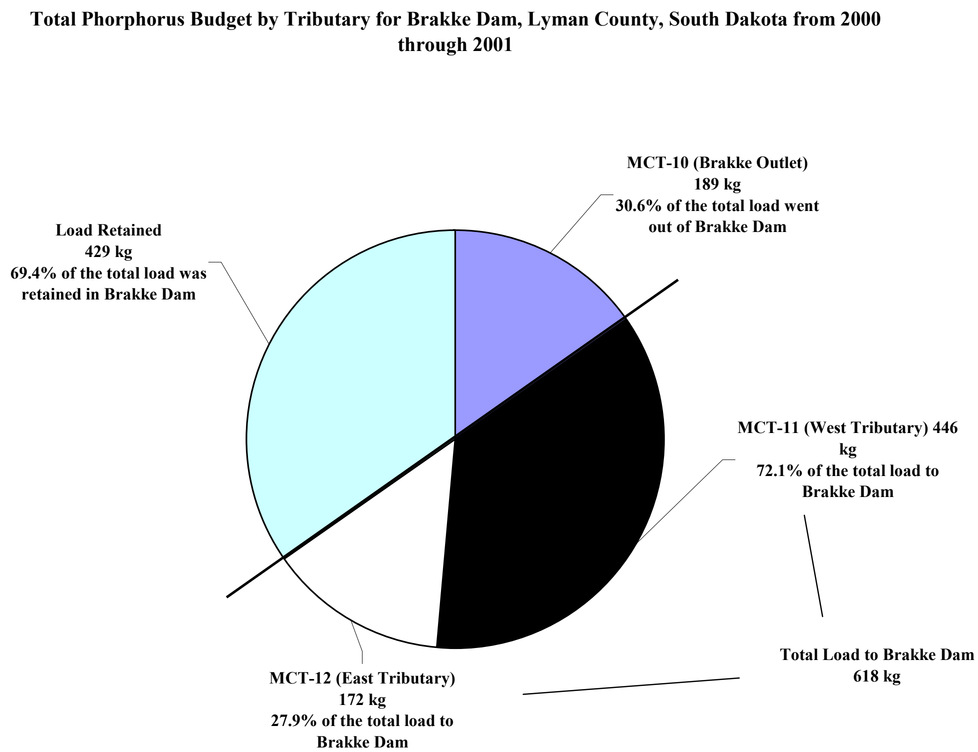


Figure 55. Total phosphorus budget for Brakke Dam, Lyman County, South Dakota by source from 2000 through 2001.

Fluctuations in in-lake total phosphorus did not appear to be from the release of phosphorus from bottom sediments (internal loading) because surface water total phosphorus concentrations were not significantly different from bottom concentrations collected at the same time (Table 28). Reducing the influx of total phosphorus will improve the overall trophic state of the lake and increase the beneficial use status of Brakke Dam.

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 Brakke Dam are shown in Table 34 and a graph showing the TSI parameters for 2000 and 2001 is plotted on Carlson's trophic levels as shown in Figure 56.

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. In 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. There are three beneficial use categories: non-supporting, partially supporting and fully supporting. Numeric ranges for beneficial use categories are shown in Table 35. Brakke Dam is in Ecoregion 43 and is categorized as non-supporting based on the document above. However, based on current data from this assessment, Brakke Dam has improved slightly and has a beneficial use category of partially supporting (Table 37).

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 ecoregion 43 beneficial use categories in Figure 57 and proposed Brakke Dam (site specific) beneficial use categories in Figure 58. Generally, most of the TSI values (especially total phosphorus and chlorophyll-*a* TSI values) were in the partially supporting category. Currently (based on assessment data), Brakke Dam is categorized as partially supporting using both targeted ecoregion 43 and proposed Brakke Dam (site specific) beneficial use categories, with the combined ecoregion targeted mean and median TSI rating 67.90 and 67.08, respectively (Table 37). Based on Carlson trophic levels, Brakke Dam ecoregion targeted combined mean and median TSI rating were hyper-eutrophic (Figure 56 and Table 37). Individually, total phosphorus, chlorophyll-*a* and Secchi mean and median TSI values were generally partially supporting/hyper-eutrophic (Figure 56, Figure 57, Figure 58 and Table 37).

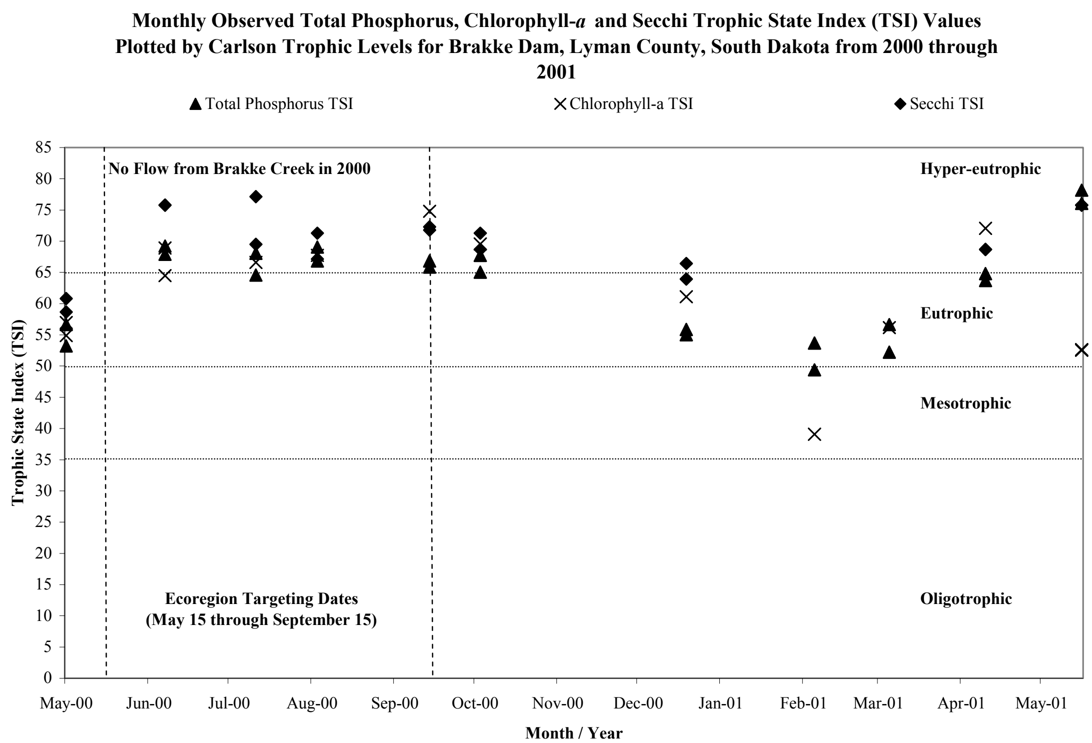


Figure 56. Monthly TSI values for total phosphorus, Secchi and chlorophyll-*a* TSI plotted by Carlson trophic level from Brakke Dam, Lyman County, South Dakota by date from 2000 through 2001.

Based on current data, Brakke Dam would not meet targeted ecoregion 43 beneficial use criteria because unrealistic reductions in total phosphorus loads (79.1 percent) would be needed to achieve ecoregion 43 criteria (Table 35). Data also suggests Brakke Dam does not currently meet the proposed Brakke Dam (site specific) beneficial use criteria (Table 36 and Figure 58). Brakke Dam attainability based on site specific beneficial use criteria (Table 37) and would require approximately a 10 percent reduction in total phosphorus to meet TSI based beneficial use criteria. BMP reductions in total phosphorus will lower total phosphorus, Secchi and chlorophyll-*a* TSI values, improving water quality in Brakke Dam and its' watershed.

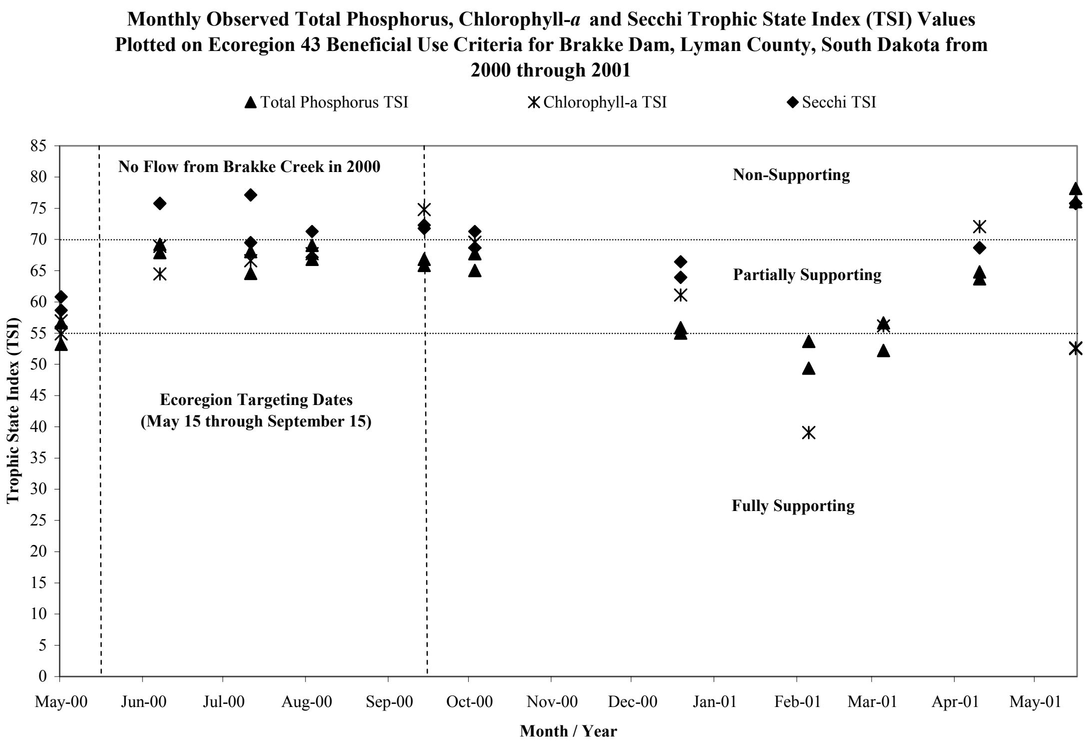


Figure 57. TSI values for phosphorus, chlorophyll-*a* and Secchi TSI plotted by Ecoregion 43 beneficial use categories for Brakke Dam, Lyman County, South Dakota by date in 2000 and 2001.

Table 36. Proposed site specific beneficial use categories for Brakke Dam.

Brakke Dam Beneficial Use Categories	TSI Numeric Range
Non-Supporting	76 – 100
Partially Supporting	66 – 75
Fully Supporting	0 – 65

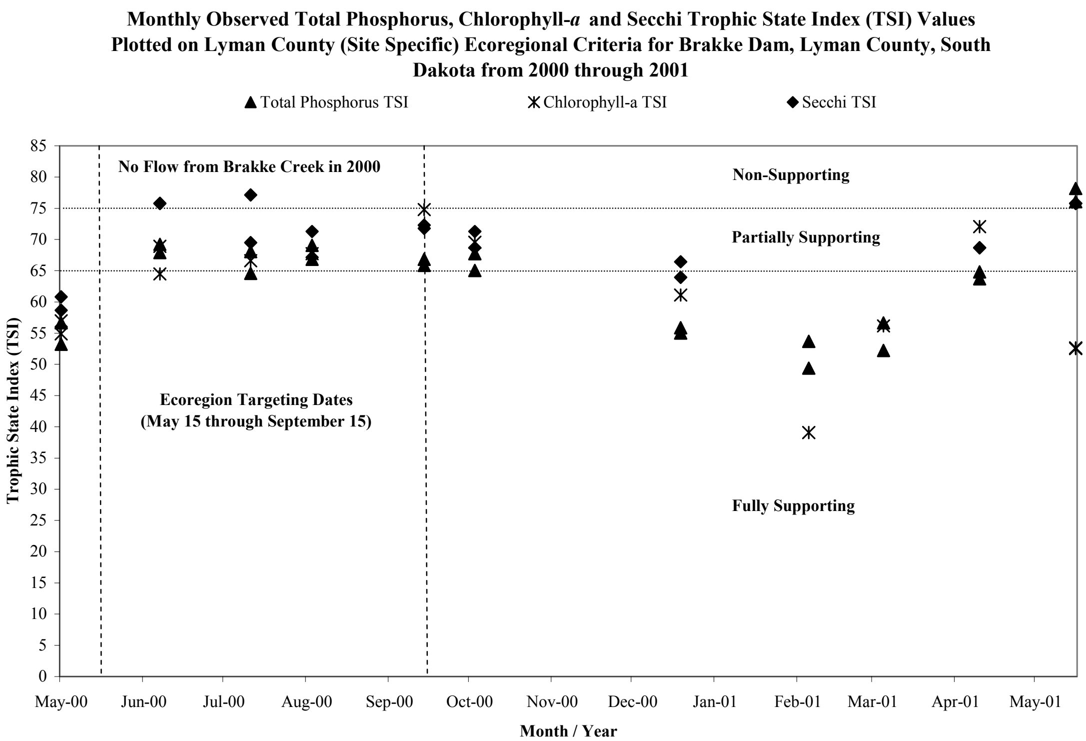


Figure 58. TSI values for phosphorus, chlorophyll-*a* and Secchi TSI plotted by proposed Lyman County (site specific) beneficial use categories for Brakke Dam, Lyman County, South Dakota by date in 2000 and 2001.

Table 37. Descriptive statistics for observed Trophic State Index values for ecoregion targeted dates and all dates collected in Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Parameter	Total Phosphorus	Chlorophyll-*a*	Secchi Depth	Parameters Combined
Ecoregion Targeted Dates (May 15 through September 15)				
Mean TSI	66.87	62.17	70.97	67.08
Median TSI	67.36	64.47	72.03	67.90
Standard Deviation	6.89	8.10	6.06	7.60
All Dates (May 2000 through May 2001)				
Mean TSI	63.02	61.25	69.96	64.87
Median TSI	64.92	62.79	70.39	66.82
Standard Deviation	7.79	9.75	5.27	8.36

Long-Term Trophic State Index Trend

Because there were a number of samples collected from this study and during the Statewide Lake Assessment (Stueven and Stewart 1996) it was possible to make some assumptions about water quality trends (TSI) in Brakke Dam over time. Since the samples taken in 1989, 1991, 1992 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 59 and Figure 60).

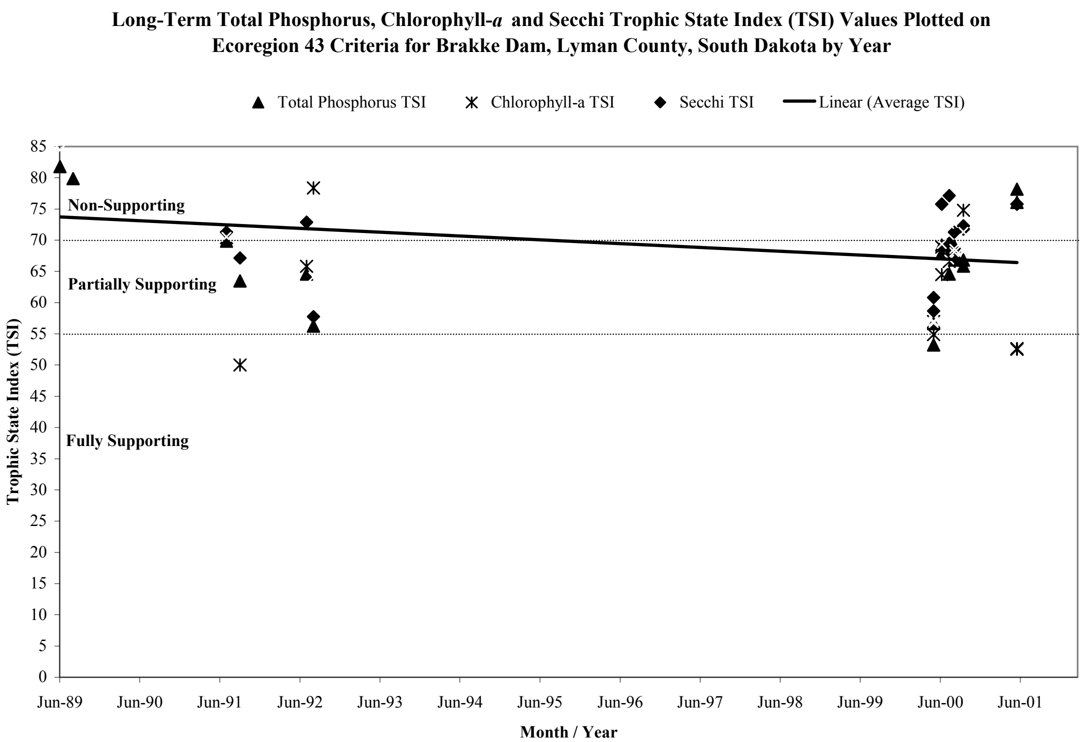


Figure 59. Long-term summer TSI trend for phosphorus, chlorophyll-*a* concentrations and Secchi depth plotted by Ecoregion 43 trophic level criteria s for Brakke Dam, Lyman County, South Dakota by year date.

The general trend for all TSI values (Secchi, chlorophyll-*a* and total phosphorus) showed a slight decrease from 1989 through 2001. However, the range of TSI values after 1991 only varied slightly. The higher total phosphorus only TSI values in 1989, if removed would show a nearly level trend line. No in-lake water quality samples were collected from 1993 through 1999 in Brakke Dam.

All TSI values, except for three chlorophyll-*a* values and one total phosphorus were in the non-supporting and partially supporting (eutrophic/hyper-eutrophic) categories (Figure 59). The long-term trend for all TSI values indicates a decreasing trend from the non-supporting to the partially supporting category (Figure 59). Long-term TSI trend values plotted on site specific criteria indicate a decreasing trend within the partially supporting category (Figure 60).

Mitigation projects (estimated BMP reductions) in the Brakke Dam watershed should, over time, reduce nutrient TSI values, complementing the overall trend observed from 1989 to 2001.

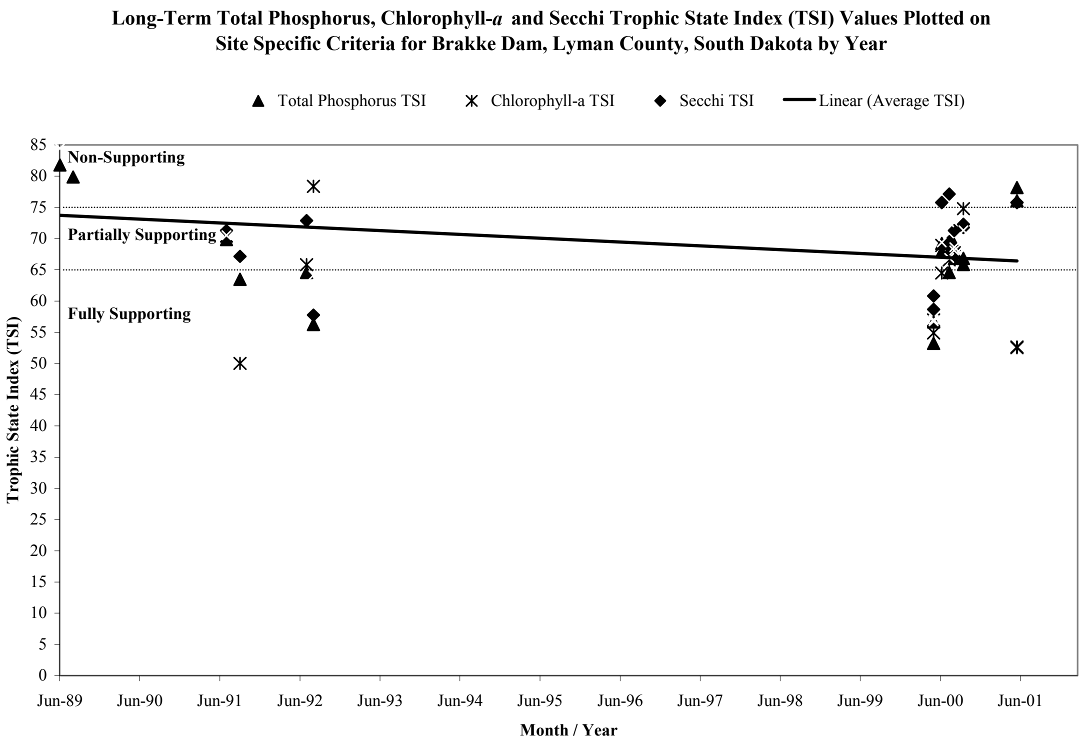


Figure 60. Long-term summer TSI trend for phosphorus, chlorophyll-*a* concentrations and Secchi depth plotted by site specific beneficial use criteria in Brakke Dam, Lyman County, South Dakota by year.

Biomass Based Spatial Comparisons

Brakke 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 with 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 61). This scenario related well with in-lake total phosphorus concentrations and algal densities. Data indicate that Brakke Dam is relatively balanced and tends to be phosphorus limited most of the year (Figure 51).

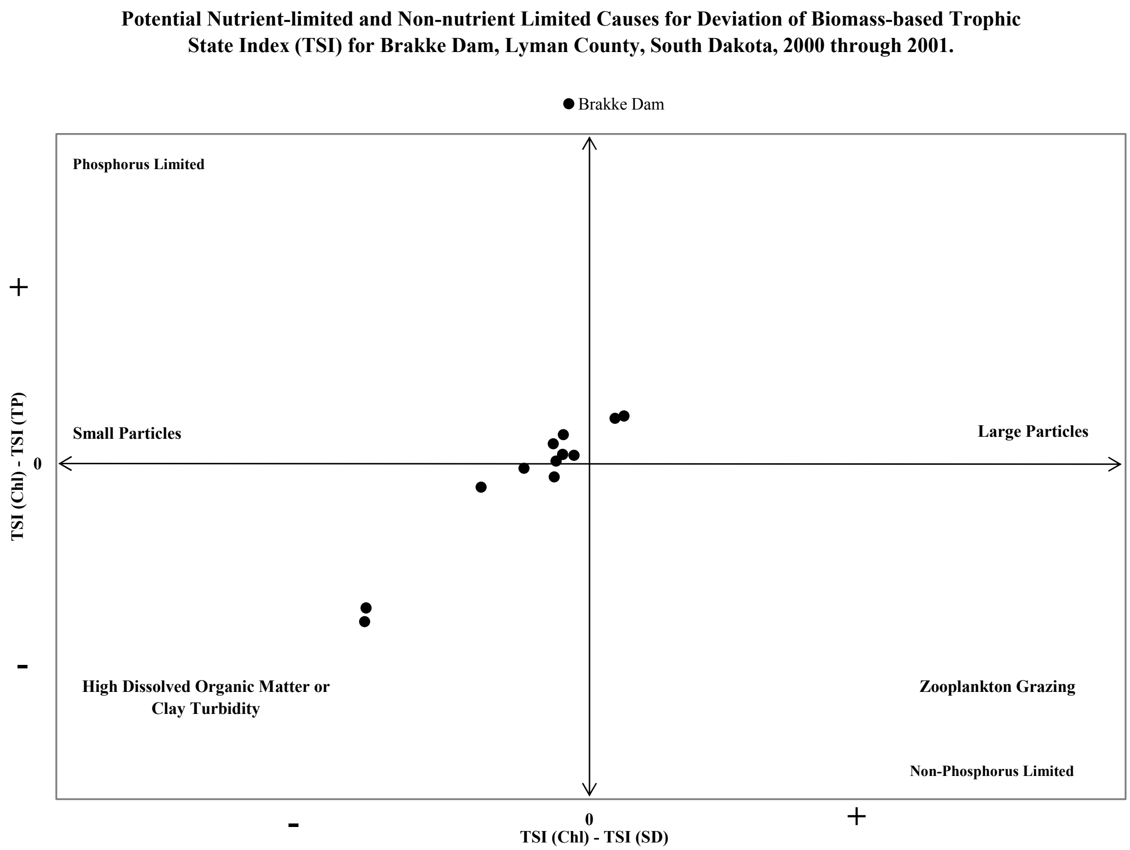


Figure 61. Potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) for Brakke Dam, Lyman County, South Dakota in 2000 and 2001.

As part of the Medicine Creek watershed assessment (2000 through 2001), data was also collected on Byre Lake and Fate Dam for separate evaluation and analysis. Brakke Dam, Fate Dam and Byre Lake TSI values adjusted using chlorophyll-*a* are provided in Figure 62 for evaluation and regional comparison.

Similar to Brakke Dam, both Fate Dam and Byre Lake, TSI data generally oscillated around zero (0), around both the X and Y-axis (Figure 62). 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 (Medicine Creek) watershed and county with similar agricultural disturbances.

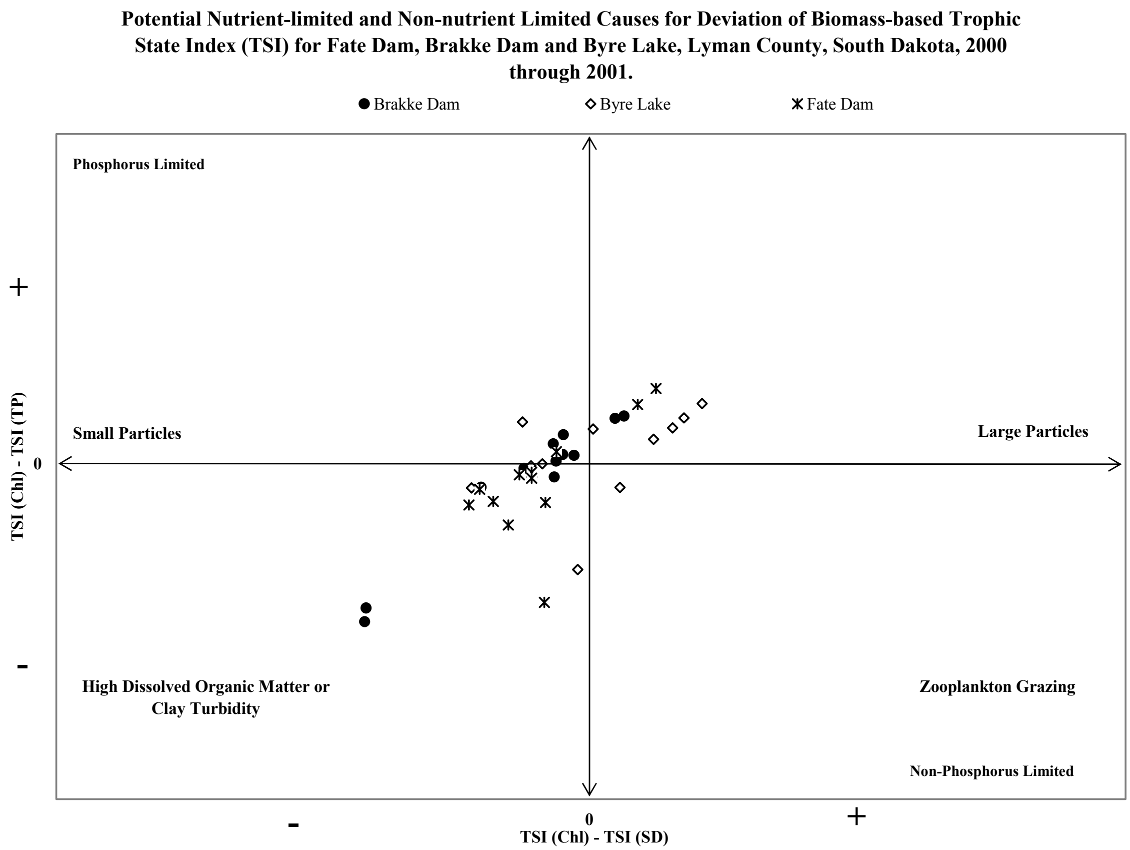


Figure 62. A comparison of potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) between Brakke Dam, Fate Dam, and Brakke Dam, Lyman County, South Dakota.

Long-term Biomass Based Spatial Trends

Long-term ecoregion targeted TSI data for Brakke Dam was also graphed to determine causes in deviation from biomass-based TSI trends (Figure 63). Brakke Dam TSI data from 1989 through 2001 (12-years) indicated neither phosphorus nor non- phosphorus limitation effected biomass (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 (1992, large algal particles) to transparency less than predicted (2001, increased organic or clay turbidity).

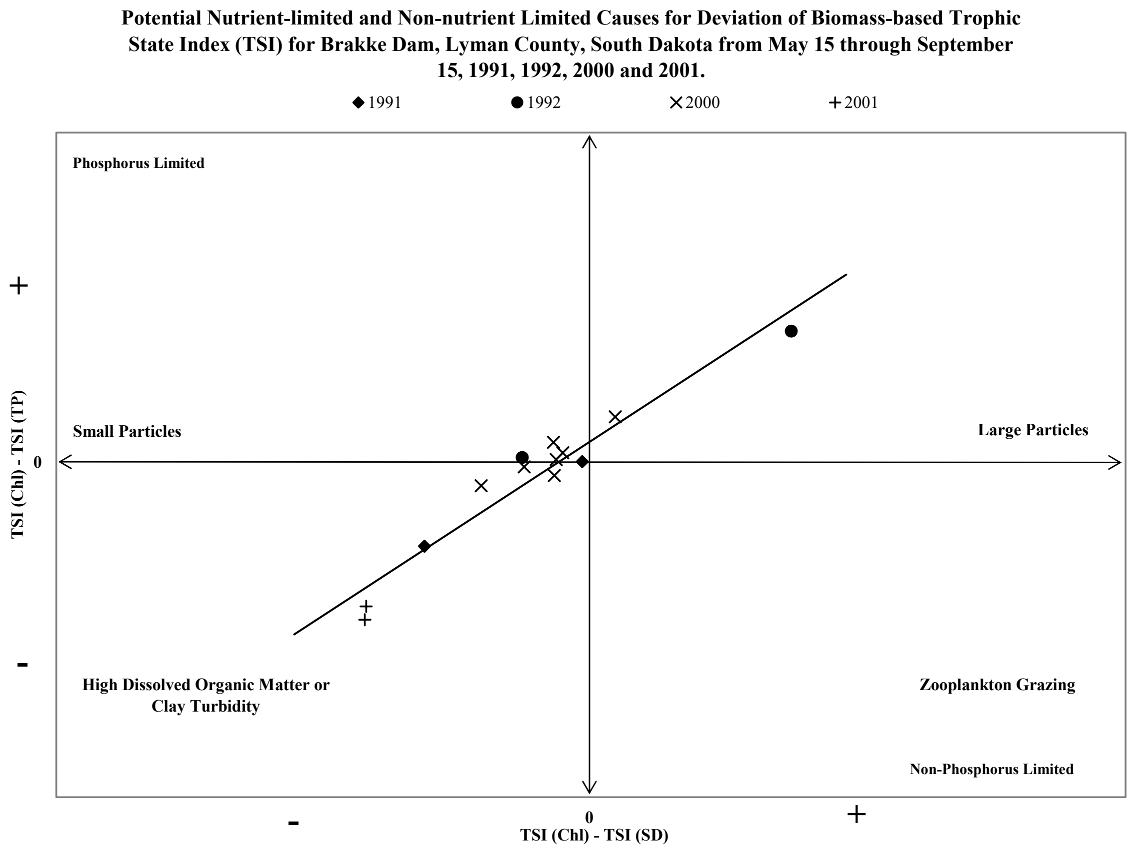


Figure 63. Long-term potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) for Brakke Dam, Lyman County, South Dakota May 15 through September 15, 1991, 1992, 2000 and 2001.

Reduction Response Model (BATHTUB)

The reduction response model used to predict in-lake response to reductions in tributary input was BATHTUB (Walker, 1996). 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 (Brakke 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 for Brakke Dam using the BATHTUB model.

Parameter	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%
Total Phosphorus (mg/m^3)	69.6	65.75	61.8	57.49	52.98	47.99	42.51	36.49	29.31	20.58	14.64	8.53
Total Nitrogen (mg/m^3)	853.4	853.4	853.4	853.4	853.4	853.4	853.4	853.4	853.4	853.4	853.4	853.4
Composite Nutrient (mg/m^3)	44.83	43.75	42.53	41.04	39.31	37.13	34.41	30.98	26.21	19.42	14.21	8.44
Chlorophyll-*a* (mg/m^3)	13.13	12.62	12.07	11.43	10.72	9.88	8.88	7.7	6.17	4.18	2.79	1.41
Secchi (Meters)	0.54	0.55	0.56	0.58	0.6	0.62	0.66	0.72	0.82	1.04	1.33	2.01
Organic Nitrogen (mg/m^3)	572.22	560.64	548.05	533.47	517.23	497.97	475.25	448.3	413.55	368.18	336.45	304.96
Total Phosphorus-Total Dissolved Phosphorus (mg/m^3)	55.72	54.82	53.84	52.7	51.43	49.93	48.15	46.05	43.34	39.79	37.32	34.86
Antilog PC-1 (Principle Components)	501.91	476.23	448.42	416.5	381.35	340.43	293.44	240.05	175.89	102.02	58.53	23.52
Antilog PC-2 (Principle Components)	4.96	4.9	4.84	4.76	4.68	4.58	4.47	4.34	4.16	3.9	3.66	3.31
(Total Nitrogen - 150) / Total Phosphorus	10.11	10.7	11.38	12.24	13.28	14.66	16.55	19.28	24	34.18	48.03	82.45
Inorganic Nitrogen / Phosphorus	20.26	26.78	38.35	66.78	216.38	355.43	378.15	405.1	439.85	485.22	516.95	548.44
Turbidity 1/M (1/Secchi – 0.025* Chlorophyll-*a*)	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54
Mixed layer Depth * Turbidity	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69
Mixed layer Depth / Secchi	5.68	5.57	5.45	5.3	5.12	4.9	4.61	4.24	3.72	2.93	2.29	1.52
Chlorophyll-*a* * Secchi	7.04	6.9	6.75	6.58	6.38	6.15	5.87	5.53	5.06	4.35	3.71	2.83
Mean Chlorophyll-*a* / Total Phosphorus	0.19	0.19	0.2	0.20	0.20	0.21	0.21	0.21	0.21	0.20	0.19	0.17
Frequency (Chlorophyll-*a* >10) %	55.16	52.64	49.74	46.25	42.15	37.06	30.79	23.2	13.83	4.31	0.9	0.03
Frequency (Chlorophyll-*a* >20) %	16.14	14.64	13.04	11.27	9.41	7.38	5.26	3.21	1.37	0.23	0.02	0
Frequency (Chlorophyll-*a* >30) %	5.02	4.4	3.77	3.1	2.44	1.78	1.15	0.61	0.21	0.02	0	0
Frequency (Chlorophyll-*a* >40) %	1.76	1.5	1.25	0.99	0.75	0.52	0.31	0.15	0.04	0	0	0
Frequency (Chlorophyll-*a* >50) %	0.68	0.57	0.46	0.36	0.26	0.17	0.1	0.04	0.01	0	0	0
Frequency (Chlorophyll-*a* >60) %	0.29	0.24	0.19	0.14	0.1	0.06	0.03	0.01	0	0	0	0
Carlson TSI-(Phosphorus)	65.33	64.51	63.62	62.57	61.4	59.97	58.22	56.02	52.86	47.76	42.85	35.06
Carlson TSI-(Chlorophyll-*a*)[1]	55.86	55.47	55.04	54.5	53.87	53.07	52.02	50.62	48.46	44.64	40.67	33.97
Carlson TSI-(Secchi)	68.97	68.7	68.37	67.97	67.48	66.83	65.96	64.77	62.87	59.45	55.89	49.97
Mean TSI	63.39	62.89	62.34	61.68	60.92	59.96	58.73	57.14	54.73	50.62	46.47	39.67

[1] = Values not adjusted by measured chlorophyll-a

Existing average tributary phosphorus concentrations (MCT-11 (west tributary) 0.346 mg/L and MCT-12 (east tributary) 0.857 mg/L) were reduced by 10 percent successively and modeled to create an in-lake reduction curve. Reductions in each TSI category (Secchi, total phosphorus and chlorophyll-*a*) are plotted by Brakke Dam site specific beneficial use categories separately in Figure 64.

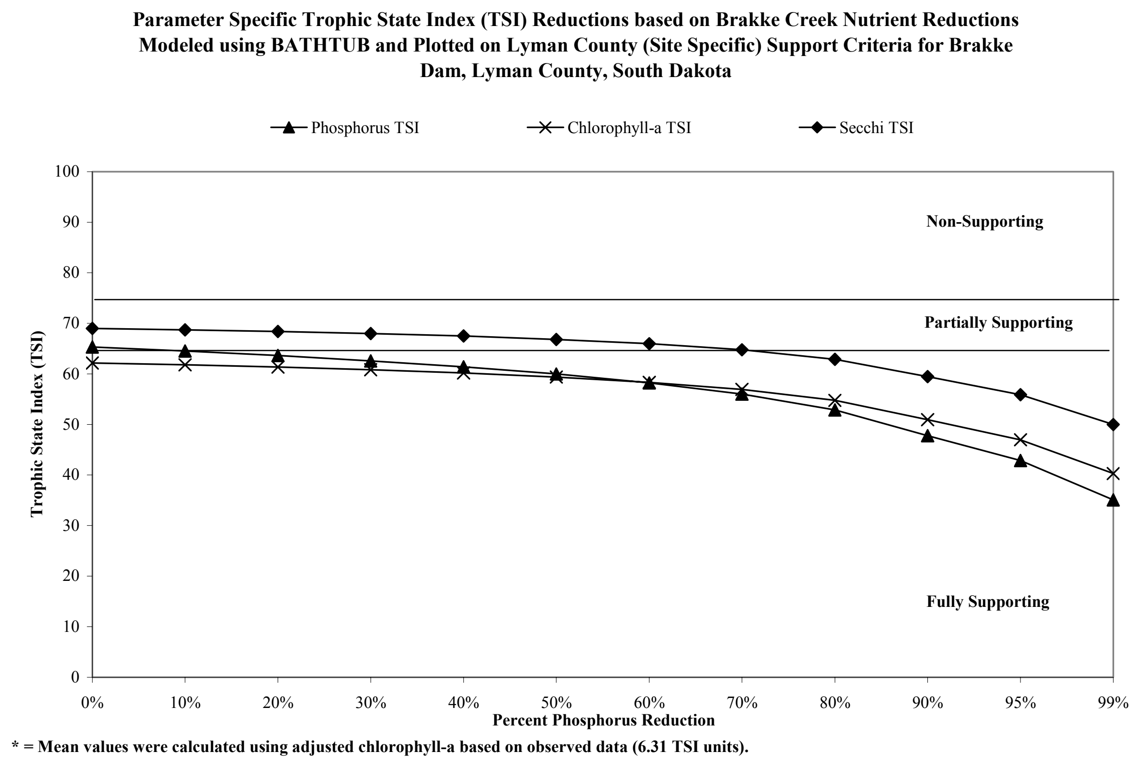


Figure 64. Predicted Trophic State Index (TSI) reductions using the BATHTUB reduction model ranked by Lyman County beneficial use criteria for Brakke Dam, Lyman County, South Dakota using 2001 loading data.

Initial Chlorophyll-a Trophic State Index (TSI) value was the only parameter to begin in the fully supporting category based on Brakke Dam site specific beneficial use categories. Total phosphorus and Secchi TSI values both begin within the partially supporting category. Predicted reduction TSI values for total phosphorus declined faster than chlorophyll-*a* and Secchi TSI reduction values.

Mean TSI values were calculated for each reduction and plotted by Brakke Dam site specific beneficial use categories (Figure 65). Current mean TSI values for Brakke Dam were calculated using "BATHTUB" and indicated partially supporting. However, using 2000 through 2001 data, BATHTUB modeling did not model observed chlorophyll-*a* response well when compared with actual observed (calculated) values (chlorophyll-*a* observed-62.17, modeled-55.86). Chlorophyll-*a* model calibration procedures were performed in BATHTUB and the best fit model was used in reduction modeling. Using this scenario, initial chlorophyll-*a* TSI values were suppressed 6.31 TSI units. Modeled initial and reduction chlorophyll-a TSI values were adjusted up 6.31 TSI units to represent current conditions. Chlorophyll-a and mean TSI values in Table 38 are actual modeled values (unadjusted); while Figure 65 represents mean initial and reduction TSI values adjusted for chlorophyll-a.

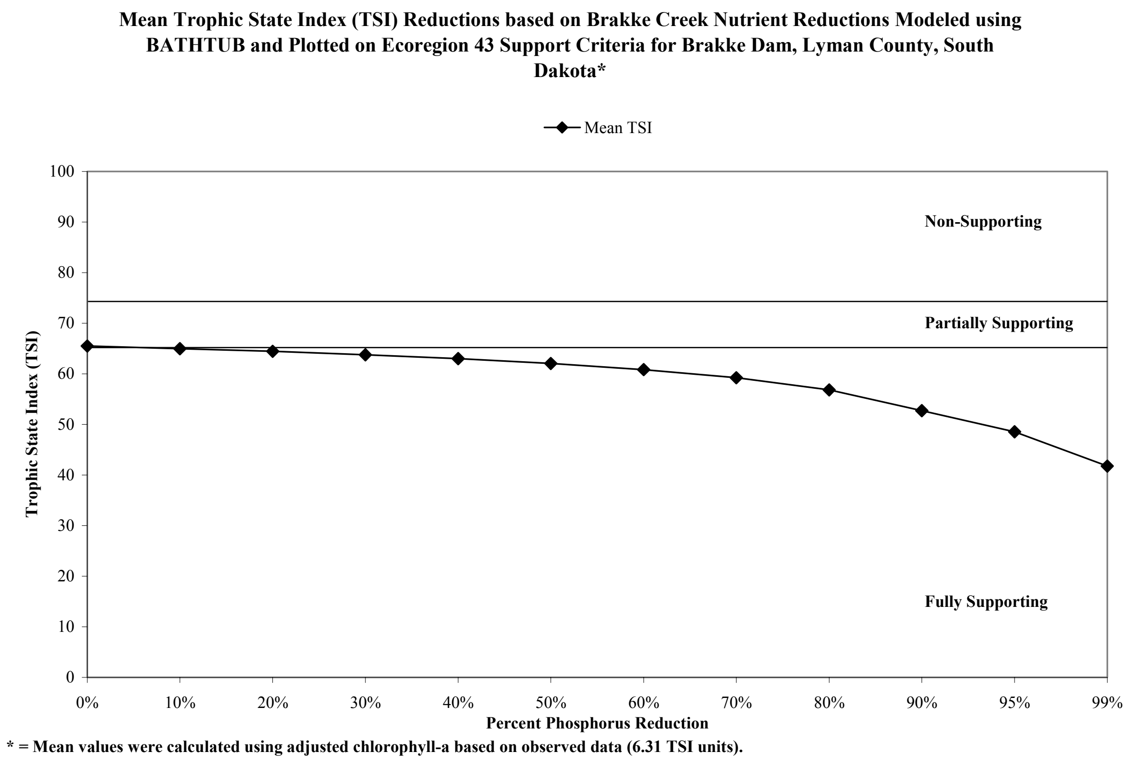


Figure 65. Predicted mean Trophic State Index (TSI) reductions using the BATHTUB reduction model ranked by Lyman County beneficial use criteria for Brakke Dam, Lyman County, South Dakota using 2001 loading data.

The current phosphorus load to Brakke Dam based on 2000 through 2001 data is 618 kg/yr (total phosphorus budget, pages 101 trough 102). At a minimum, current phosphorus loading would have to be reduced by 61.8 kg/yr (approximately 10 percent) for Brakke Dam to fully support beneficial uses based on current mean TSI values. Based on AnnAGNPS current modeling, an 18.9 percent reduction in total phosphorus loading can be attained with an estimated annual total phosphorus loading of 501 kg/yr. This translates to a chlorophyll-*a* adjusted mean TSI of 64.51 fully supporting Brakke Dam site specific beneficial uses.

3.2 Groundwater Monitoring

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

3.3 Biological Monitoring (In-lake)

Brakke Dam Phytoplankton

Composited surface algae samples were collected monthly at two in-lake water quality monitoring sites, from May 1 to December 19, 2000, and February 5 to April 10, 2001. Algae samples were not taken in November 2000. A total of 68 algae taxa (genera or species) including two 'unidentified' categories were collected in 17 samples from this small 130-acre reservoir during this survey (Table 39). Algae species richness (the number of taxa observed) was rated as 'below average' compared to 13 other recently monitored small (< 200 ac.) eutrophic state lakes (mean: 74 taxa). Moreover, the relative abundance of those taxa was uneven. Only six species made up 69 percent of total algae density and nearly 70 percent of biovolume. Fifty-four taxa (79 percent) each contributed less than 1 percent to total algae abundance during this project (Table 39).

Table 39. Algae species, type, density, biovolume and percentages for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Taxa	Type	Density (Cells/ml)	Density Percent	Biovolume μm^3/ml	Biovolume Percent
Achnanthes hauckiana	Non-Motile Green Algae	48	0.06	2,304	0.02
Achnanthes minutissima	Non-Motile Green Algae	19	0.02	950	0.01
Achnanthes sp.	Non-Motile Green Algae	9	0.01	1,080	0.01
Actinastrum hantzschii	Diatom	934	1.08	224,160	1.53
Anabaena circinalis	Blue-Green Algae	742	0.86	106,848	0.73
Anabaena flos-aquae	Blue-Green Algae	14,446	16.76	1,155,680	7.91
Anabaena planctonica	Blue-Green Algae	2,794	3.24	2,106,676	14.41
Anacystis marina	Blue-Green Algae (colonial)	376	0.44	1,504	0.01
Ankistrodesmus falcatus	Non-Motile Green Algae	514	0.60	12,850	0.09
Ankistrodesmus sp.	Non-Motile Green Algae	1	0.00	25	0.00
Aphanizomenon flos-aquae	Blue-Green Algae	10,257	11.90	1,200,069	8.21
Aphanocapsa sp.	Blue-Green Algae	180	0.21	720	0.00
Asterionella formosa	Diatom	1,343	1.56	295,460	2.02
Attheya zachariasi	Diatom (centric)	194	0.23	457,064	3.13
Chlamydomonas sp.	Flagellated Algae (Green Algae)	2,549	2.96	382,350	2.62
Chlorogonium sp.	Flagellated Algae (Green Algae)	1	0.00	95	0.00
Chromulina sp.	Flagellated Algae (Yellow-Brown Algae)	796	0.92	51,740	0.35
Chrysochromulina parva	Flagellated Algae (Yellow-Brown Algae)	9,982	11.58	835,180	5.71
Chrysococcus rufescens	Flagellated Algae (single, yellow-brown)	11	0.01	935	0.01
Coelastrum microporum	Non-Motile Green Algae	133	0.15	108,528	0.74
Cosmarium sp.	Non-Motile Green Algae (Desmid)	1	0.00	210	0.00
Crucigenia quadrata	Non-Motile Green Algae	532	0.62	45,220	0.31
Cryptomonas erosa	Flagellated Algae (cryptophyte)	3,454	4.01	1,514,506	10.36
Cyclotella atomus	Diatom	59	0.07	1,180	0.01
Cyclotella meneghiniana	Diatom	22	0.03	5,500	0.04

Table 39 (continued). Algae species, type, density, biovolume and percentages for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Taxa	Type	Density (Cells/ml)	Density Percent	Biovolume μm^3/ml	Biovolume Percent
Cyclotella pseudostelligera	Diatom	33	0.04	5,445	0.04
Cyclotella stelligera	Diatom	583	0.68	90,365	0.62
Dinobryon sertularia	Flagellated Algae (Yellow-Brown Algae)	3	0.00	2,400	0.02
Elakatothrix gelatinosa	Non-Motile Green Algae (colonial)	165	0.19	6,930	0.05
Euglena sp.	Flagellated Algae (euglenoid)	42	0.05	24,360	0.17
Fragilaria vaucheriae	Diatom (filamentous)	48	0.06	13,824	0.09
Glenodinium sp.	Flagellated Algae (Dinoflagellate)	126	0.15	88,200	0.60
Gloeocystis ampla	Non-Motile Green Algae (colonial)	133	0.15	69,692	0.48
Gymnodinium sp.	Flagellated Algae (Dinoflagellate)	7	0.01	18,900	0.13
Kephyrion littorale	Flagellated Algae (Yellow-Brown Algae)	19	0.02	1,805	0.01
Kirchneriella sp.	Non-Motile Green Algae	20	0.02	360	0.00
Mallomonas akrokomos	Flagellated Algae (Yellow-Brown Algae)	1	0.00	1,503	0.01
Mallomonas sp.	Flagellated Algae (Yellow-Brown Algae)	38	0.04	19,000	0.13
Melosira ambigua	Diatom	67	0.08	39,463	0.27
Melosira granulata	Diatom	141	0.16	77,550	0.53
Melosira granulata v. angustissima	Diatom	414	0.48	103,500	0.71
Navicula biconica	Diatom	28	0.03	1,680	0.01
Nitzschia acicularis	Diatom	170	0.20	47,600	0.33
Nitzschia paleacea	Diatom	279	0.32	27,342	0.19
Nitzschia sp.	Diatom	137	0.16	16,440	0.11
Nitzschia tryblionella	Diatom	28	0.03	5,320	0.04
Nitzschia vermicularis	Diatom	2	0.00	240	0.00
Ochromonas sp.	Non-Motile Green Algae	10	0.01	850	0.01
Oocystis parva	Non-Motile Green Algae (colonial)	412	0.48	4,120	0.03
Oocystis pusilla	Non-Motile Green Algae (colonial)	1,433	1.66	77,382	0.53
Pediastrum duplex	Non-Motile Green Algae (colonial)	536	0.62	268,000	1.83
Peridinium cinctum	Dinoflagellate	36	0.04	151,200	1.03
Rhodomonas minuta	Flagellated Algae (cryptophyte)	11,865	13.77	513,150	3.51
Scenedesmus acuminatus	Non-Motile Green Algae	122	0.14	7,320	0.05
Scenedesmus quadricauda	Non-Motile Green Algae	366	0.42	57,462	0.39
Selenastrum minutum	Non-Motile Green Algae	1,165	1.35	23,300	0.16
Sphaerocystis schroeteri	Non-Motile Green Algae	349	0.40	93,532	0.64
Stephanodiscus astraea minutula	Diatom	9,592	11.13	3,357,200	22.97
Stephanodiscus hantzschii	Diatom	13	0.02	2,600	0.02
Synedra ulna	Diatom	98	0.11	195,020	1.33
Tetraedron sp.	Non-Motile Green Algae	48	0.06	1,296	0.01
Trachelomonas crebea	Flagellated Algae (euglenoid)	31	0.04	46,500	0.32
Trachelomonas hispida	Flagellated Algae (euglenoid)	66	0.08	138,600	0.95
Trachelomonas pulchella	Flagellated Algae (euglenoid)	17	0.02	34,000	0.23
Trachelomonas sp.	Flagellated Algae (euglenoid)	40	0.05	80,000	0.55
Trachelomonas volvocina	Flagellated Algae (euglenoid)	80	0.09	150,800	1.03
Unidentified algae	Algae	1,425	1.65	42,750	0.29
Unidentified flagellates	Flagellated Algae	6,607	7.67	198,210	1.36
Total Taxa	**68**				

Diatoms (Bacillariophyceae) and five phyla of motile (flagellated) algae represented the most diverse groups of algae in Brakke Lake with 22 taxa each that together comprised nearly 65 percent of all species collected. Non-motile green algae (Chlorophyta) accounted for 17 taxa and blue-green algae (Cyanophyta) were present as 6 taxa. In other eutrophic lakes, blue-greens were usually the least diverse but often the most abundant algal group observed. In Brakke Lake, blue-greens comprised about 33 percent of total algae abundance (density) and 31 percent of biovolume during this survey (Table 40).

Yellow-brown flagellates (Chrysophyta) were the most diverse phylum of motile algae, by a small margin, in Brakke Lake with 8 taxa, followed by euglenoid flagellates (Euglenophyta) with 6 taxa. The remaining divisions of motile algae were even less diverse. Dinoflagellates (Pyrrhophyta) were represented by 3 taxa, whereas cryptomonads (Cryptophyta) and green flagellates (Chlorophyta) accounted for only 2 species apiece.

Brakke Dam algae density and biovolume (a relative expression of biomass) showed a seasonal variability of about a magnitude during the study period. Algal abundance (density) ranged from 1,786 cells/ml on May 1, 2000, to 25,493 cells/ml on October 30, 2000. Even with large differences in the cell sizes seasonally, the lowest monthly biovolume (207,378 μm^3/ml) was recorded in December 2000 whereas the maximum biovolume (4,768,401 μm^3/ml) was noted on October 3, 2000 the numerical peak (Table 40). The algae (mostly diatom) population recorded on May 1, 2000 was unusually small for a eutrophic lake in mid-spring (May). Similar small algae densities were also observed on the same date in two nearby small lakes, Fate Dam and Byre Lake. Small waterbodies are, understandably, more rapidly affected by large amounts of runoff and other weather conditions than are large lakes.

Average monthly algae density and biovolume in Brakke Dam for the study period amounted to 8,619 cells/ml and 1,461,605 um^3/ml. In terms of algal biovolume produced during this survey, Brakke Dam would be placed in the bottom 25 percent of recently monitored small eutrophic state lakes (Fate Dam, Dante Lake and Byre Lake). Since the reservoir is rated as borderline hyper-eutrophic, it would be expected to produce larger algae populations than those observed. Possibly, some limitations imposed on algal growth during this assessment may be high water turbidity, limiting micronutrients and/or the hydrologic conditions (lack of runoff in the 2000 sampling period).

The plankton algae population during this survey consisted of 33 percent blue-green algae which made up slightly more than 31 percent of total algal volume. Diatoms contributed 15.5 percent and 32.5 percent to total algae numbers and volume, respectively. Flagellated algae represented the most prominent algae group in Brakke Dam, accounting for 41.5 percent of algal abundance and 29 percent of total biovolume. Non-motile green algae were the least common algal division, providing 8 percent of total algal density and nearly 7 percent of biovolume. Unidentified algae made up the remaining 2 percent of density and 0.3 percent of biovolume (Table 40).

Table 40. Algae density, biovolume and percentages by group for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Algae Group		May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Dec-00	Feb-01	Mar-01	Apr-01	Grand Total
Blue Green Algae	Total Density[1]	0	0	297	2,356	11,475	14,487	0	0	180	0	28,795
Blue Green Algae	Total Biovolume[2]	0	0	34,749	1,041,804	1,784,834	1,709,390	0	0	720	0	4,571,497
Blue Green Algae	% Density	0.0	0.0	8.2	48.4	77.3	56.8	0.0	0.0	5.4	0.0	33.4
Blue Green Algae	% Biovolume	0.0	0.0	4.8	44.6	67.2	35.8	0.0	0.0	0.3	0.0	31.3
Diatom	Total Density	1,394	312	535	884	1,080	8,123	363	2	0	634	13,327
Diatom	Total Biovolume	311,360	163,803	135,950	822,455	307,612	2,787,957	61,530	240	0	156,220	4,747,127
Diatom	% Density	78.1	9.5	14.8	18.2	7.3	31.9	10.9	0.1	0.0	2.9	15.5
Diatom	% Biovolume	66.5	31.5	18.8	35.2	11.6	58.5	29.7	0.1	0.0	6.6	32.5
Flagellated Algae	Total Density	151	1,785	2,256	841	484	767	2,798	3,290	2,892	20,517	35,781
Flagellated Algae	Total Biovolume	144,334	280,368	452,663	241,558	81,541	184,924	135,873	284,970	271,065	2,176,988	4,254,284
Flagellated Algae	% Density	8.5	54.4	62.3	17.3	3.3	3.0	83.9	88.3	86.0	93.8	41.5
Flagellated Algae	% Biovolume	30.8	53.9	62.5	10.3	3.1	3.9	65.5	95.5	96.7	92.4	29.1
Non-Motile Green Algae	Total Density	241	1,183	536	782	1,811	2,116	173	1	20	1	6,864
Non-Motile Green Algae	Total Biovolume	12,638	75,631	100,604	230,838	483,976	86,130	9,975	25	360	210	1,000,387
Non-Motile Green Algae	% Density	13.5	36.1	14.8	16.1	12.2	8.3	5.2	0.0	0.6	0.0	8.0
Non-Motile Green Algae	% Biovolume	2.7	14.5	13.9	9.9	18.2	1.8	4.8	0.0	0.1	0.0	6.8
Unidentified Algae	Total Density	0	0	0	0	0	0	0	435	270	720	1,425
Unidentified Algae	Total Biovolume	0	0	0	0	0	0	0	13,050	8,100	21,600	42,750
Unidentified Algae	% Density	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7	8.0	3.3	1.7
Unidentified Algae	% Biovolume	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	2.9	0.9	0.3
Sum of Density (all groups)		**1,786**	**3,280**	**3,624**	**4,863**	**14,850**	**25,493**	**3,334**	**3,728**	**3,362**	**21,872**	**86,192**
Sum of Biovolume (all groups)		**468,332**	**519,802**	**723,966**	**2,336,655**	**2,657,963**	**4,768,401**	**207,378**	**298,285**	**280,245**	**2,355,018**	**14,616,045**

[1] = Density (cells/ml)
[2] = Biovolume (μm^3/ml)

The seasonal pattern of algal abundance and biovolume in Brakke Dam consisted of two population peaks, one in early autumn 2000 and the other in early spring 2001 (Figure 66). The October 3 population pulse consisted mainly of the blue-green algae *Anabaena* and *Aphanizomenon* and a small centric diatom *Stephanodiscus astraea minutula*. The April 10 algae pulse consisted of 94 percent flagellated algae, primarily cryptomonads (*Rhodomonas* and *Cryptomonas*), *Chlamydomonas*, and *Chrysochromulina* (Figure 67 and Figure 68).

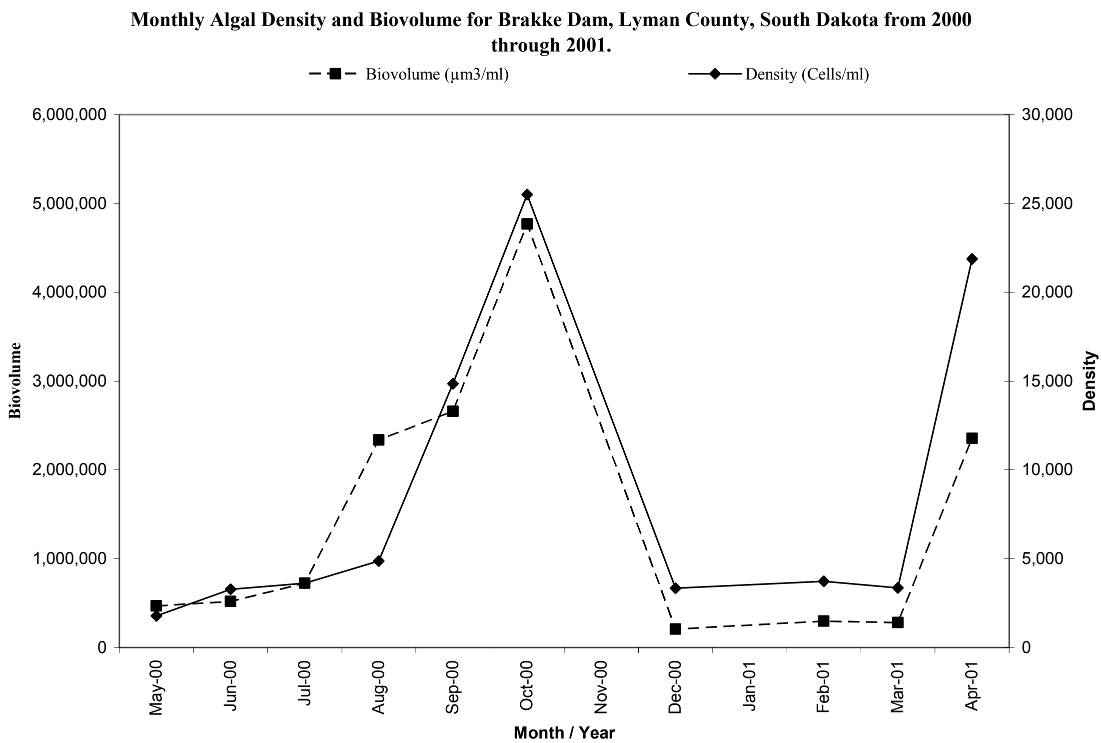


Figure 66. Monthly algal density and biovolume for Brakke Dam, Lyman County, South Dakota from 2000 through 2001

Nuisance blue-green algae, primarily *Aphanizomenon flos-aquae*, *Anabaena flos-aquae*, and *Anabaena planctonica*, were not collected in Brakke Dam until July 11 when *Aphanizomenon* was present at a low mean density of 296 cells/ml. The above three taxa then became dominant in the reservoir plankton numerically and/or volumetrically until October 3, 2000. Those blue-green taxa were absent on the next sampling date in December and for the rest of the project period (Figure 67 and Figure 68). *Aphanizomenon* and *Anabaena* spp. ranged in abundance from 296 cells/ml in July to 14, 487 cells/ml in early October with a combined mean for this time span of 7,052 cells/ml. These are considered very moderate densities of blue-greens in a eutrophic lake.

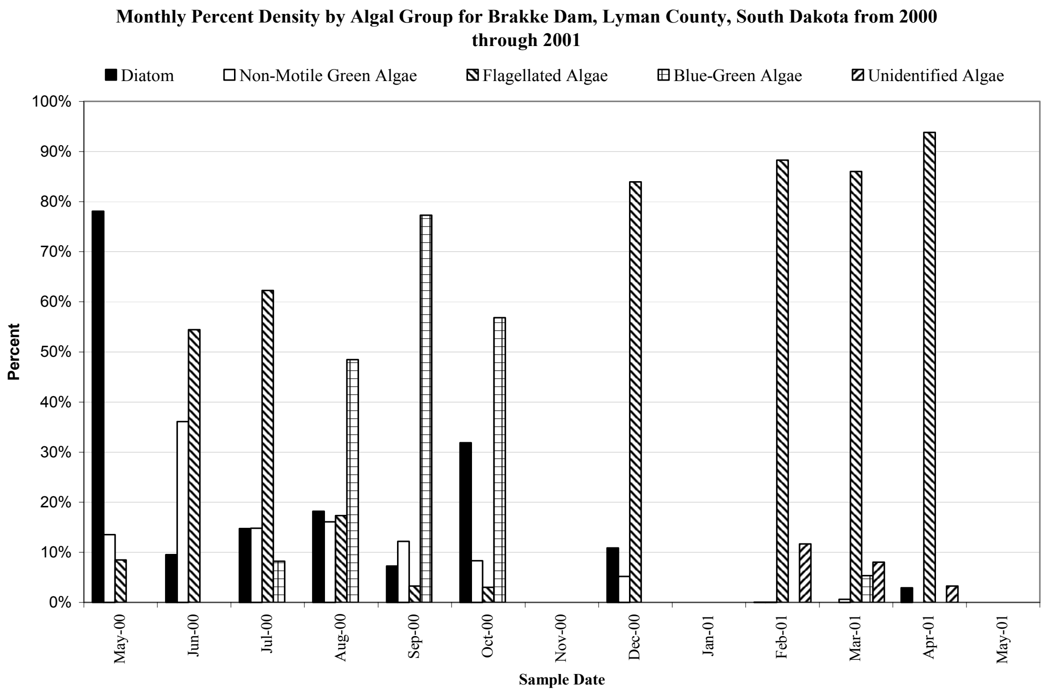


Figure 67. Monthly Percent Density by Algal Group for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

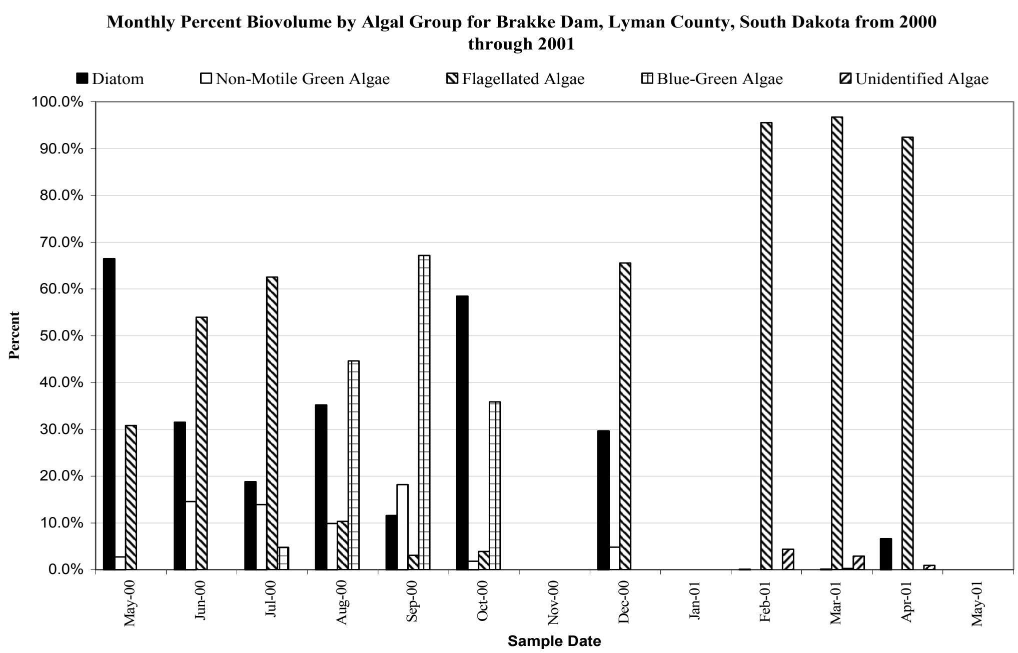


Figure 68. Relative percent biovolume by algal group for Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Aquatic Macrophyte Survey

An aquatic macrophyte survey of Brakke Dam was conducted on August 21, 1999. The survey consisted of surveying 21 transects, quantify and identifying the submergent plant community (Figure 69). Each transect had at least one survey point to evaluate the macrophyte community. 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.

The survey also identified bank stability, vegetative protection and riparian vegetative zone width using a rating scale ranging from zero through ten. These were used to identify potential erosional areas around Brakke Dam. Aquatic plant species were identified using Fassett (1957) and Crow and Hellquist (2000 and 2000a) and are listed in Table 41. Sago pondweed (*Stuckenia pectinata*), floating-leaf pondweed (*Potamogeton natans*) and coontail (*Ceratophyllum demersum*) were the most abundant submerged species in Brakke Dam in 2001.

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

Number		Scientific Name
	Transect Submerged Species	
1	Floating Leaf Pondweed	*Potamogeton natans*
2	Sago Pondweed	*Stuckenia pectinata*
3	Bushy Pondweed	*Najas* sp.
4	Clasping-leaf Pondweed	*Potamogeton richardsonii*
5	Coontail	*Ceratophyllum demersum*
6	Flat-stemmed Pondweed	*Potamogeton zosteriformis*
7	Periphyton	-
8	Unidentified	-

Submergent macrophyte species were sampled using 21 transects (Figure 69) with 124 survey points throughout the lake. Six separate transect species were identified during the survey and are listed on Table 41. One species (unidentified grass species) was encountered at two transect locations (transect 1 and 15). All six identified macrophyte species, sago pondweed (*Stuckenia pectinata*), floating-leaf pondweed (*Potamogeton natans*), bushy pondweed (*Najas* sp.), flat-stemmed pondweed (*Potamogeton zosteriformis*), coontail (*Ceratophyllum demersum*) and clasping-leaf pondweed (*Potamogeton richardsonii*) are relatively ubiquitous and commonly found in many lakes in South Dakota. Eighteen of the twenty-one (85.7 percent) transects (survey points) yielded submerged vegetation (Table 42).

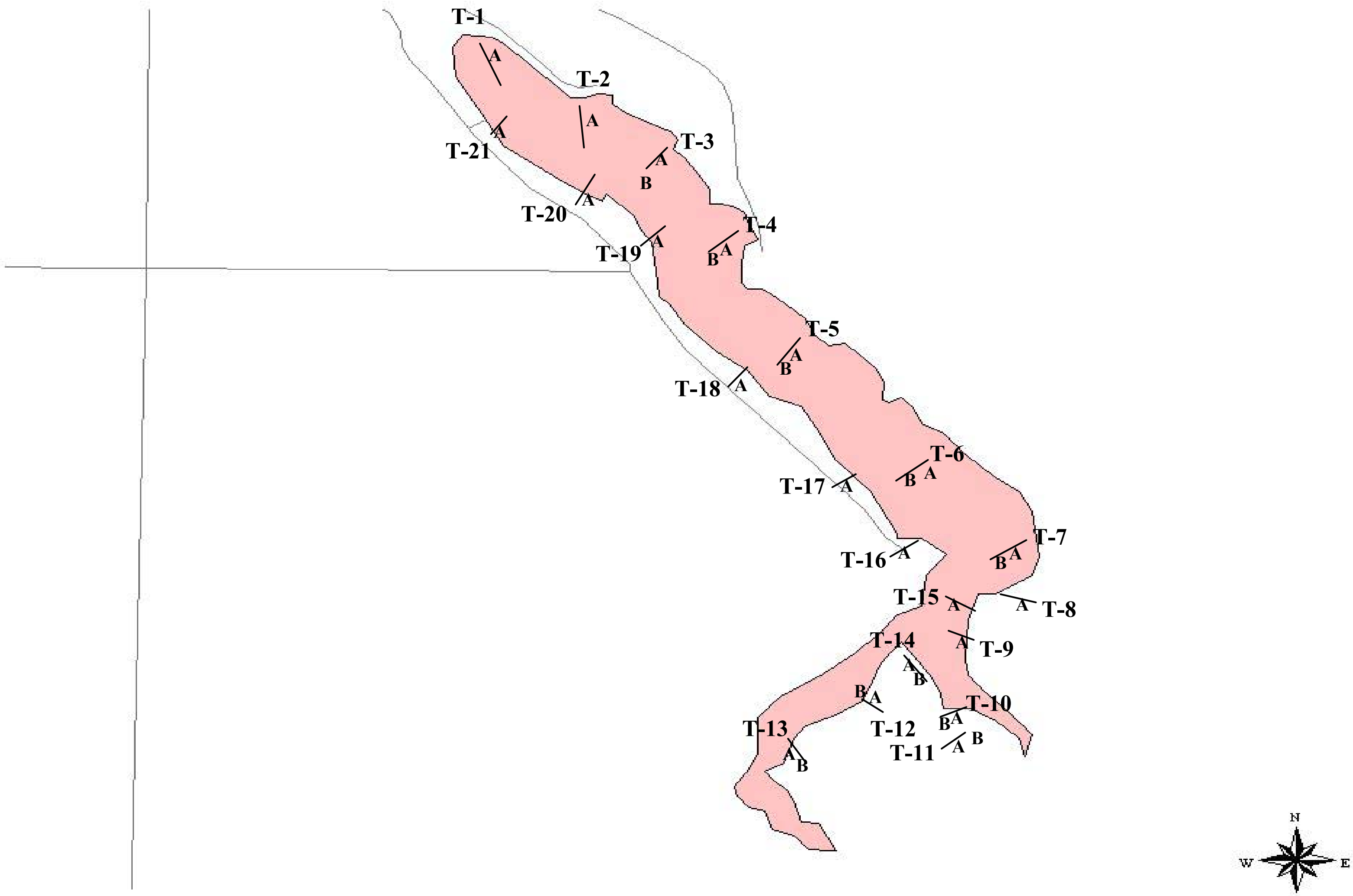


Figure 69. Submergent macrophyte transect locations at Brakke Dam, Lyman County, South Dakota in 2001.

Table 42. Shoreline and transect submergent plant species sampled from Brakke Dam, Lyman County, South Dakota in 2001.

Transect and Station	Total Depth (m)	Secchi Depth (m)	Transect Submergent Species	Transect Density[1]	Habitat Parameter Score: Bank Stability	Vegetative Protection	Riparian Vegetative Zone Width	Total Out of (30 Points)
1A	0.9	0.4	*Potamogeton natans*	4	4	5	5	14
			Stuckenia pectinata	2				
			Potamogeton richardsonii	1				
			Periphyton	3				
2A	1.4	0.9	*Stuckenia pectinata*	1	8	4	2	14
			Periphyton	1				
3A	1.0	0.8	*Potamogeton natans*	1	5	7	8	20
			Stuckenia pectinata	3				
			Najas sp.	2				
			Periphyton	4				
3B	1.5	0.9	*Stuckenia pectinata*	2				
			Unidentified	1				
			Periphyton	1				
4A	1.25	0.85	*Stuckenia pectinata*	3	2	7	5	14
			Periphyton	3				
			Unidentified	4				
4B	2.29	0.9	Periphyton	1				
5A	0.8	0.6	*Najas* sp.	2	8	7	3	18
			Unidentified	1				
			Periphyton	3				
			Stuckenia pectinata	3				
			Potamogeton natans	1				
			Ceratophyllum demersum	2				
5B	1.4	0.9	*Potamogeton natans*	1				
			Ceratophyllum demersum	4				
			Stuckenia pectinata	3				
			Periphyton	2				
			Unidentified	1				
6A	1.0	0.7	*Potamogeton natans*	2	7	6	3	16
			Periphyton	1				
			Unidentified	3				
			Ceratophyllum demersum	1				
6B			Unidentified	4				
			Ceratophyllum demersum	2				
			Periphyton	2				
			Stuckenia pectinata	1				
7A	1.1	0.55	*Potamogeton natans*	2	8	6	5	19
			Unidentified	4				
			Ceratophyllum demersum	1				
7B	1.6	0.9	Unidentified	3				
8A	0.2	0.2	None	0	4	6	3	13
9A	0.5	0.5	None	0	4	6	3	13

Table 42 (continued). Shoreline and transect submergent plant species sampled from Brakke Dam, Lyman County, South Dakota in 2001.

					Habitat Parameter Score			
Transect and Station	Total Depth (m)	Secchi Depth (m)	Transect Submergent Species	Transect Density[1]	Bank Stability	Vegetative Protection	Riparian Vegetative Zone Width	Total Out of (30 Points)
10A	0.9	0.6	Periphyton	3	9	8	2	19
			Potamogeton natans	3				
			Ceratophyllum demersum	4				
			Najas sp.	1				
			Unidentified	1				
			Stuckenia pectinata	1				
10B	1.3	0.9	Periphyton	2				
			Ceratophyllum demersum	4				
			Unidentified	2				
11A	-	0.5	*Ceratophyllum demersum*	3	9	8	2	19
			Periphyton	4				
			Stuckenia pectinata	3				
			Potamogeton natans	2				
11B	1.4	0.8	*Stuckenia pectinata*	4				
			Ceratophyllum demersum	4				
12A	1.6	0.6	*Potamogeton natans*	1	10	5	5	20
			Ceratophyllum demersum	4				
			Periphyton	1				
			Unidentified	1				
			Potamogeton zosteriformis	1				
12B	1.7	0.7	*Ceratophyllum demersum*	3				
			Potamogeton zosteriformis	1				
			Periphyton	1				
13A	0.9	0.5	*Potamogeton natans*	1	5	2	3	10
			Stuckenia pectinata	3				
			Potamogeton zosteriformis	2				
			Periphyton	2				
			Ceratophyllum demersum	3				
13B	-	-	*Potamogeton natans*	-[2]				
			Stuckenia pectinata	-				
			Potamogeton zosteriformis	-				
			Periphyton	-				
			Ceratophyllum demersum	-				
14A	1.0	0.8	*Potamogeton natans*	2	10	7	7	24
			Ceratophyllum demersum	4				
			Stuckenia pectinata	1				
			Potamogeton zosteriformis	2				
			Periphyton	1				
14B	-	-	None	0				
15A	1.5	0.5	*Ceratophyllum demersum*	3	10	8	8	26
			Potamogeton richardsonii	2				
			Periphyton	1				
			Stuckenia pectinata	1				
16A	1.45	0.7	Unidentified	2	10	9	7	26
			Periphyton	1				

Table 42 (continued). Shoreline and transect submergent plant species sampled from Brakke Dam, Lyman County, South Dakota in 2001.

Transect and Station	Total Depth (m)	Secchi Depth (m)	Transect Submergent Species	Transect Density[1]	Habitat Parameter Score: Bank Stability	Vegetative Protection	Riparian Vegetative Zone Width	Total Out of (30 Points)
17A	1.7	0.6	None	0	10	8	7	25
18A	1.6	0.5	*Potamogeton natans*	1	10	8	7	25
			Unidentified	2				
19A	1.6	0.6	*Potamogeton natans*	2	9	6	5	20
			Stuckenia pectinata	3				
			Periphyton	1				
			Unidentified	2				
			Ceratophyllum demersum	1				
20A	1.85	0.5	Periphyton	1	9	6	7	22
			Unidentified	1				
			Najas sp.	1				
			Potamogeton natans	1				
21A	1.8	0.6	*Potamogeton natans*	1	7	5	1	13
			Unidentified	1				
			Stuckenia pectinata	1				

[1] = Transect Density = 5-dense, 4-heavy, 3-moderate, 2-scattered and 1-sparse
[2] = Species identified but no densities recorded.

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

The calculated maximum depth of colonization in Brakke Dam was 1.41 meter (4.64 feet). Calculations were based upon the average measured Secchi depth in meters during the aquatic macrophyte survey (Table 42). Reductions in sediment and nutrient loads to the lake should improve Secchi depth and transparency. Improving Secchi depth will allow increased littoral colonization of submerged macrophytes in regions of Brakke Dam conducive to colonization, which will increase the uptake of nutrients and increase habitat for fish and macroinvertebrates.

Habitat data indicate that the shoreline between transects 14 and 18 had higher total habitat scores ($\geq$ 24) with bank stability scores rated as optimal.

3.4 Other Monitoring

Brakke Dam Sediment Survey

A sediment survey was completed on Brakke Dam in January 23, January 26 and January 28, 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 forty survey sites were recorded by GPS (Global Positioning System) (Figure 70).

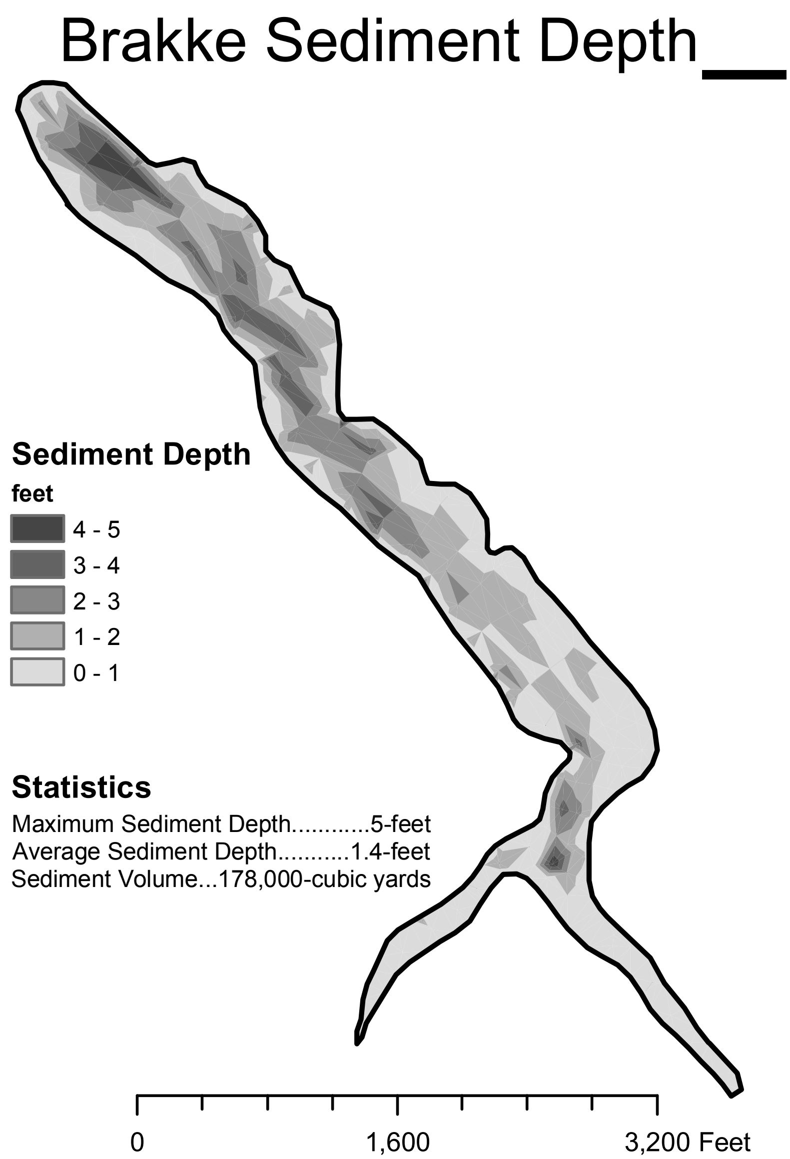


Figure 70. Sediment survey sediment depth for Brakke Dam, Lyman County, South Dakota for January 2002.

Figure 70 indicate sediment depths ranged from 0 to 1.52 meters (0 to 5 feet). At the time of this survey, the average depth of sediment in Brakke Dam was approximately 0.43 meters (1.4 feet). Total sediment volume accumulated within Brakke Dam was estimated at 136,095 m^3 (177,983 yd^3). The total loss in water volume due to sedimentation was estimated at 110.2 acre-feet; while the water volume loss due to sedimentation during this study (May 2000 through May 2001) was 27.6 m^3 or 0.02 acre-feet.

The estimated load (Brakke Creek) to Brakke Dam for 2001 was 82,656 kg or 38.2 m^3 (0.031 acre/feet). Adjusting the load for sediment leaving the lake, based on FLUX loading, via the outlet (MCT-10) was approximately 22,938 kg or 10.6 m^3 (0.009 acre-feet). The corrected amount of suspended solids retained in Brakke Dam during this study was approximately 59,718 kg, which is 27.6 m^3 (0.02 acre-feet) or 72.2 percent of the total of suspended solids loading to the lake. This translates to an overall increase of 0.05 mm of sediment depth over the entire lake during this study. During this study very little runoff was recorded and should be considered below average.

Brakke 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 43). 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 Brakke Dam on July 11, 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 and transported to the laboratory at 4° C.

Composite receiving water and elutriate samples collected at Brakke 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 Brakke Dam.

Table 43. Receiving water and elutriate chemical concentrations collected from Brakke Dam, Lyman County, South Dakota in August 2001.

Parameter	Receiving Water Brakke Dam	Elutriate Sample Brakke Dam	Actual in Sediment Brakke Dam	Unit
COD	25.9	29.1	3.2	mg/L
Phosphorus, total	0.018	0.055	0.037	mg/L
TKN	0.83	2.49	1.66	mg/L
Hardness	110	120	10	mg/L
Nitrate	<0.1	0.1	0.1	mg/L
Nitrite	< 0.02	< 0.02	< 0.02	mg/L
Aluminum	4.5	39.1	34.6	µg/L
Zinc	<3.0	<3.0	<3.0	µg/L
Silver	0.3	<0.2	-0.1	µg/L
Selenium	0.6	<0.5	-0.1	µg/L
Nickel	5.8	3.8	-2	µg/L
Mercury, total	<0.2	<0.2	<0.2	µg/L
Lead	<0.1	<0.1	<0.1	µg/L
Copper	2.9	1.9	-1	µg/L
Cadmium	<0.2	<0.2	<0.2	µg/L
Arsenic	4.2	5.8	1.6	µg/L
Ammonia	0.03	1.60	1.57	mg/L
Endosulfan II	< 0.500	< 0.500	0	µg/L
Atrazine	1.00	< 0.639	-0.361	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 June 6 through June 8, 2001. That report is summarized below and is presented in Appendix F. Brakke Dam is being managed using the latest management plan (F-21-R-30) 1998. The lake is classified as a warm-water permanent fishery and supports seven species of fish.

Fish collection consisted of setting eight 19 mm (¾ inch) for three 24-nour periods from June 6 through June 8, 2001 and six 10-mimute electrofishing transects on October 22, 2001. 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 54 largemouth bass and 16 walleye and eight 24-hour frame nets yielded 1 black bullhead, 5 black crappie, 106 bluegill, 2 northern pike, 20 walleye and 1 yellow perch. Scales were also collected from largemouth bass and walleye to back-calculate length by year class (age). A significant decline in the bluegill population was recorded (89 percent reduction in CPUE, Catch Per Unit Effort). Bluegills that were caught had a relatively good condition factor (Wr = 98.2); however, with relatively high PSD and RSD-P (Proportional Stock Density and Relative Stock Density-Preferred, respectively) indicate few young bluegill to replace the aging population. Largemouth bass CPUE was 54 per hour with decreasing Wr indices values by category, indicating a relatively high number of predators for the forage available. This supports the bluegill data which indicated low numbers of small bluegill. Walleye numbers were similar to those in 1998 (CPUE 2.5); however, similar to the largemouth bass population, the walleye population was dominated by larger fish.

South Dakota Game, Fish and Parks (SD GF&P) recommendations for Brakke Dam indicate that bluegill adults should be transferred to Brakke Dam to increase the number of smaller fish in this aging population and to discontinue walleye stocking to improve bluegill size structure and numbers (Appendix F).

Endangered Species

The South Dakota Natural Heritage Database identified one species, the whooping crane, as being endangered in the Brakke watershed. This database contains documented identifications of rare, threatened or endangered species across the state and is listed in Appendix G. The whooping crane (*Grus americana*), a federally-listed endangered species, has been recorded in the / Brakke Dam 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 Medicine Creek/Brakke Dam watershed; however, six species are identified as being rare. Species identified as rare in the Brakke 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 Brakke Dam/Brakke Creek watershed.

3.5 Quality Assurance Reporting

Eleven 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. 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. Ten tributary samples were collected at MCT-10, MCT-11 and MCT-12 for an overall quality assurance / quality control percentage of 10.0 percent. Three tributary replicate sample parameters (total suspended solids, volatile total suspended solids and fecal coliform bacteria) had industrial statistic (%I) greater than 10 percent (absolute percent). All other replicate parameter samples were within 10 percent from the original samples. Total suspended solids, volatile total suspended solids concentrations can vary considerably because of variations in sample collection and processing. Variations in field sampling techniques and preparation of routine and replicates samples may be some reasons for differences. Fecal coliform colony counts often vary due to variations in bacterial growth on incubated media and temperature. Over all, 80.0 percent of all tributary industrial statistics values were less than 10 percent different (Table 44).

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 44. Tributary quality assurance/quality control samples collected in Brakke Creek, Lyman County, South Dakota from 2000 and 2001.

Sample	Site	Date	Time	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	5/23/2001	4:28	-	-	10	6	7	6	1	1	0.36	0.02	0.1	0.34	0.12	0.46	0.002	0.002
Blank	BL	5/23/2001	4:28	-	-	10	6	7	6	1	1	0.36	0.02	0.1	0.34	0.12	0.46	0.002	0.002
	Mean					10.0	6.0	7.0	6.0	1.0	1.0	0.4	0.0	0.1	0.3	0.1	0.5	0.0	0.0
	Standard Deviation					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Routine	MCT-10	05/23/00	11:30	Surface	11.9	80	123	244	213	31.0	4.0	0.81	0.01	0.30	0.80	0.31	1.11	0.112	0.061
Replicate	MCT-10	05/23/00	11:30	Surface	11.9	10	123	245	220	25.0	3.0	0.81	0.01	0.30	0.80	0.31	1.11	0.114	0.060
	Industrial Statistic (I%)				0.00%	**77.78%**	0.00%	0.20%	1.62%	**10.71%**	**14.29%**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.88%	0.83%

Table 45. In-lake quality assurance/quality control samples collected in Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Sample	Site	Date	Time	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	10/3/2000	11:30	-	-	10	**34**	**92**	**92**	1	1	0.21	0.01	0.1	0.20	0.11	0.31	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	14	1	1	0.36	0.01	0.2	0.35	0.21	0.56	0.002	0.002
	Mean					10.0	15.3	38.0	38.0	1.0	1.0	0.3	0.0	0.1	0.3	0.1	0.4	0.0	0.0
	Standard Deviation					0.00	**16.17**	**46.86**	**46.86**	0.00	0.00	0.09	0.00	0.06	0.09	0.06	0.13	0.00	0.00
Routine	BD-2	10/03/00	11:30	Surface	14.7	10	124	225	208	17.0	7.0	0.90	0.01	0.10	0.89	0.11	1.00	0.068	0.034
Replicate	BD-2	10/03/00	11:30	Surface	14.7	20	125	230	210	20.0	5.0	0.74	0.01	0.10	0.73	0.11	0.84	0.066	0.064
	Industrial Statistic (I%)				0.00%	**33.33%**	0.40%	1.10%	0.48%	8.11%	**16.67%**	9.76%	0.00%	0.00%	9.88%	0.00%	8.70%	1.49%	**30.61%**
Routine	BD-2	05/16/01	9:00	Surface	20.3	10	117	247	236	11.0	2.0	1.09	0.13	0.30	0.96	0.43	1.39	0.169	0.110
Replicate	BD-2	05/16/01	9:00	Surface	20.3	20	118	249	237	12.0	3.0	1.08	0.13	0.30	0.95	0.43	1.38	0.156	0.108
	Industrial Statistic (I%)				0.00%	**33.33%**	0.43%	0.40%	0.21%	4.35%	**20.00%**	0.46%	0.00%	0.00%	0.52%	0.00%	0.36%	4.00%	0.92%

Eight tributary quality assurance / quality control samples were collected for in-lake monitoring samples. Twenty two in-lake samples were collected in Brakke Dam for an overall quality assurance/quality control percentage of 9.1 percent. Three in-lake replicate sample parameters (volatile total suspended solids, fecal coliform bacteria and total dissolved phosphorus) had industrial statistics (%I) greater than 10 percent (absolute percent) on at least one sampling date. Volatile total suspended solids concentrations are the organic portion of total suspended solids and can vary considerably because of variations in sample and fecal coliform colony counts often vary due to variations in bacterial growth on incubated media and temperature. All other replicate parameter samples were within 10 percent from the original samples. Over all, 80.0 percent of sampling parameters had all in-lake industrial statistics values less than 10 percent different (Table 45).

One quality assurance / quality control blank in-lake sample (10/03/00) detected elevated total dissolved solids in the distilled water used on that date. This sample skewed the blank data by increasing the standard deviation greater than the mean for total solids, total dissolved solids and by default alkalinity (Table 45). These chemical parameters were out of compliance with respect to criterion proposed previously.

3.6 Monitoring Summary and Recommendations

Monitoring Summary

Tributary

Brakke Dam is listed on the 2002 303(d) Impaired Waterbody List (SD DENR 2002). Brakke Creek (unnamed tributary of Medicine Creek) drains a watershed of approximately 4,568.1 ha (11,288 acres) and is impounded by Brakke Dam in Lyman County, South Dakota (Figure 1). Brakke Dam is a recreational lake of approximately 52.6 ha (130 acres) and has been impacted by periodic algal blooms. American Creek Conservation District (ACCD) sponsored this project as part of the Medicine Creek Watershed Assessment Project.

Brakke Creek was monitored for tributary loading to Brakke Dam from April 2000 through May 2001. Approximately 1,461 acre-feet of water flowed into Brakke Dam from the gauged portion of the watershed (10,745 acres) in 2000 and 2001. The export coefficient (water delivered per acre) for the Brakke Dam/Brakke Creek watershed was 0.12 acre-foot. Peak hydrologic load for the watershed occurred in the spring. Because of dry conditions in Lyman County, no runoff was recorded in the 2000 sampling season. Approximately 95.9 percent of the total hydrologic load delivered to Brakke Dam was delivered in the spring of 2001.

Brakke Creek was monitored using nineteen water quality parameters. More than half of the parameterswhich (57.9 percent) had the highest average concentrations for all tributary sites in the spring of 2001. The remaining six water quality parameters (42.1 percent) had the highest average concentrations and/or values in the winter of 2001. Brakke Creek tributary samples did not exceed water quality standards during the project period.

South Dakota water quality standards for fecal coliform bacteria do not apply to Brakke Creek (designated beneficial uses, 9-Fish and wildlife propagation, recreation, and stock watering waters and 10-irrigation waters) however, during this study, one high fecal coliform count (29,000 colonies/100ml) collected in late April (MCT-12 on 4/25/01) was observed in the watershed (bacteria standards in effect from May 1 through September 30). Although not applicable, elevated fecal coliform counts are unhealthy when in contact with contaminated water. Runoff from land-applied manure, cattle or even wildlife may be responsible for the sporadic high fecal concentrations.

Brakke Dam is listed in South Dakota's impaired waterbodies list for increasing TSI trend. Water quality data from this study identify Brakke Dam as partially supporting using assigned beneficial uses criteria based on current Ecoregion 43 criteria (mean TSI ≤ 55.00). An alternate site-specific (watershed-specific) evaluation criterion was proposed (fully supporting, mean TSI ≤ 65.00). Currently, Brakke Dam still only partially supports site specific beneficial use criteria. Current data indicate increased nutrient (phosphorus) loading from the watershed (Brakke Creek) to Brakke 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 B. All watershed nutrient parameters eventually affect in-lake concentrations and TSI values in Brakke Dam so reductions in any or all of these parameters may lower in-lake TSI values.

Total phosphorus loading to Brakke Dam from Brakke Creek is 618 kg/yr; at a minimum, all modeled Best Management Practices (BMPs) should be implemented in the watershed to reduce the nutrient (phosphorus) loading to Brakke Dam. Based on site-specific standards for Brakke Dam, an 18.9 percent reduction in total phosphorus (approximately 117 kg/yr) is needed to fully support site specific beneficial use criteria and meet the total phosphorus TMDL of 501 kg/yr. AnnAGNPS modeling indicates an 18.9 percent reduction in total phosphorus is attainable in the Brakke Dam watershed.

Table 46. Brakke 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-11	1	9.6	71,538
	MCT-12	2	3.4	11,118
Nitrogen	MCT-11	1	0.25	1,862
	MCT-12	2	0.11	357
Phosphorus	MCT-11	1	0.06	446
	MCT-12	2	0.05	172

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 46.

In-lake

Brakke Dam is a 52.6 ha (130 acre) impoundment located in Lyman County, South Dakota and was included in the 1998 and the 2002 South Dakota's impaired waterbodies list. Current data indicate Brakke 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 in during this study.

Current data indicate that a reduction in total phosphorus is needed in both the watershed and in Brakke Dam to meet proposed site-specific designated beneficial uses based on modeled attainability criteria. Every effort should be made to improve current management practices to control and reduce sediment and nutrient runoff in the Brakke Dam watershed. Decreasing tributary sediment, nitrogen and phosphorus inputs from Brakke Creek will improve (lower) Brakke 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 ≤ 55.00. However, current ecoregional (Ecoregion 43) target criteria appear not to fit Brakke 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 88.2 percent would result in a phosphorus TSI of 52.40 and a mean TSI of 54.37 for Brakke Dam (21.2 percent mean TSI reduction). Under this extreme situation Brakke Dam could not meet current ecoregional-based beneficial use criteria; obviously, this scenario is not realistic based on financial, logistical and technical constraints.

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 47 are the expected percent reduction in sediment and nutrients delivered to Brakke 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 48 and Appendix B (Table B-2).

Table 47. AnnAGNPS modeled overall BMP reduction percentages for the Brakke Dam/Brakke Creek watershed, Lyman County, South Dakota based on data collected from 2000 through 2003.

Best Management Practice	Sediment	Nitrogen	Phosphorus
Fertilizer Reduction	0.0	1.3	5.2
Grazing Management Reduction	3.9	6.5	8.9
Conservation Tillage Reduction	1.6	0.4	0.3
Buffer Strips	3.1	3.6	4.5
Overall Watershed Percent Reduction	**8.6**	**11.8**	**18.9**

Table 48. Sediment, nitrogen and phosphorus critical cell acreage by priority ranking for the Brakke Dam/Brakke 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	993	8.8	528	4.7	187	1.7
2	908	8.0	1,128	10.0	1,064	9.4
3	597	5.3	917	8.1	90	0.8
Total	**2,498**	**22.1**	**2,573**	**22.8**	**1,341**	**11.9**

Additional BMPs (streambank stabilization, conversion of highly erodible land to grass, etc.) should be considered and implemented in the Brakke Dam/Brakke Creek watershed to further reduce sediment and nutrient loads to Brakke 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 Brakke Dam 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 49 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 49 were calculated using a conservative percent reduction in in-lake phosphorus concentrations.

Table 49. Estimated reduction percentages using BATHTUB for in-lake Alum treatment Best Management Practices for Brakke Dam, Lyman County, South Dakota in 2000 and 2001.

		Percent TSI Parameter Reduction		
In-lake Best Management Practice	**In-lake Phosphorus Reduction**	**Secchi**	**Chlorophyll-*a***	**Phosphorus**
Alum Treatment	30%	1.4	2.4	4.2

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

Implementing and alum treatment in Brakke Dam to further reduce phosphorus in Brakke Dam and 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 Brakke Dam watershed. Other in-lake BMPs should be considered to augment tributary mitigation having an overall positive impact on Brakke Dam over time.

Targeted Reduction and TMDL

Alternative site specific (watershed-specific) evaluation criteria (fully supporting, mean TSI ≤ 65.00) was proposed based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability.

Based on site-specific criteria under current conditions, using chlorophyll-*a* adjusted mean TSI (65.49), Brakke Dam only partially supports beneficial uses using this evaluation criteria. The site (watershed) specific criteria/goals are more realistic and attainable based on AnnAGNPS modeling and BMP reductions within the Brakke Dam watershed. BMP based reduction criteria for Brakke Dam were estimated based on a 18.9 percent reduction in total phosphorus loads (117 kg/yr) to Brakke Dam resulting in a phosphorus TMDL of 501 kg/yr resulting in a mean TSI of 64.51.

The 18.9 percent modeled reduction is based on AnnAGNPS watershed modeling and consisted of: (1) all phosphorus fertilized fields with moderate to low fertilizer rates (29.4 percent) reduced one level (moderate to low or low to none) or 5.2 percent phosphorus reduction; (2) converting all current pastures from fair condition to good condition or 8.9 percent reduction; (3) applying conservation tillage to all priority-one and priority-two phosphorus critical cells (4-critical cells) or 0.3 percent and (4) converting tilled/cropped priority-one and priority-two phosphorus critical cells to all grass and results were again reduced 50 percent to better simulate typical phosphorus reduction or 4.5 percent. Combining all reductions the best estimated phosphorus reduction for Brakke Dam watershed is 18.9 percent.

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 71 and Figure 72. 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 and in-lake BMP recommendations outlined on pages 135 through 137 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 (Appendix I). Any additional implemented BMP reductions were incorporated into the TMDL equation as implicit margin of safety.

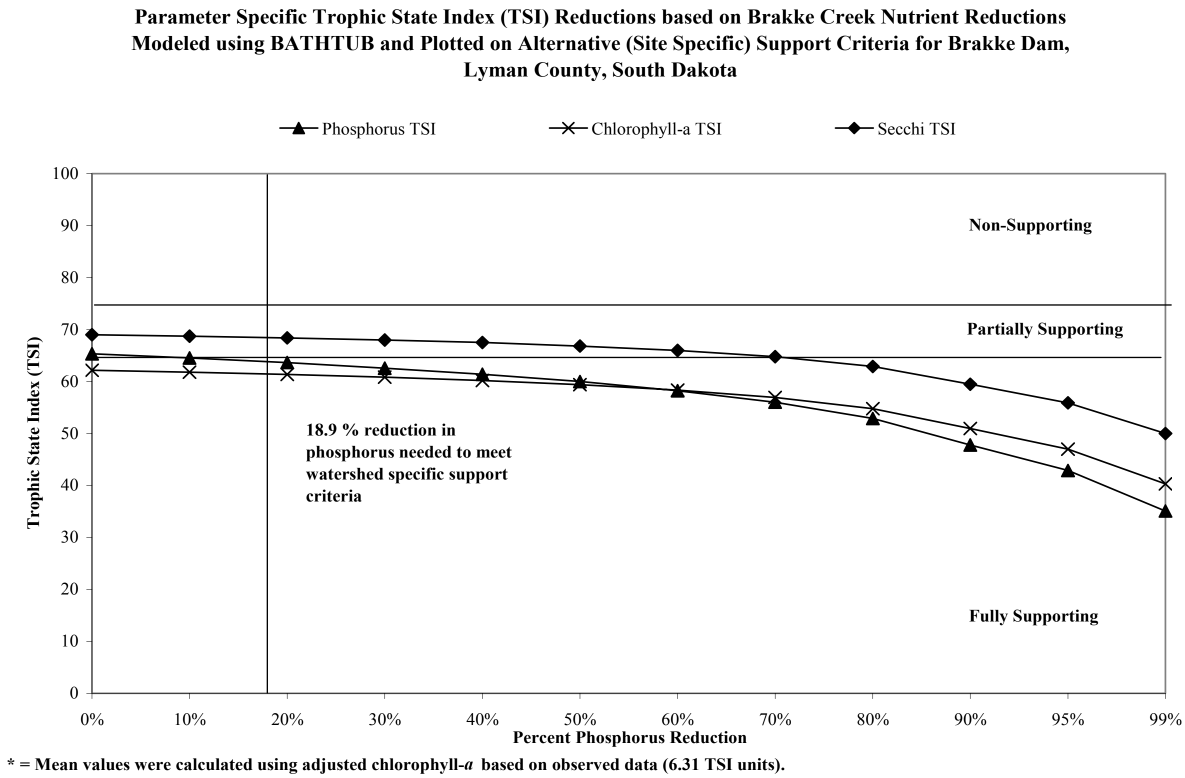


Figure 71. TMDL-predicted parameter specific Trophic State Index (TSI) reductions using the BATHTUB reduction model based on tributary BMPs reductions and ranked by watershed-specific beneficial use categories for Brakke Dam, Lyman County, South Dakota using 2000 and 2001 data.

Based upon 2000 and 2001 modeled data, both phosphorus TSI (65.33) and Secchi TSI (68.97) values were partially supporting; however adjusted chlorophyll-*a* TSI values (62.17) were fully supporting based on previously defined watershed-specific beneficial use criteria (Figure 71). SD DENR-recommended targets for specific TSI parameters for Brakke Dam based on watershed-specific criteria and tributary BMP attainability. They are 63.72 for phosphorus, 61.40 for adjusted chlorophyll-*a* and 68.41 for Secchi visibility (Table 50). To reach these goals, tributary total phosphorus loads will have to be reduced by 18.9 percent. Reductions should improve phosphorus TSI by 2.5 percent, chlorophyll-*a* TSI by 1.2 percent and Secchi TSI by 0.8 percent, which will improve in-lake water quality. Both during and after implementing BMPs to reduce sediment, nitrogen and phosphorus loads to the lake, long-term tributary and in-lake monitoring should be conducted to evaluate BMPs' effectiveness and determine if in-lake TSI targets have been met. SD DENR will continue to monitor Brakke Dam as part of the statewide lakes assessment project.

The average TSI values for phosphorus, adjusted chlorophyll-*a* and Secchi combined as modeled by BATHTUB (65.49) were also in the partially supporting category (Figure 72). The recommended target for an average TSI value in Brakke Dam is 64.51 (Table 49, Table 50 and Table 51). Implementing tributary BMPs in priority 1 and 2 critical cells in the watershed should decrease the in-lake mean TSI value by 1.5 percent and fully support new site-specific beneficial use criteria.

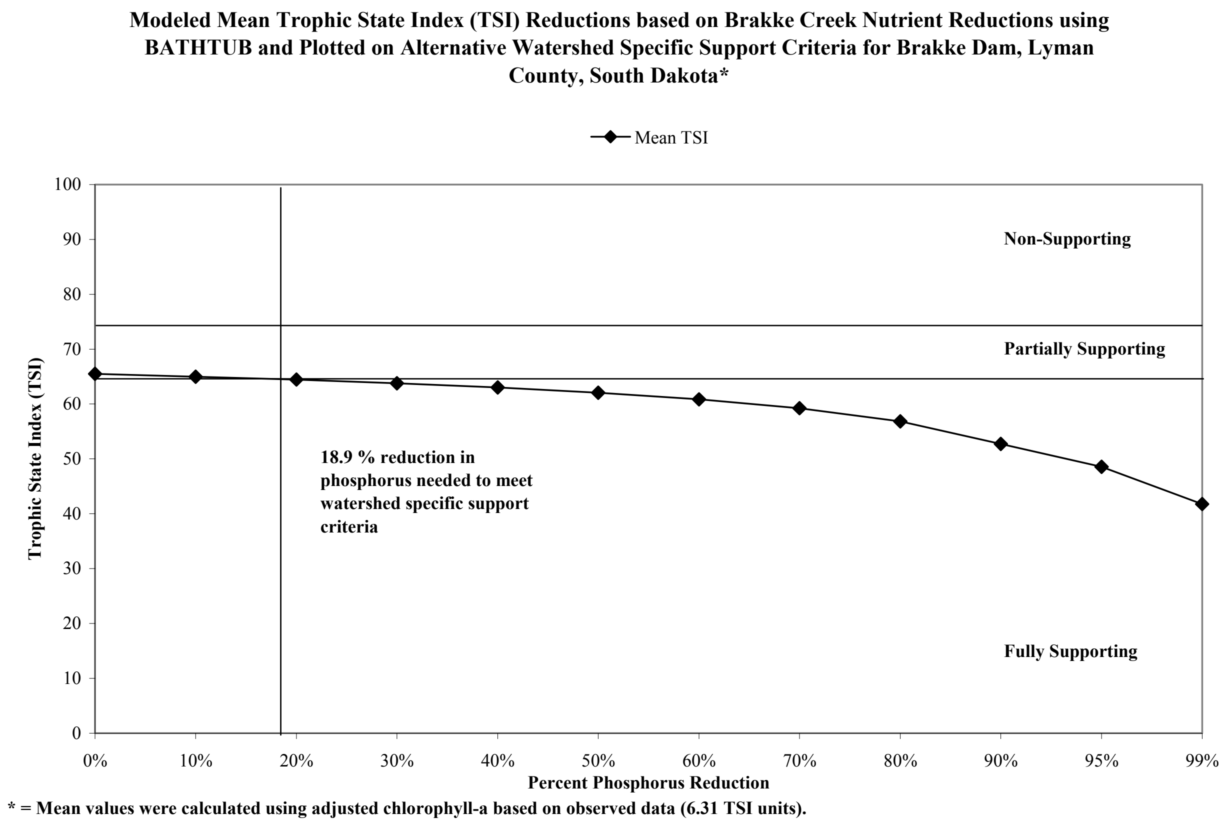


Figure 72. TMDL-predicted mean Trophic State Index (TSI) reduction using the BATHTUB reduction model based on tributary BMPs reductions ranked by Ecoregion 43 watershed-specific beneficial use categories for Brakke Dam, Lyman County, South Dakota based on 2000 and 2001 data.

If an in-lake alum treatment is considered, all tributary BMPs should be in place and implemented before alum treatment begins. In-lake BMPs may improve TSI values (an estimated 4.2 percent, based on modeled tributary 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 a major phosphorus load from in-lake sediments.

An appropriate TMDL for total phosphorus in Brakke Dam is 501 kg/yr, producing a mean TSI of 64.51 (Equation 6, Table 50 and Table 51).

Over all, mean TSI values should be reduced by 1.5 percent for modeled tributary BMPs. In-lake BMPs (alum treatment (implicit margin of safety) should be implemented to achieve additional reductions (estimated approximately 4.2 percent) after tributary BMPs to achieve maximum benefit.

Table 50. Current, targeted and percent reduction for parameter specific and mean TSI values based on 2000 and 2001 data for Brakke Dam, Lyman County, South Dakota.

TSI Parameter	2000 -2001 Estimated TSI Values (BATHTUB)	TMDL Targeted TSI Value	Percent TSI Reduction
Total Phosphorus	65.33	63.72	2.5
Chlorophyll-*a*[1]	62.17	61.40	1.2
Secchi	68.97	68.41	0.8
Average	**65.49**	**64.51**	**1.5**

[1] = Chlorophyll-*a* TSI values were adjusted by measured chlorophyll-*a*

Table 51. Total phosphorus TMDL target loading for Brakke Dam, Lyman County, South Dakota in 2000 and 2001.

Parameter	Best Management Practice	Margin of Safety	TMDL
Total Phosphorus	Tributary and In-lake BMPs	Implicit (conservative estimations)	Total Phosphorus TSI 63.72 (501 kg/year) (Mean TSI 64.51)

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

Equation 6. TMDL equation for Brakke Dam, Lyman County, South Dakota based on 2000 and 2001.

Component	Maximum Load
Waste Load Allocation (WLA):	0 (kg/yr)
+ **Load Allocation (LA)**	501 (kg/yr)
+ **Margin of Safety:**	Implicit
TMDL[1]	**501 (kg/yr)**

[1] = Represents a total phosphorus tributary load reduction of approximately 18.9 percent, based upon 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 Brakke Dam. 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 up front 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 Brakke 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 Brakke Dam watershed should take 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 implemented with local landowners.

4.4 Other Sources of Funds

The Brakke Dam Watershed Assessment project 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
Conservation Commission	Local	$47,864
Counties	Local	$20,000
Total Budget		**$169,660**

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 1999 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 (2000). This delay could have been avoided had the funding been released in early March of 1999. 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 Brakke Dam watershed.

6.0 Future Activity Recommendations

The Brakke Dam watershed is an estimated 4,568.1 ha (11,288 acres) in size. This assessment project documented priority and critical areas for erosion, total nitrogen and total phosphorus in the watershed (Appendix B). As indicated in the report, certain areas in the Brakke Dam watershed have been identified as areas of concern. Implementation efforts should be undertaken to implement/install BMPs on critical areas in the Brakke Dam watershed.

The Brakke Dam/Brakke Creek watershed can not meet current ecoregional based beneficial use criteria which are unrealistic due to logistical, financial and technical constraints are unachievable in the Brakke Dam watershed. An alternative site-specific (watershed-specific) evaluation criterion (fully supporting, mean TSI < 65.00) 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 Brakke Dam/Brakke Creek watershed. Implementation of select BMPs in the Brakke Dam/Brakke Creek watershed will reduce nutrient loading, allowing Brakke Dam, based on watershed-specific criteria, to fully support beneficial uses.

Current data indicate that a 18.9 percent reduction in total phosphorus can be achieved in this watershed to meet the TMDL goal of 501 kg/yr total phosphorus for a mean in-lake TSI of 64.51. 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 Brakke Dam (501 kg/year of total phosphorus). Critical cells by priority ranking are outlined in Brakke Dam/Brakke Creek AnnAGNPS final report (Appendix B). Implementing all modeled tributary BMPs outlined in this report will reduce sediment, nitrogen and phosphorus loading and improve the trophic status of Brakke Dam.

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APPENDIX A

Tributary Stage Discharge Regression Graphs and Equations from 2000 through 2001

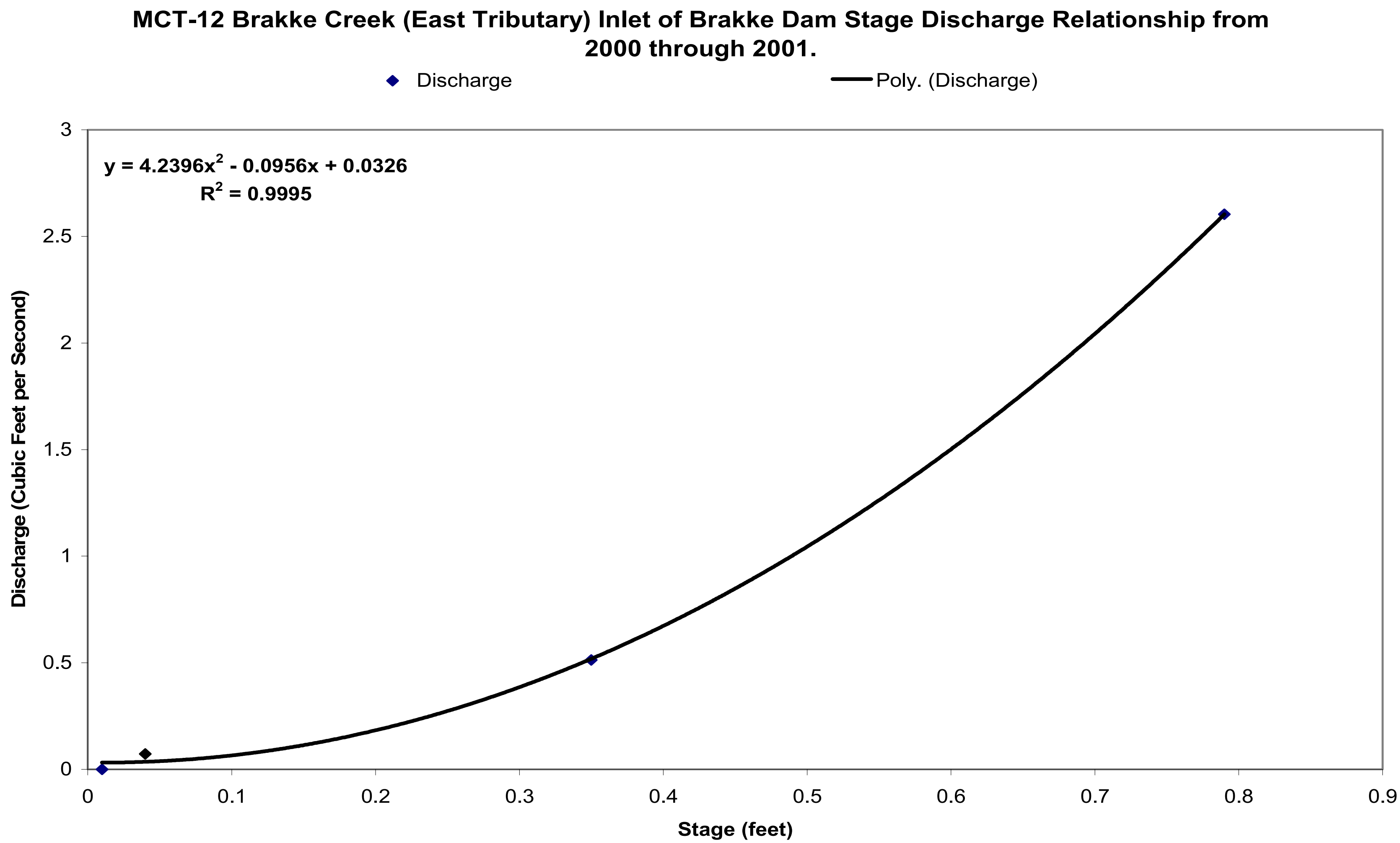
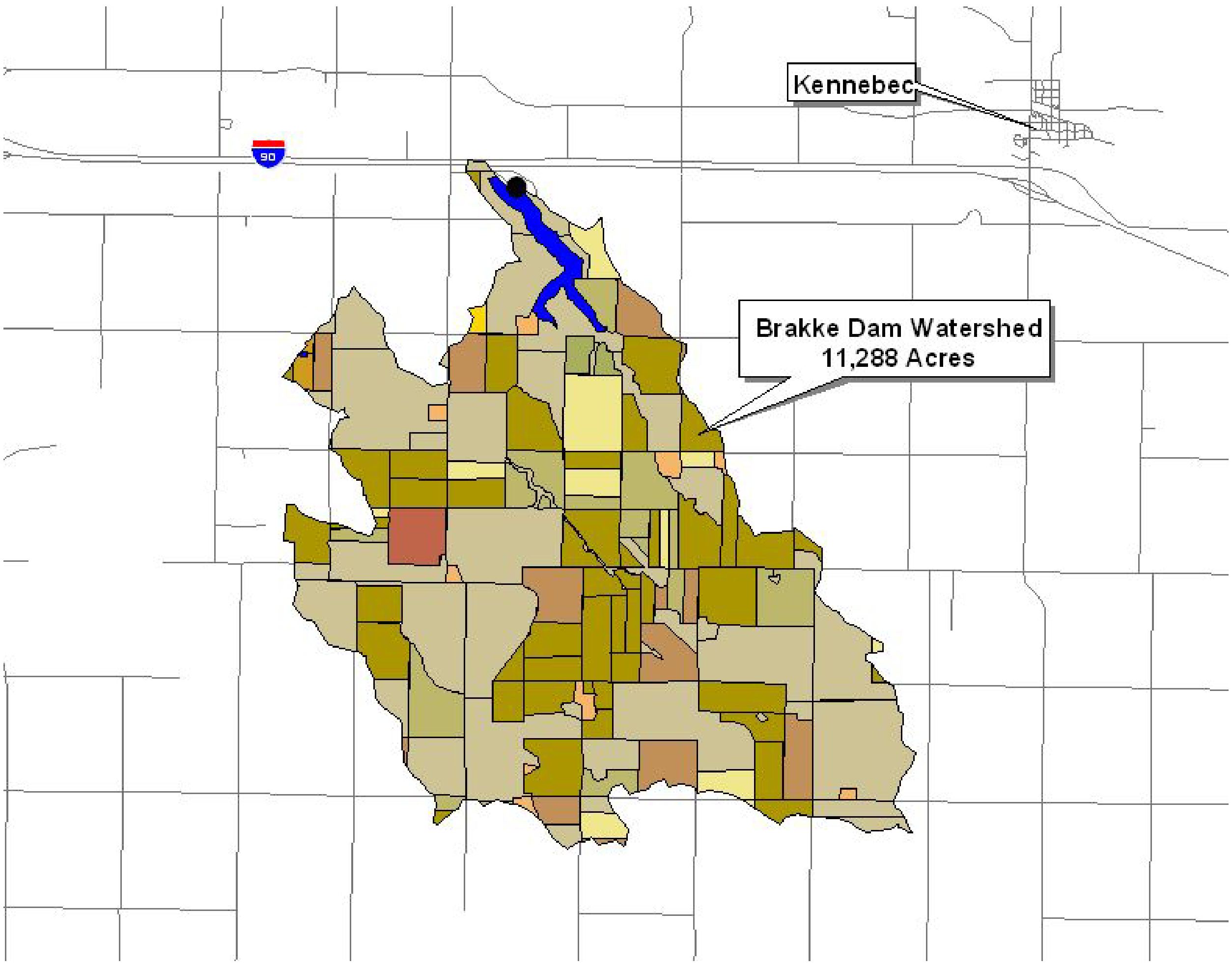


Figure A1. Stage discharge relationship for MCT-12 (east tributary of Brakke Creek) from 2000 through 2001.

APPENDIX B

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

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



Prepared by:
Robert L. Smith
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SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
WATER RESOURCES ASSISTANCE PROGRAM

February 2004

Table of Contents

List of Figures

List of Tables

INTRODUCTION

Water quality is a major concern, especially in the agricultural states of the Midwest 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% 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 Brakke Dam/Brakke Creek watershed (Figure B-1) was modeled and analyzed using AnnAGNPS modeling program.

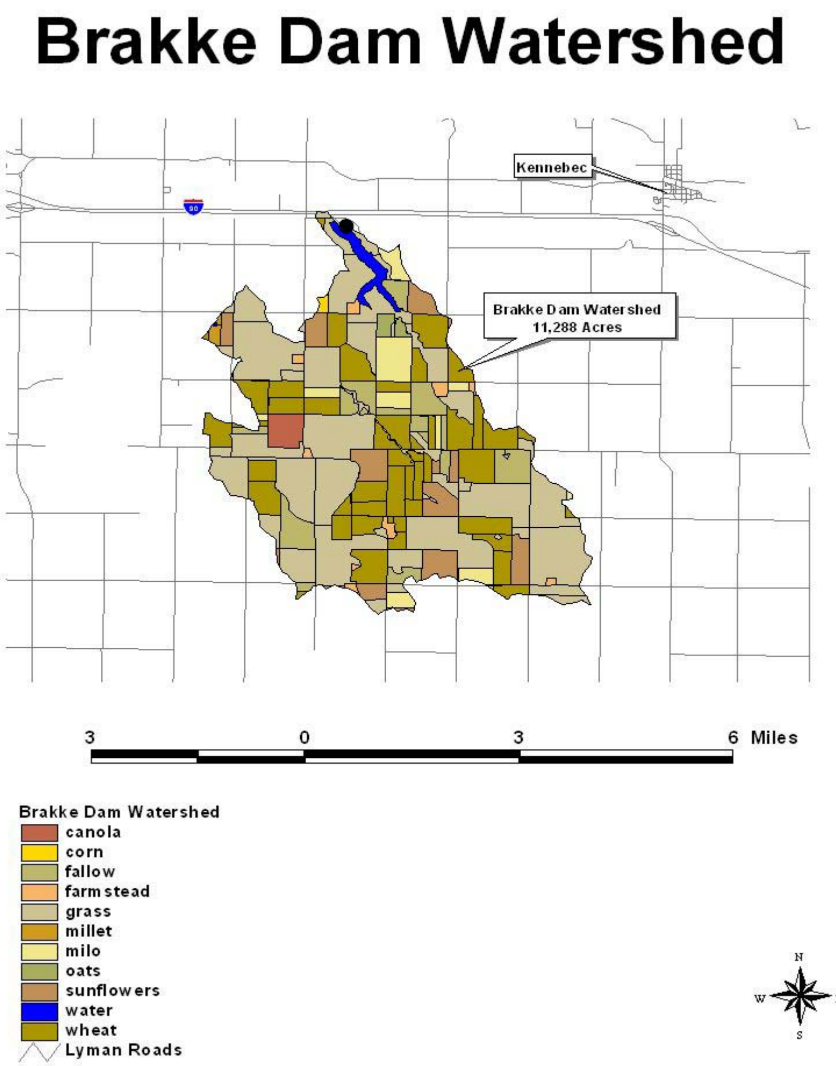

Figure B-1. Landuse in the Brakke Dam/Brakke Creek watershed, Lyman County, South Dakota in 2003.

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 data and field digitizing in ArcView® for the Brakke Dam/Brakke Creek watershed analysis was 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 Brakke Dam/Brakke 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).

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.

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 upon 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.

Brakke Dam was identified in the Brakke Dam/Brakke 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.

RESULTS AND DISCUSSION

Critical Cells

Priority critical cells for sediment, nitrogen and phosphorus for the Brakke Dam/Brakke Creek watershed based on AnnAGNPS modeling appear in Figure B-2, Figure B-3 and Figure B-4. AnnAGNPS model identified approximately 1,341 acres of critical areas for phosphorus, or 11.9 percent of the watershed, within the Brakke Dam/Brakke Creek watershed, based on the above criteria (Table B-1). The Brakke Dam watershed has been identified as contributing increased nutrients (phosphorus) to Brakke Bam, increasing in-lake TSI values above ecoregional targets (Ecoregion 43 - mean TSI $\leq$ 55.00). Table B-2 lists sediment, nitrogen and phosphorus critical phosphorus cells by priority rank for the Brakke Dam/Brakke Creek watershed.

Table B-1. Critical cell acreage by priority ranking for the Brakke Dam/Brakke 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	993	8.8	528	4.7	187	1.7
2	908	8.0	1,128	10.0	1,064	9.4
3	597	5.3	917	8.1	90	0.8
Total	**2,498**	**22.1**	**2,573**	**22.8**	**1,341**	**11.9**

Spatially, approximately two-thirds of the critical cells are in the middle section of the watershed (Figure B-2). Table B-1 indicates approximately 1.7 percent of the total acres in the Brakke Dam/Brakke Creek watershed were priority one, 9.4 percent of the watershed were priority two and 0.8 percent of the watershed were priority three. All priority cells should be field verified prior to BMP implementation.

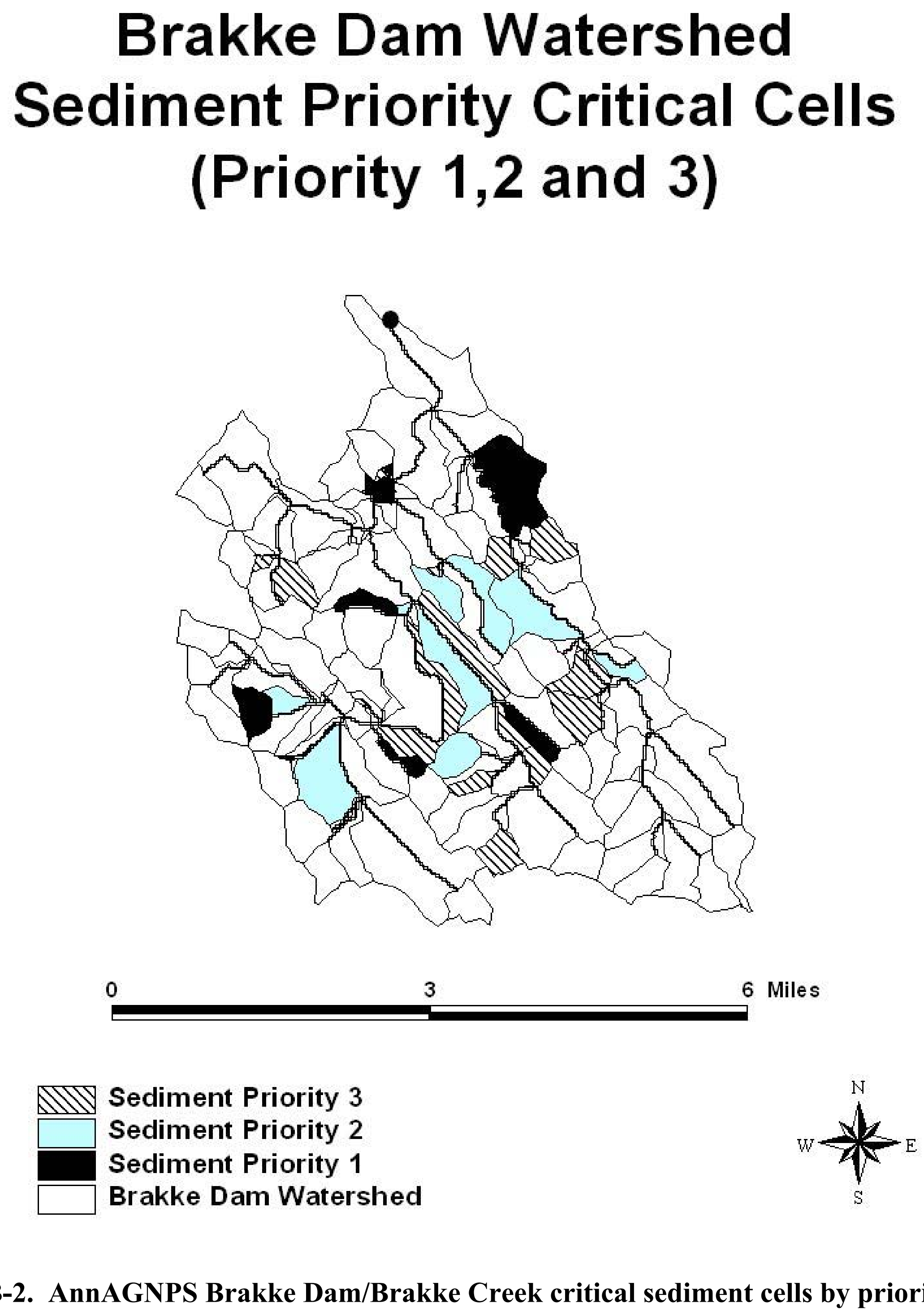

Figure B-2. AnnAGNPS Brakke Dam/Brakke Creek critical sediment cells by priority ranking based on data from 2000 through 2003.

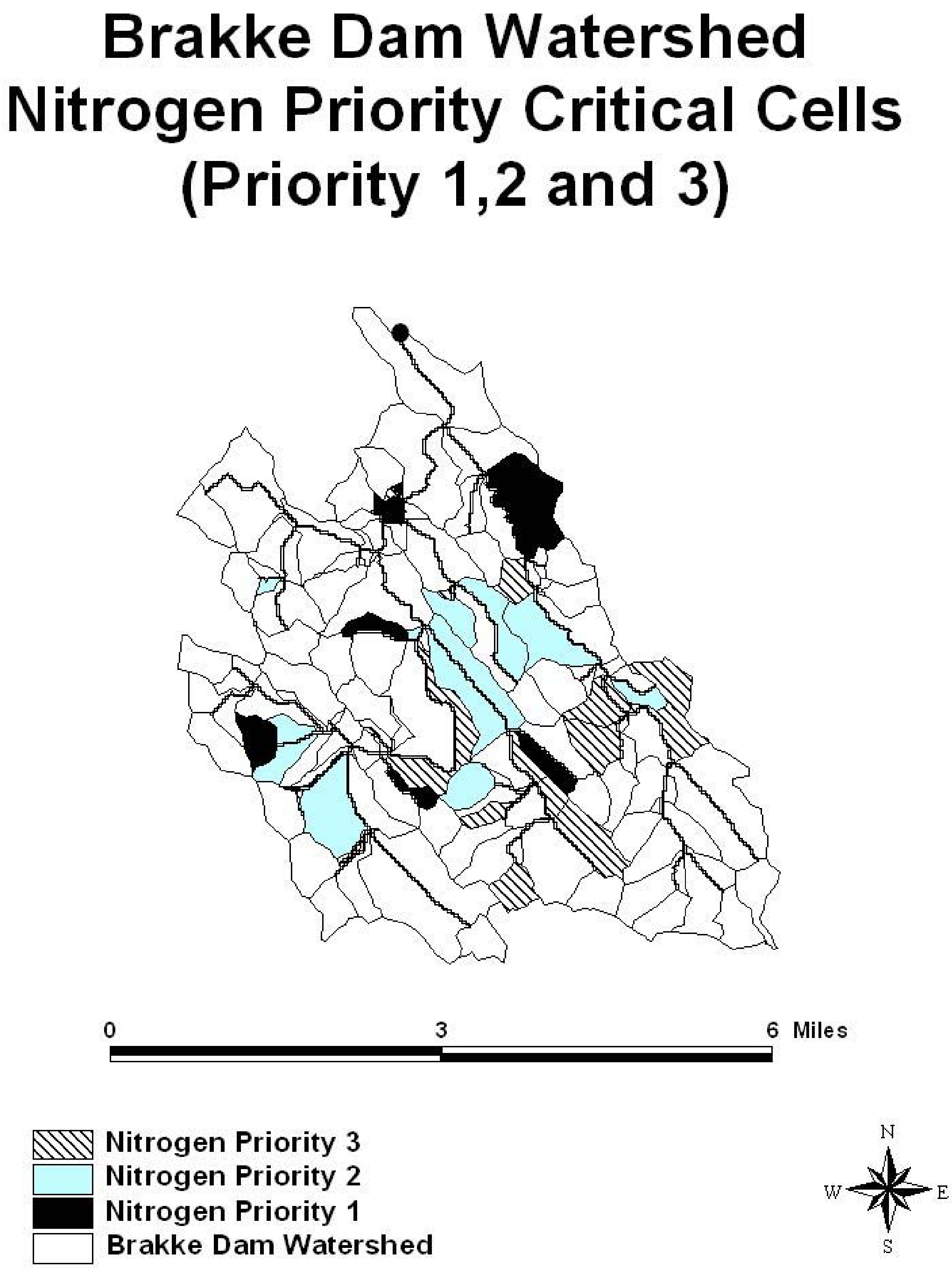

Figure B-3. AnnAGNPS Brakke Dam/Brakke Creek critical nitrogen cells by priority ranking based on data from 2000 through 2003.

Brakke Dam Watershed Phosphorus Priority Critical Cells (Priority 1,2 and 3)

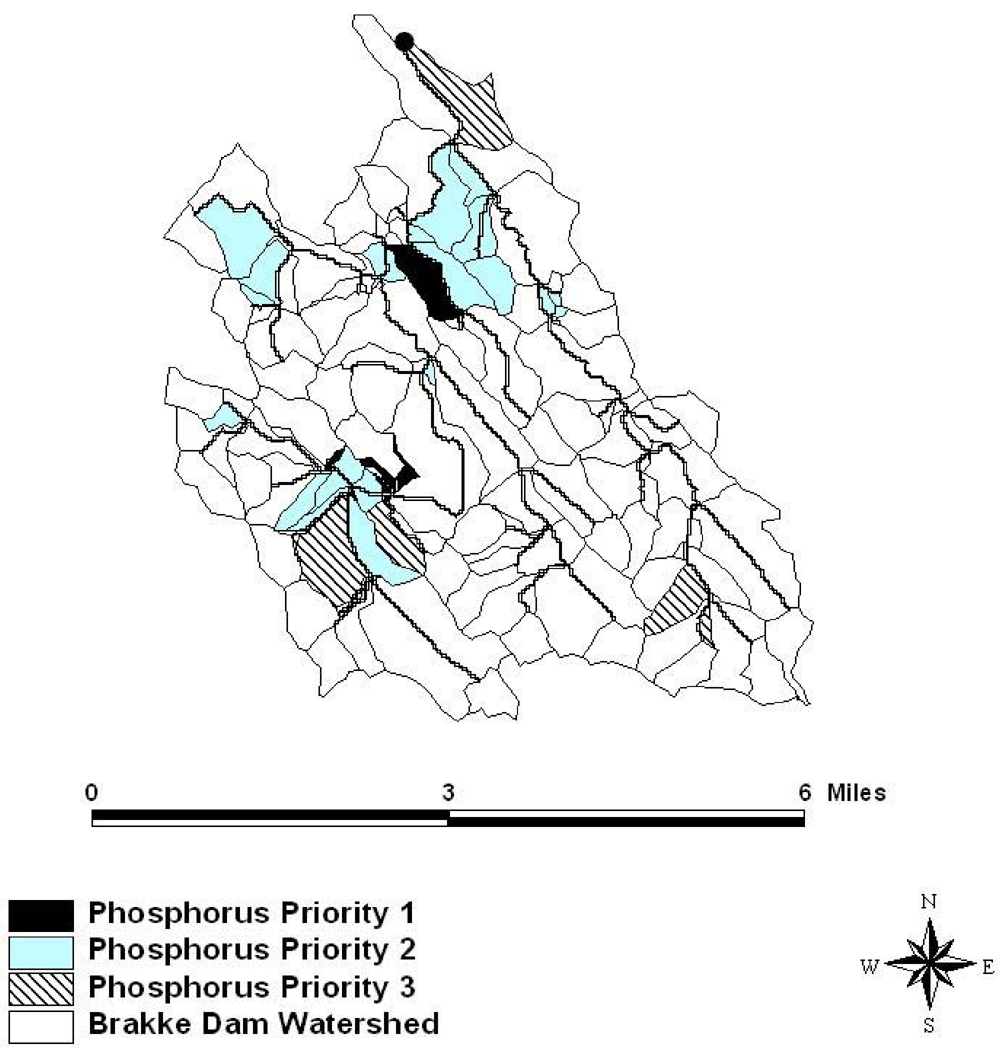

Figure B-4. AnnAGNPS Brakke Dam/Brakke Creek critical phosphorus cells by priority ranking based on data from 2000 through 2003.

Table B-2. Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Brakke Dam/Brakke Creek watershed, Lyman County, South Dakota from 2000 through 2003.

Sediment			Nitrogen			Phosphorus		
Priority	**Cell**	**Acres**	**Priority**	**Cell**	**Acres**	**Priority**	**Cell**	**Acres**
1	233	15	**1**	233	15	**1**	243	81
1	683	3	**1**	683	3	**1**	272	21
1	273	8	**1**	273	8	**1**	412	2
1	313	56	**1**	313	56	**1**	572	3
1	593	48	**1**	593	48	**1**	413	5
1	422	40	**1**	422	40	**1**	582	16
1	531	79	**1**	531	79	**1**	573	5
1	42	264	**1**	42	264	**1**	442	3
1	673	10	**1**	673	10	**1**	583	18
1	503	6	**1**	503	6	**1**	512	32
1	532	69	**2**	532	69	**2**	452	109
2	83	172	**2**	83	172	**2**	432	20
2	103	6	**2**	393	6	**2**	433	17
2	393	6	**2**	103	40	**2**	443	21
2	533	40	**2**	303	148	**2**	513	28
2	252	131	**2**	302	139	**2**	522	49
2	261	77	**2**	652	15	**2**	562	29
2	381	90	**2**	533	40	**2**	212	36
2	363	2	**2**	252	131	**2**	211	77
2	453	204	**2**	261	77	**2**	242	99
2	303	148	**2**	381	90	**2**	213	45
3	302	139	**2**	453	204	**2**	633	67
3	263	6	**3**	363	2	**2**	662	165
3	682	7	**3**	682	7	**2**	653	15
3	652	15	**3**	322	44	**2**	392	10
3	322	44	**3**	332	41	**2**	53	6
3	63	60	**3**	351	74	**2**	62	16
3	332	41	**3**	113	76	**2**	232	17
3	351	74	**3**	101	91	**2**	222	149
3	113	76	**3**	112	24	**2**	33	44
3	402	198	**3**	263	6	**2**	282	23
3	112	24	**3**	63	60	**2**	283	22
3	93	5	**3**	373	39	**3**	72	6
3	373	39	**3**	342	140	**3**	153	99
3	193	103	**3**	402	198	**3**	453	204
3	642	83	**3**	502	10	**3**	502	10
3	51	81	**3**	193	103	**3**	22	204
			3	362	2	**3**	423	89
						3	172	21

AnnAGNPS Load Reduction Estimates

Existing conditions for the years 2000 through 2003, including row crop, pasture, fertilizer application rates, buffers and tillage practices were modeled using AnnAGNPS. Initial conditions were modeled and loads were estimated at the outlet cell of the watershed (Table B-3). To model the best possible condition the watershed could attain, all land use in the watershed was switched to all grass.

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

Best Management Practice	Sediment (tns/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.022	.614	4.063
Entire Watershed All Grass	0.001	.061	0.479
Percent Reduction	**95.5**	**90.1**	**88.2**

Data indicate under ideal conditions, sediment and nutrients would be drastically reduced.

Brakke Dam/Brakke Creek watershed has been identified as producing considerable nutrient (phosphorus) loading resulting in increased Trophic State Index (TSI) values in Brakke Dam. AnnAGNPS estimated by converting current conditions to all grass a phosphorus reduction of 88.2 percent. An 88.2 percent reduction in current phosphorus loading would result in a phosphorus TSI of 52.40 and a mean TSI of 54.37 for Brakke Dam (21.2 percent mean TSI reduction). Obviously, this scenario is not realistic based on technical, social and financial constraints.

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

Best Management Practice	Sediment (tns/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.0129	0.614	4.063
Fertilizer Reduction[1]	0.0129	0.606	3.852
Percent Reduction	**0**	**1.3**	**5.2**

[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 on select locations in the Brakke Dam/Brakke Creek watershed using 2000 through 2003 field application rates. Application rates varied in the type and amount of fertilizer applied throughout the watershed. Both nitrogen and phosphorus may be applied, nitrogen only or phosphorus only, depending upon field, crop and/or tillage practice. Seventeen separate field operations were identified in the Brakke Dam/Brakke Creek watershed, five (29.4 percent) applied nitrogen and phosphorus, zero (0 percent) applied phosphorus only and eleven (64.7 percent) applied nitrogen fertilizer only. Phosphorus applications rates also varied from moderate to low in pounds/acre.

Reductions were modeled by reducing phosphorus application rates in fields where phosphorus application rates were moderate or low 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 or low to none), overall estimated phosphorus loading was reduced by 5.2 percent (Table B-4).

AnnAGNPS was used to predict/estimate phosphorus load reduction based on grazing management. Field data on pastures in Brakke Dam/Brakke 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 upon 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 8.9 percent (Table B-5).

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

Best Management Practice	Sediment (tns/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.0129	0.614	4.063
Grazing Management[1]	0.0124	0.574	3.702
Percent Reduction	**3.9**	**6.5**	**8.9**

[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 priority one and two phosphorus critical cells (4 critical cells) to estimate reductions. AnnAGNPS predicted a 0.3 percent phosphorus reduction by converting critical cell tillage to no tillage (Table B-6).

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

Best Management Practice	Sediment (tns/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.0129	0.614	4.063
Conservation Tillage Reduction[1]	0.0127	0.611	4.051
Percent Reduction	**1.6**	**0.4**	**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 and two critical cells for Brakke Dam/Brakke Creek were converted from current crops to all grass and modeled using AnnAGNPS. Parameter specific reduction results were again reduced by 50 percent to better simulate typical buffer reductions. AnnAGNPS predicted a 4.5 percent phosphorus reduction by applying buffer strips to and phosphorus priority-one critical cells (Table B-7).

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

Best Management Practice	Sediment (tns/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.0129	0.614	4.063
Buffer Strips[1]	0.0125	0.592	3.877
Percent Reduction	**3.1**	**3.6**	**4.5**

[1] = Modeled for phosphorus and combined priority-one critical cells.

CONCLUSION

Modeled BMP reductions were: minimum tillage to no tillage, grazing management, buffer strips and fertilizer reduction (Table B-8). The combination of increased implementation of conservation tillage, grazing management, fertilizer reduction and buffer strips will result in reductions in sediment nitrogen and phosphorus. Installing these practices on priority critical cells the Brakke Dam/Brakke Creek will reduce the amount of sediment, nitrogen and phosphorus entering annually (Table B-8). An 18.9 percent reduction in phosphorus loading would result in a phosphorus TSI of 63.72 and a mean TSI of 64.51 (a 1.5 percent mean TSI reduction).

The suspected/estimated source of the elevated nutrient levels found within the Brakke Dam/Brakke Creek watershed is grazing management followed by runoff from fertilized cropland. Therefore, it is recommended that efforts to reduce nutrients should be focused within the identified critical nutrient cells.

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

Best Management Practice	Sediment	Nitrogen	Phosphorus
Fertilizer Reduction	0.0	1.3	5.2
Grazing Management Reduction	3.9	6.5	8.9
Conservation Tillage Reduction	1.6	0.4	0.3
Buffer Strips	3.1	3.6	4.5
Overall Watershed Percent Reduction	8.6	11.8	18.9

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 Brakke Dam/Brakke 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 Brakke Dam/Brakke Creek watershed.

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APPENDIX C

Tributary Chemical Data for 2000 through 2001

Table C-1. Tributary chemical data for the MCT-11 (west tributary) and MCT-12 (east tributary) and MCT-10 (outlet) of Brakke Dam, Lyman County, South Dakota from 2000 through 2001.

Site	Date	Season	Water Temperature (°C)	Dissolved Oxygen (mg/L)	pH (s.u.)	Conductivity (µS/cm^{-1})	Fecal Coliform (# 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)
MCT10	04/10/01	Spring	7.20	13.10	8.42	329	5	122	225	216	9	2	0.01	0.00038	0.20	0.39	0.38	0.21	0.59	0.062	0.015	9.52
MCT10	05/13/01	Spring	20.28	10.47	8.56	302	20	116	243	214	29	2	0.09	0.01155	0.40	0.73	0.49	0.64	1.13	0.157	0.109	7.20
MCT10	05/16/01	Spring	19.70	7.50	8.31	305	5	116	254	239	15	1	0.15	0.01103	0.30	0.89	0.74	0.45	1.19	0.146	0.101	8.15
MCT10	05/23/01	Spring	11.95	13.66	8.90	362	5	123	244	213	31	4	0.01	0.00146	0.30	0.81	0.31	0.80	1.11	0.112	0.061	9.91
MCT11	03/13/01	Winter	0.63	10.96	8.65	490	5	11	63	56	7	1	0.62	0.02324	0.80	2.17	1.42	1.55	2.97	0.390	0.345	7.62
MCT11	04/25/01	Spring	5.09	11.81	8.13	148	5	66	151	122	29	3	0.01	0.00017	0.50	0.37	0.51	0.36	0.87	0.235	0.194	3.70
MCT11	04/12/01	Spring	2.26	14.30	8.02	240	20	88	301	199	102	4	0.04	0.00041	0.80	0.82	0.84	0.78	1.62	0.412	0.174	3.93
MCT12	05/13/01	Spring	16.48	4.32	8.19	365	100	183	304	247	57	3	0.01	0.00045	0.05	1.30	0.06	1.29	1.35	0.175	0.101	7.71
MCT12	04/25/01	Spring	3.77	6.85	7.85	314	29,000	113	401	303	98	12	0.15	0.00119	0.52	2.13	0.67	1.98	2.65	1.660	1.320	1.60
MCT12	03/19/01	Winter	6.32	8.54	7.95	247	5	74	269	218	51	4	0.48	0.00588	4.40	1.94	4.88	1.46	6.34	0.736	0.617	8.61

APPENDIX D

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

Table D-1. In-lake surface chemical samples for Brakke 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 (°C)	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
May-00	BD-1	Surface	10.6	7.84	-	16.0	0.945	5	-	140	221	217	4.0	0.5	0.01	0.00020	0.05	0.56	0.55	0.06	0.61	0.030	0.005	20.33	5.87
Jun-00	BD-1	Surface	8.4	8.35	330	18.4	0.335	5	-	143	248	220	28.0	1.0	0.05	0.00367	0.10	0.98	0.93	0.15	1.08	0.091	0.022	11.87	19.84
Jul-00	BD-1	Surface	5.2	8.12	333	25.1	0.305	10	-	137	257	221	36.0	11.0	0.07	0.00493	0.20	0.58	0.51	0.27	0.78	0.084	0.015	9.29	-
Aug-00	BD-1	Surface	6.8	8.41	313	25.4	0.610	5	-	126	241	221	20.0	2.0	0.01	0.00131	0.05	1.11	1.10	0.06	1.16	0.090	0.026	12.89	-
Sep-00	BD-1	Surface	1.5	8.77	307	19.4	0.442	5	-	122	231	212	19.0	8.0	0.01	0.00183	0.05	0.89	0.88	0.06	0.94	0.072	0.026	13.06	-
Oct-00	BD-1	Surface	9.2	8.68	268	15.3	0.457	10	-	125	233	211	22.0	7.0	0.01	0.00118	0.05	0.79	0.78	0.06	0.84	0.082	0.034	10.24	21.20
Dec-00	BD-1	Surface	9.8	8.24	389	3.9	0.762	5	-	155	256	252	4.0	1.0	0.10	0.00195	0.10	0.84	0.74	0.20	0.94	0.036	0.028	26.11	8.95
Feb-01	BD-1	Surface	13.2	8.30	434	4.1	-	5	-	108	183	178	5.0	1.0	0.09	0.00205	0.20	0.58	0.49	0.29	0.78	0.023	0.010	33.91	0.95
Mar-01	BD-1	Surface	7.7	7.60	449	3.9	-	5	-	175	300	299	1.0	0.5	0.25	0.00114	0.10	0.91	0.66	0.35	1.01	0.038	0.012	26.58	5.40
Apr-01	BD-1	Surface	13.1	8.42	329	7.2	0.549	5	1	122	225	216	9.0	2.0	0.01	0.00038	0.20	0.39	0.38	0.21	0.59	0.062	0.015	9.52	27.35
May-01	BD-1	Surface	7.5	8.31	305	19.7	0.335	5	3.1	116	254	239	15.0	0.5	0.15	0.01102	0.30	0.89	0.74	0.45	1.19	0.146	0.101	8.15	3.78
May-00	BD-2	Surface	10.8	8.52	-	16.0	1.097	10	-	140	217	212	5.0	2.0	0.01	0.00089	0.05	0.74	0.73	0.06	0.79	0.038	0.006	20.79	4.75
Jun-00	BD-2	Surface	8.1	8.43	330	18.8	0.335	10	-	141	250	219	31.0	4.0	0.04	0.00356	0.10	0.72	0.68	0.14	0.82	0.083	0.020	9.88	12.62
Jul-00	BD-2	Surface	6.7	8.32	331	26.4	0.518	30	-	133	243	221	22.0	7.0	0.01	0.00116	0.10	0.67	0.66	0.11	0.77	0.066	0.010	11.67	15.68
Aug-00	BD-2	Surface	5.9	8.36	312	24.6	0.457	5	-	127	232	219	13.0	5.0	0.01	0.00113	0.05	0.07	0.06	0.06	0.12	0.077	0.023	1.57	17.57
Sep-00	BD-2	Surface	1.2	8.73	313	18.3	0.427	5	-	125	229	211	18.0	8.0	0.01	0.00159	0.05	0.56	0.55	0.06	0.61	0.077	0.022	7.92	36.09
Oct-00	BD-2	Surface	9.6	8.62	266	14.7	0.549	5	-	124	225	208	17.0	7.0	0.01	0.00100	0.05	0.90	0.89	0.06	0.95	0.068	0.034	13.97	-
Dec-00	BD-2	Surface	12.6	8.30	404	3.5	0.640	5	-	158	259	256	3.0	1.0	0.01	0.00022	0.10	0.71	0.70	0.11	0.81	0.034	0.016	23.82	-
Feb-01	BD-2	Surface	10.9	8.19	434	3.9	-	5	-	148	247	241	6.0	2.0	0.19	0.00329	0.20	0.86	0.67	0.39	1.06	0.031	0.015	34.19	-
Mar-01	BD-2	Surface	9.9	7.63	446	3.2	-	5	-	176	304	302	2	0.5	0.14	0.00064	0.1	0.7	0.56	0.24	0.8	0.028	0.006	28.57	-
Apr-01	BD-2	Surface	12.8	8.41	328	7.7	0.488	5	2	120	234	214	20.0	7.0	0.01	0.00038	0.20	0.48	0.47	0.21	0.68	0.067	0.015	10.15	-
May-01	BD-2	Surface	6.8	8.70	305	20.3	0.335	5	1	117	247	236	11.0	2.0	0.13	0.02203	0.30	1.09	0.96	0.43	1.39	0.169	0.110	8.22	3.73

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

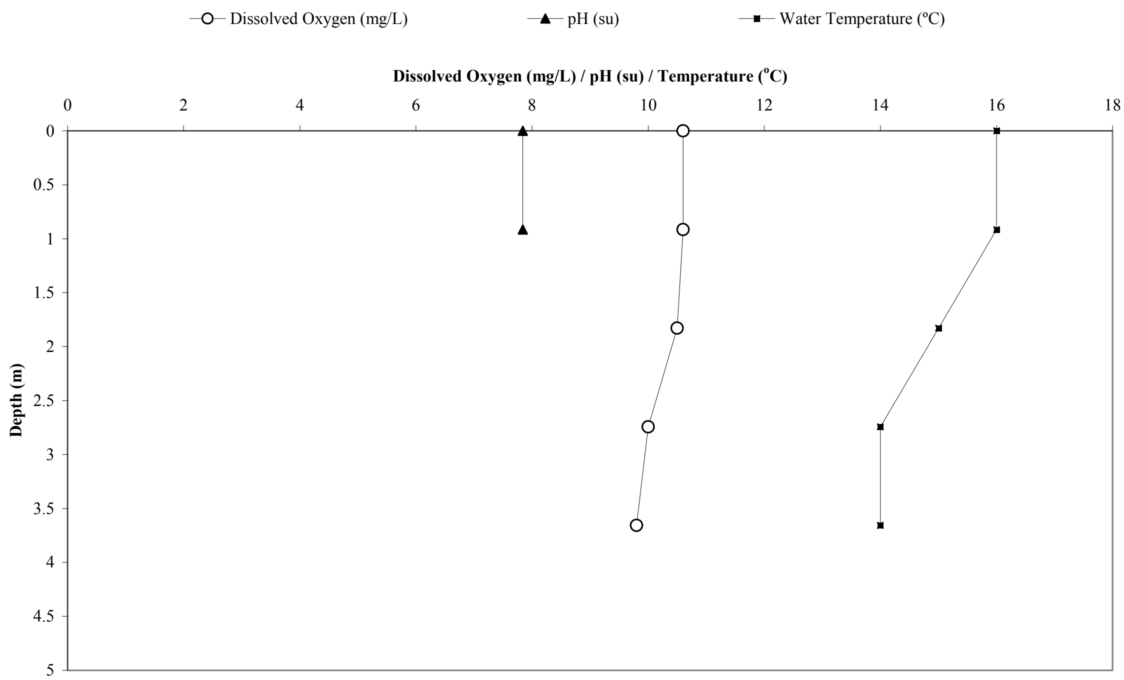
Date	Site	Location	Dissolved Oxygen (mg/L)	pH (s.u.)	Conductivity (µS/cm-1)	Water Temperature (°C)	Total Depth (meters)	Fecal Coliform (# colonies/100 ml)	E-Coli Bacteria (# colonies/100 ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	Ammonia (mg/L)	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)
May-00	BD-1	Bottom	9.8	8.39	-	14.0	4.42	5	-	140	223	215	8.0	3.0	0.01	0.05	0.62	0.61	0.06	0.67	0.032	0.005	20.94
Jun-00	BD-1	Bottom	8.02	8.35	329	18.6	2.44	5	-	141	246	220	26.0	3.0	0.05	0.10	0.88	0.83	0.15	0.98	0.084	0.020	11.67
Apr-01	BD-1	Bottom	13.3	8.42	329	7.2	-	5	0.5	121	224	213	11.0	4.0	0.01	0.20	0.18	0.17	0.21	0.38	0.054	0.015	7.04
May-01	BD-1	Bottom	7.67	8.28	305	19.4	4.57	5	3.1	116	249	232	17.0	2.0	0.17	0.30	0.82	0.65	0.47	1.12	0.146	0.102	7.67
May-00	BD-2	Bottom	9.8	8.44	-	14.0	3.41	5	-	139	221	217	4.0	1.0	0.01	0.05	0.61	0.60	0.06	0.66	0.032	0.005	20.63
Jun-00	BD-2	Bottom	7.33	8.28	330	18.5	3.69	10	-	142	258	223	35.0	4.0	0.06	0.10	0.85	0.79	0.16	0.95	0.094	0.018	10.11
Jul-00	BD-2	Bottom	1.12	7.95	348	24.7	3.66	10	-	143	282	239	43.0	8.0	0.01	0.10	0.80	0.79	0.11	0.90	0.142	0.024	6.34
Aug-00	BD-2	Bottom	5.73	8.32	313	25.2	3.96	5	-	126	224	214	10.0	4.0	0.01	0.05	0.79	0.78	0.06	0.84	0.075	0.023	11.20

APPENDIX E

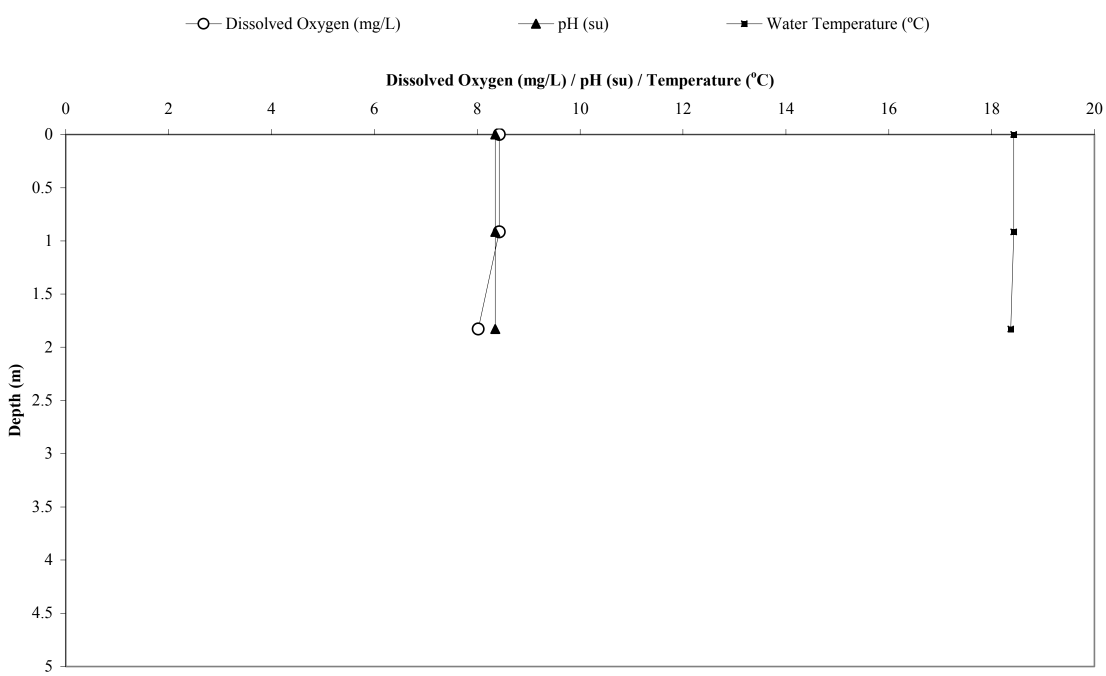
Brakke Dam In-lake Temperature, Dissolved Oxygen and pH Profiles from 2000 and 2001

Brakke Dam Profiles 2000 (BD-1)

Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at BD-1 for Brakke Dam, Lyman County, South Dakota in May 2000

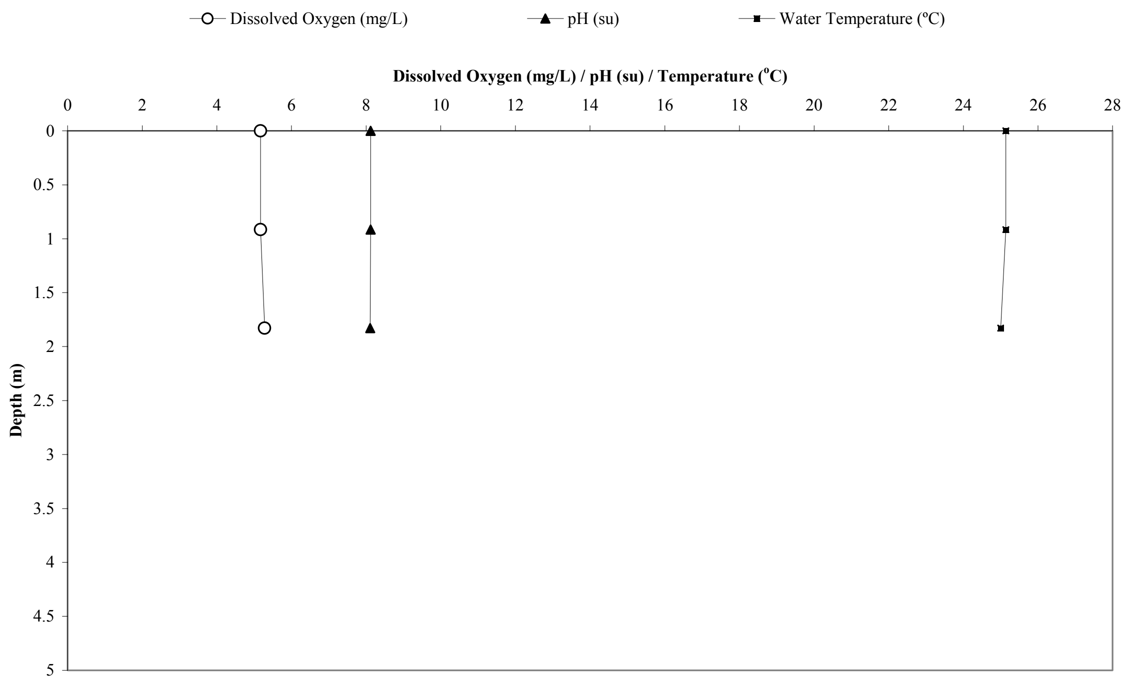


Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at BD-1 for Brakke Dam, Lyman County, South Dakota in June 2000

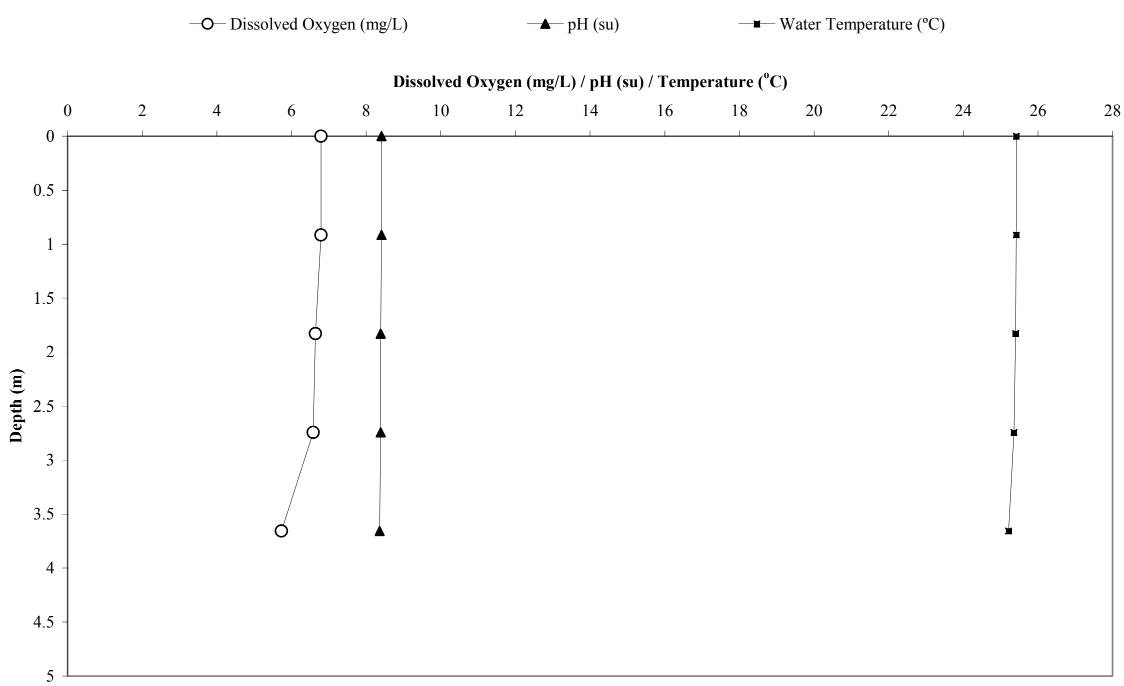


Brakke Dam Profiles 2000 (BD-1)

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

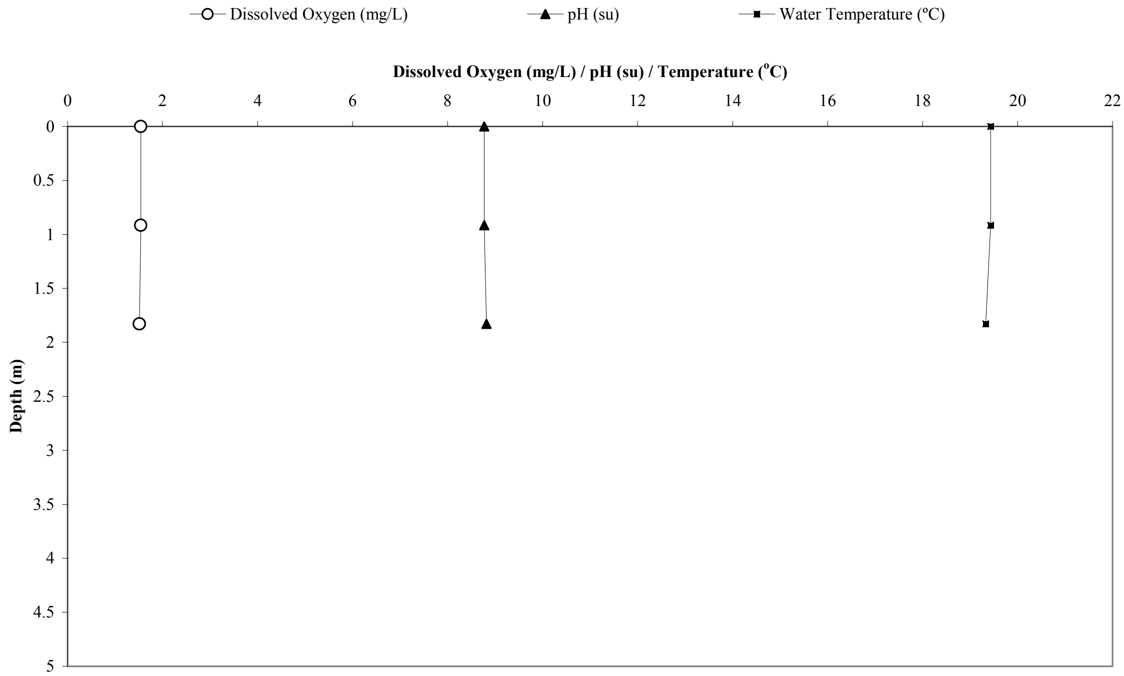


Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at BD-1 for Brakke Dam, Lyman County, South Dakota in August 2000

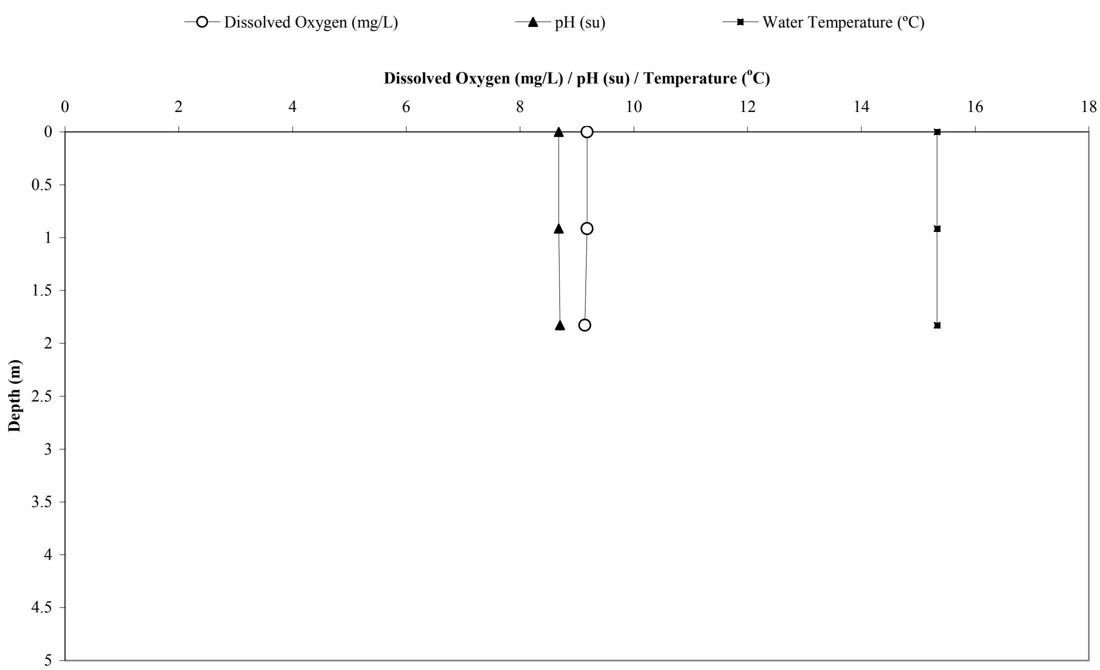


Brakke Dam Profiles 2000 (BD-1)

Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at BD-1 for Brakke Dam, Lyman County, South Dakota in September 2000

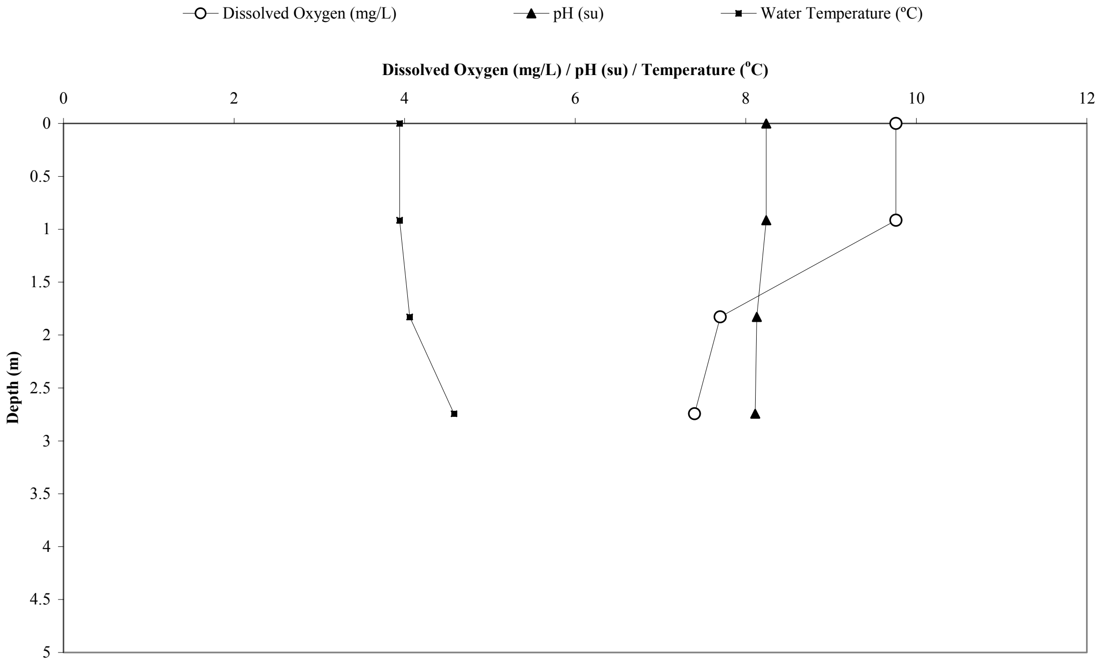


Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at BD-1 for Brakke Dam, Lyman County, South Dakota in October 2000



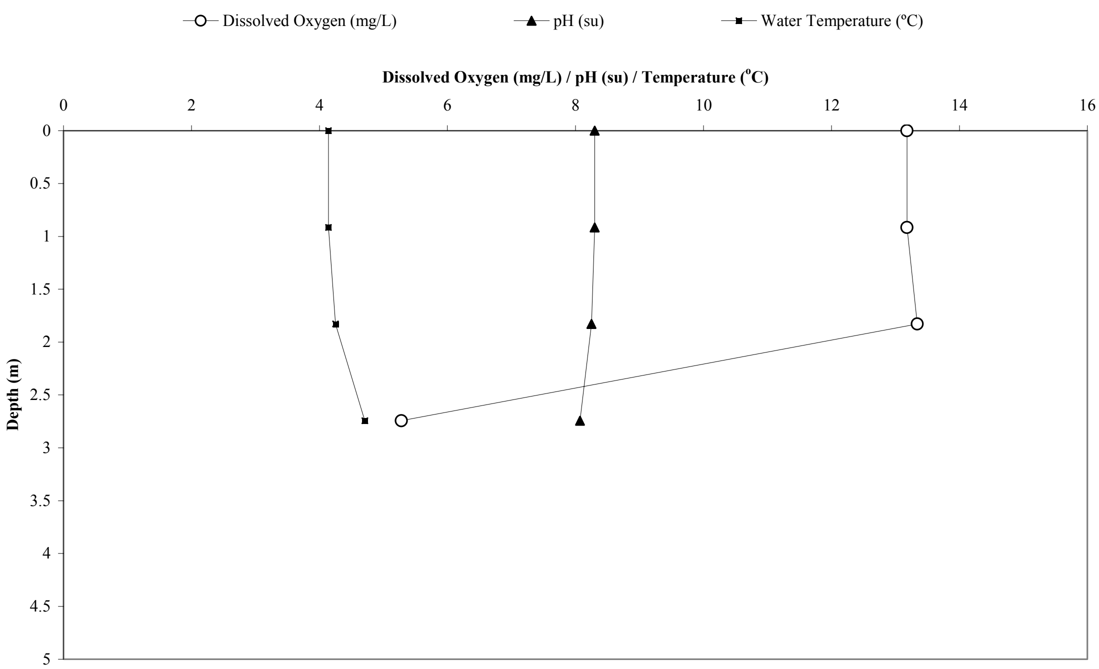
Brakke Dam Profiles 2000 (BD-1)

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



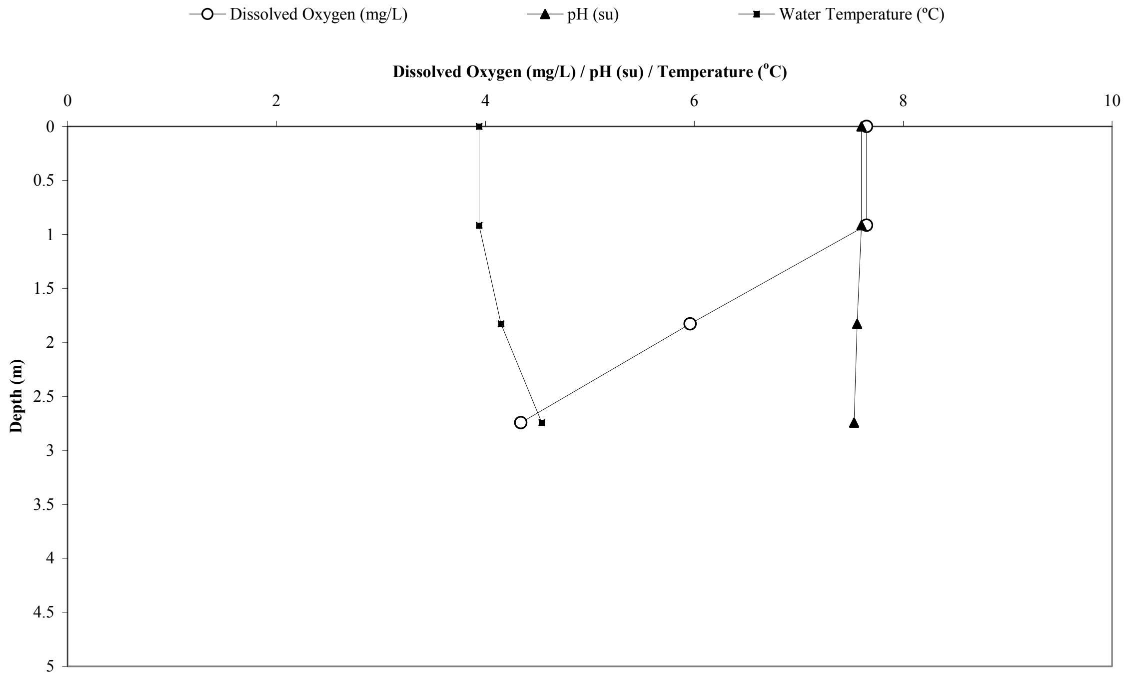
Brakke Dam Profiles 2001 (BD-1)

Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) Profiles at BD-1 for Brakke Dam, Lyman County, South Dakota in February 2001

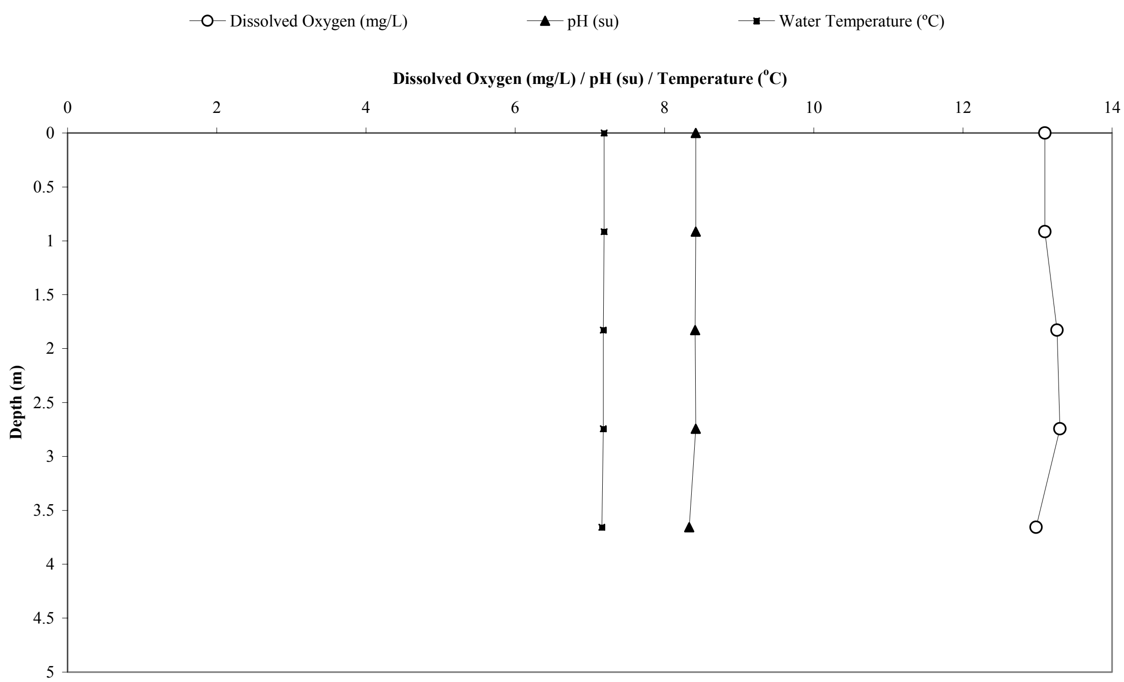


Brakke Dam Profiles 2001 (BD-1)

Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at BD-1 for Brakke Dam, Lyman County, South Dakota in March 2001

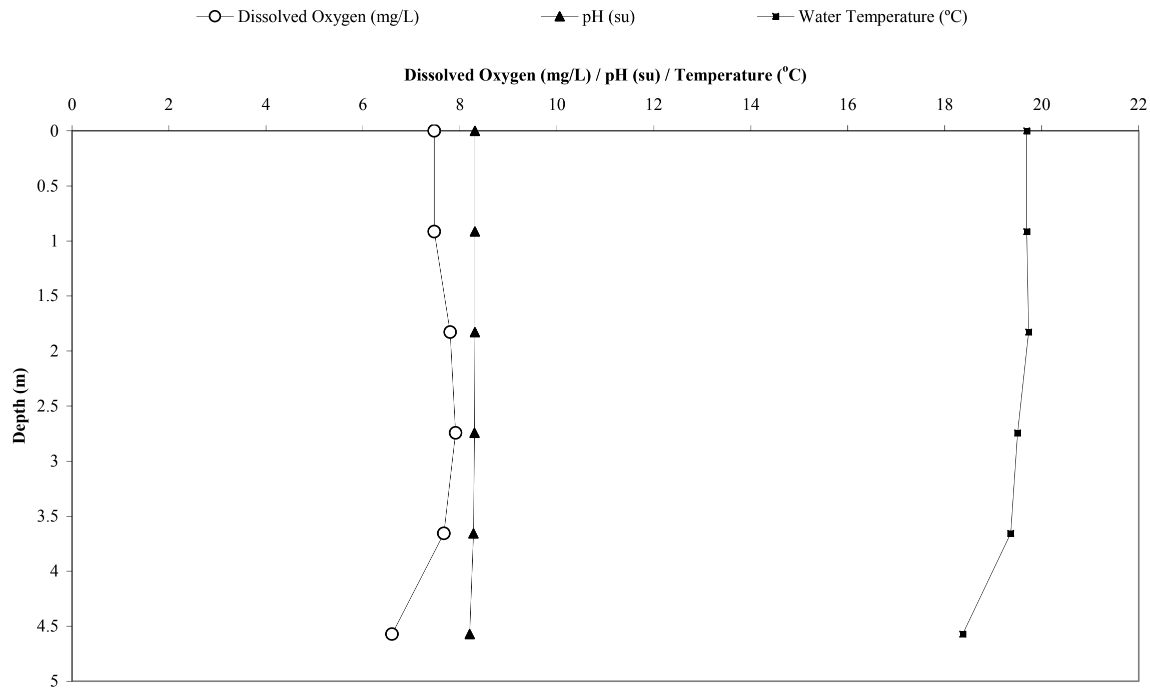


Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at BD-1 for Brakke Dam, Lyman County, South Dakota in April 2001



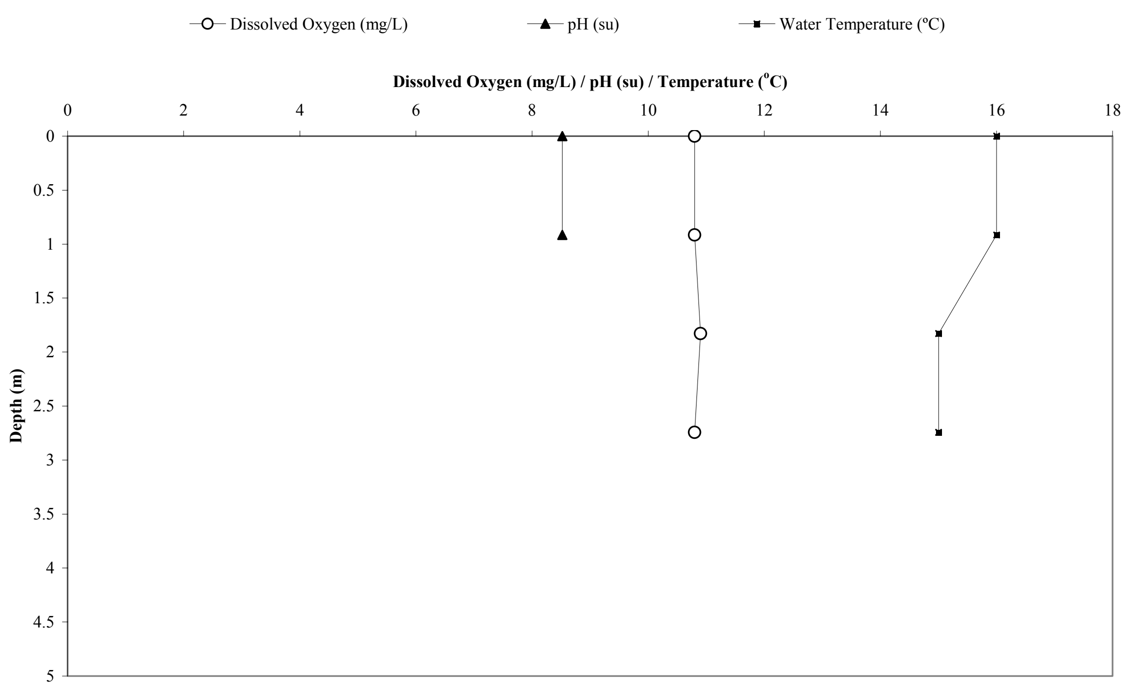
Brakke Dam Profiles 2001 (BD-1)

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



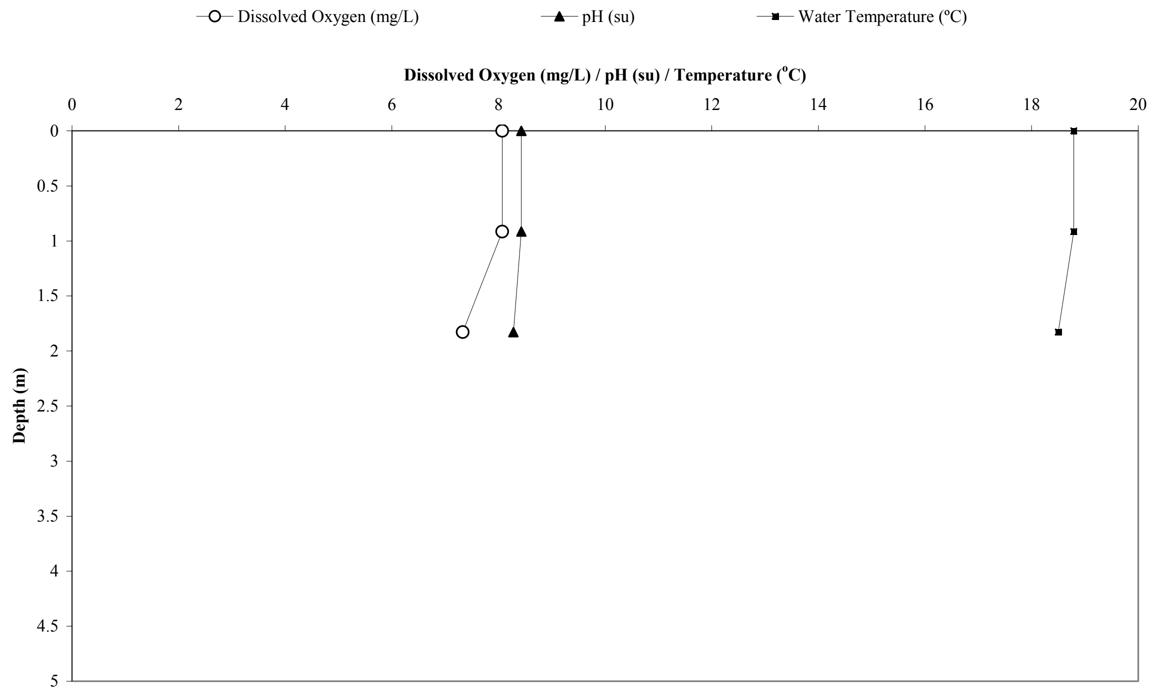
Brakke Dam Profiles 2000 (BL-2)

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

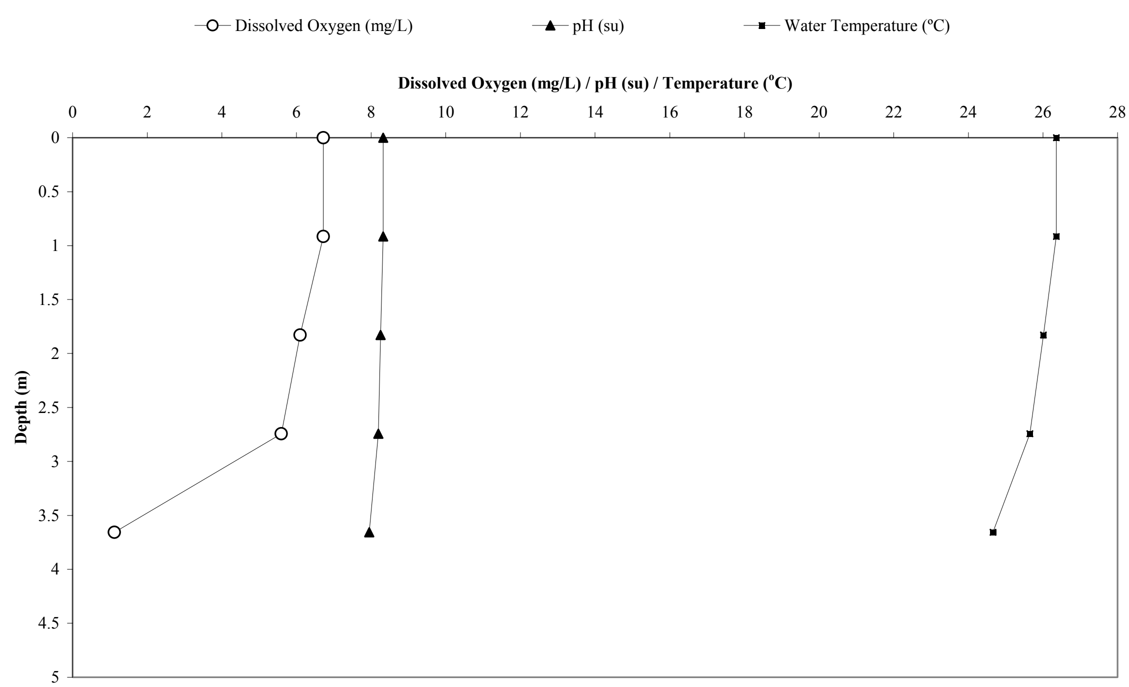


Brakke Dam Profiles 2000 (BL-2)

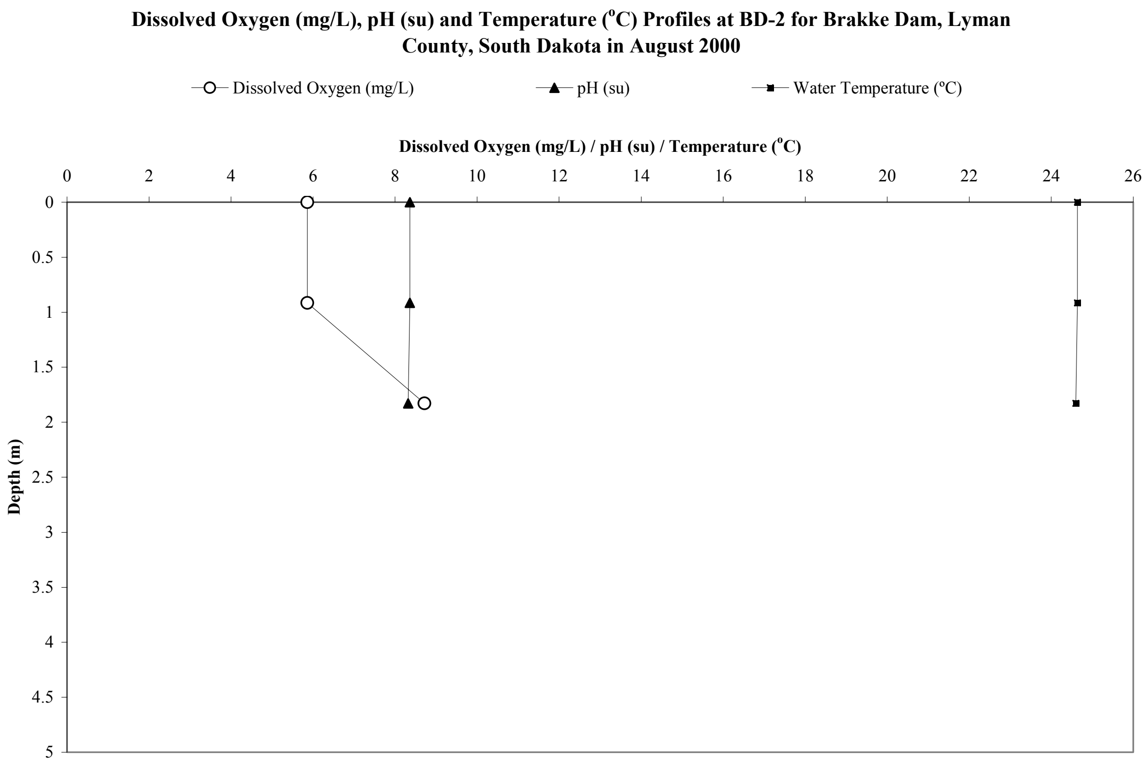
Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at BD-2 for Brakke Dam, Lyman County, South Dakota in June 2000

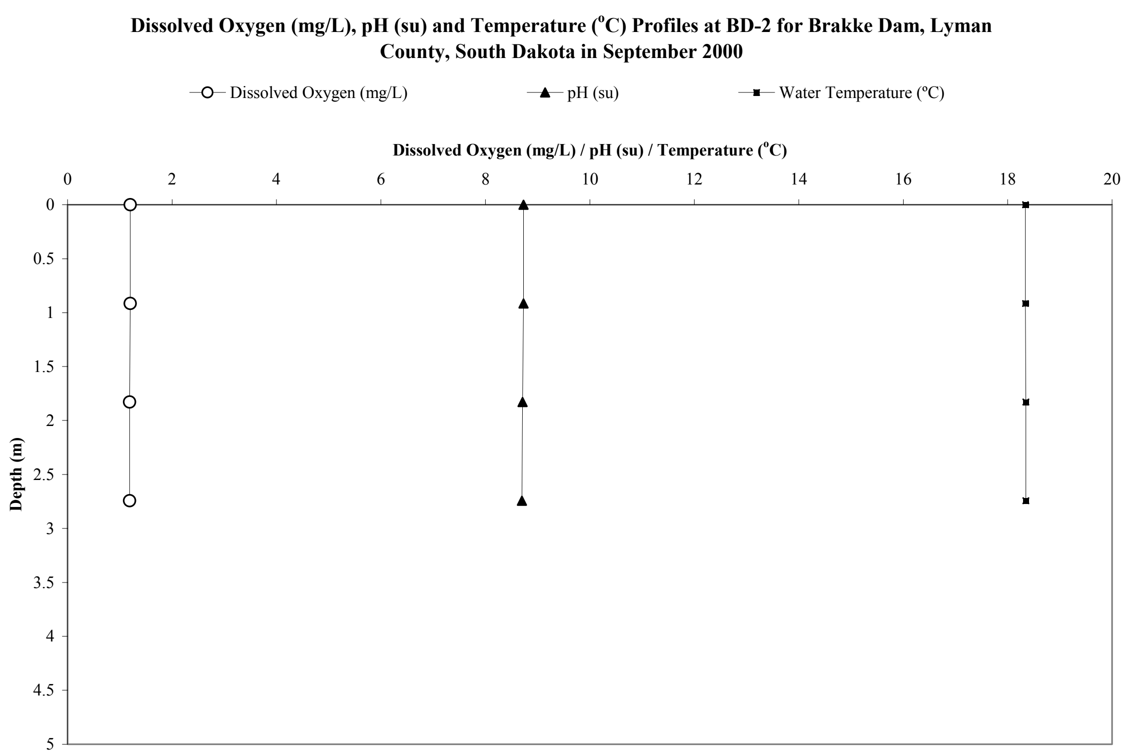


Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) Profiles at BD-2 for Brakke Dam, Lyman County, South Dakota in July 2000



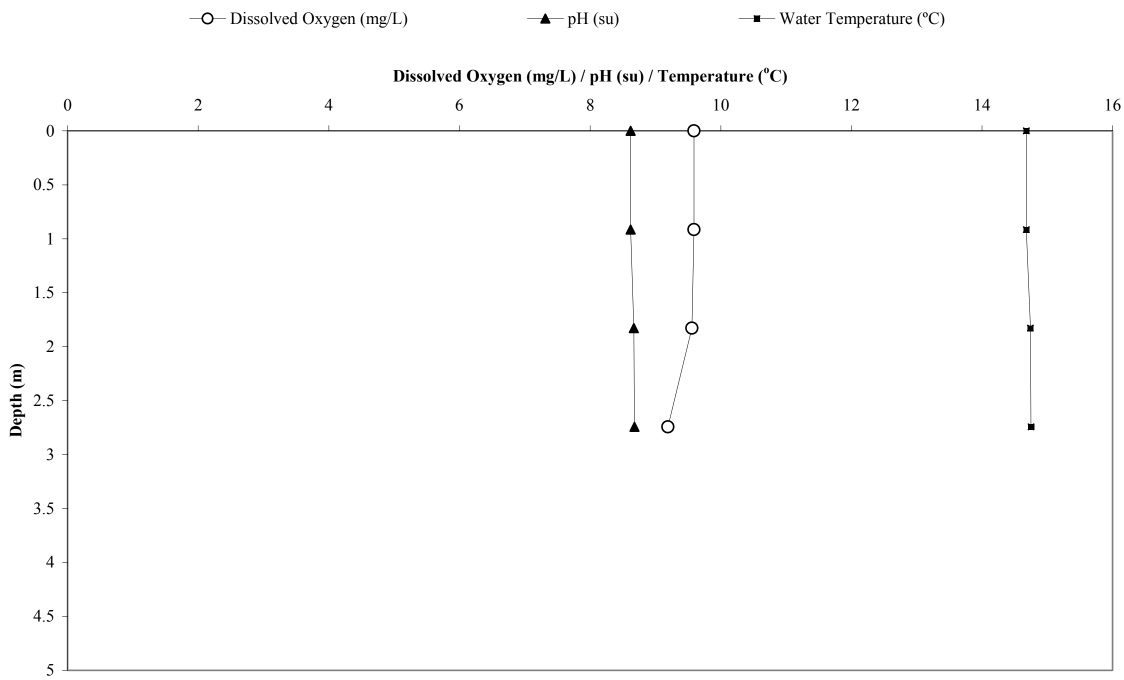
Brakke Dam Profiles 2000 (BL-2)



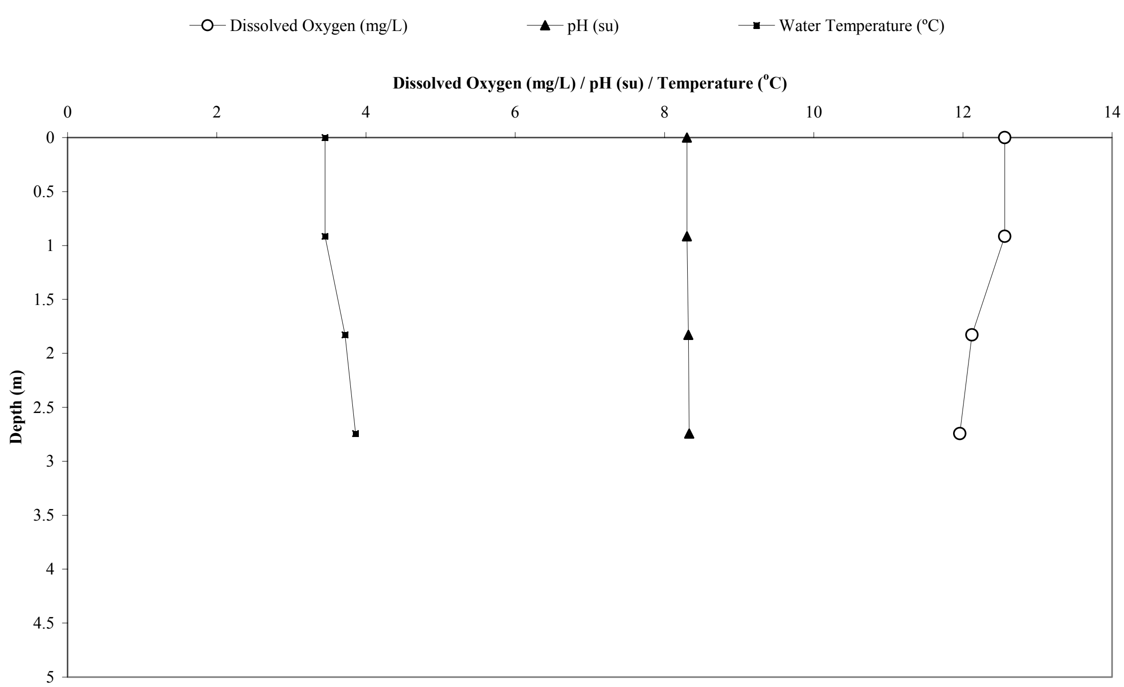


Brakke Dam Profiles 2000 (BL-2)

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

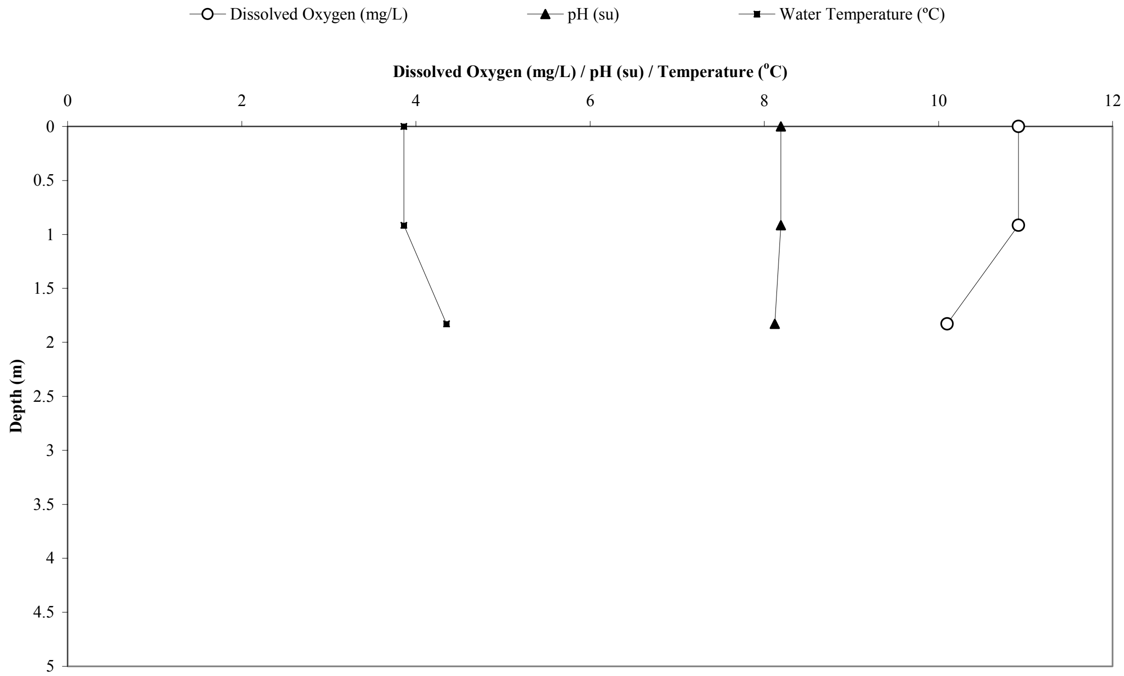


Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at BD-2 for Brakke Dam, Lyman County, South Dakota in December 2000

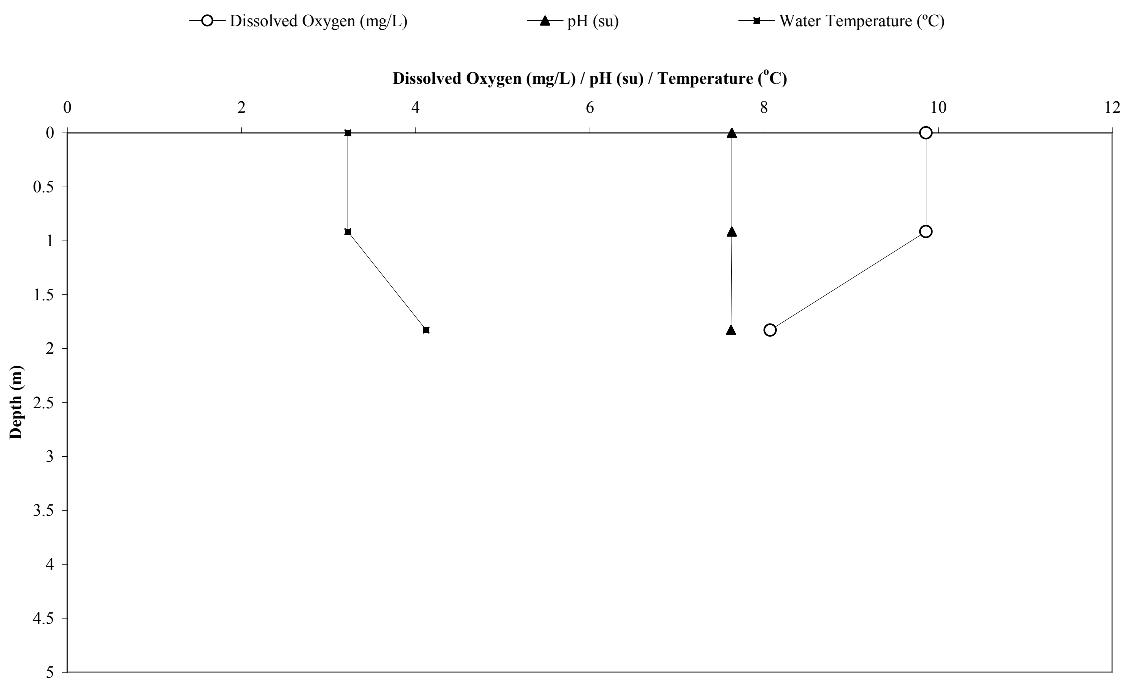


Brakke Dam Profiles 2001 (BL-2)

Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) Profiles at BD-2 for Brakke Dam, Lyman County, South Dakota in February 2001

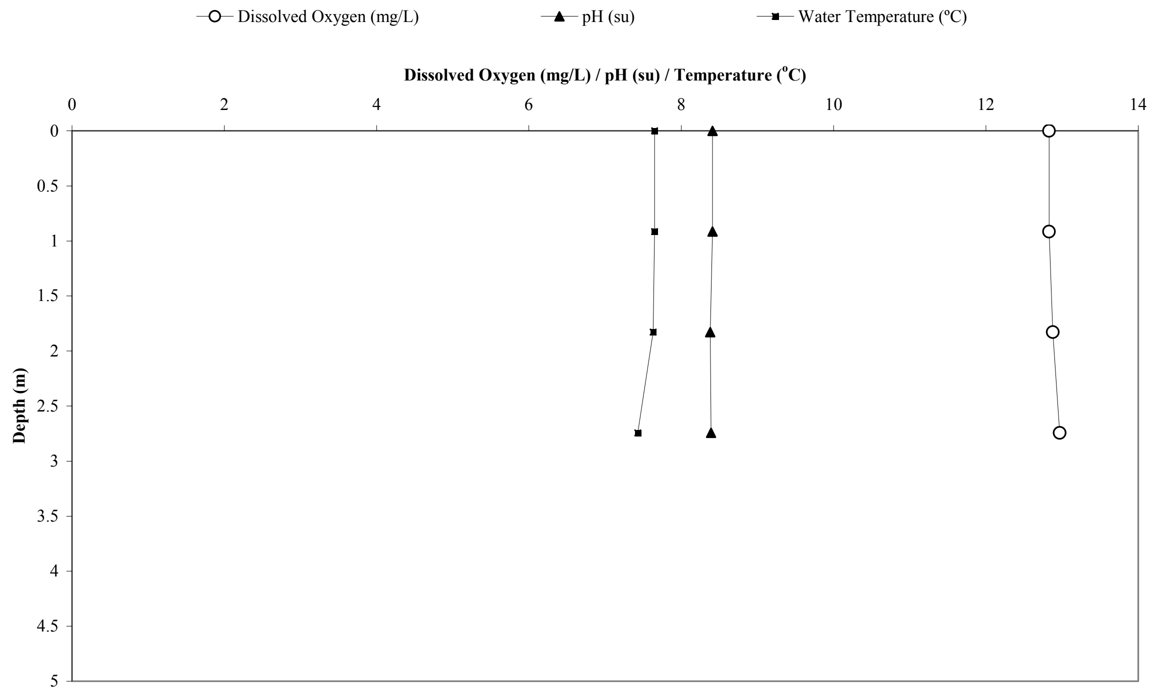


Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) Profiles at BD-2 for Brakke Dam, Lyman County, South Dakota in March 2001

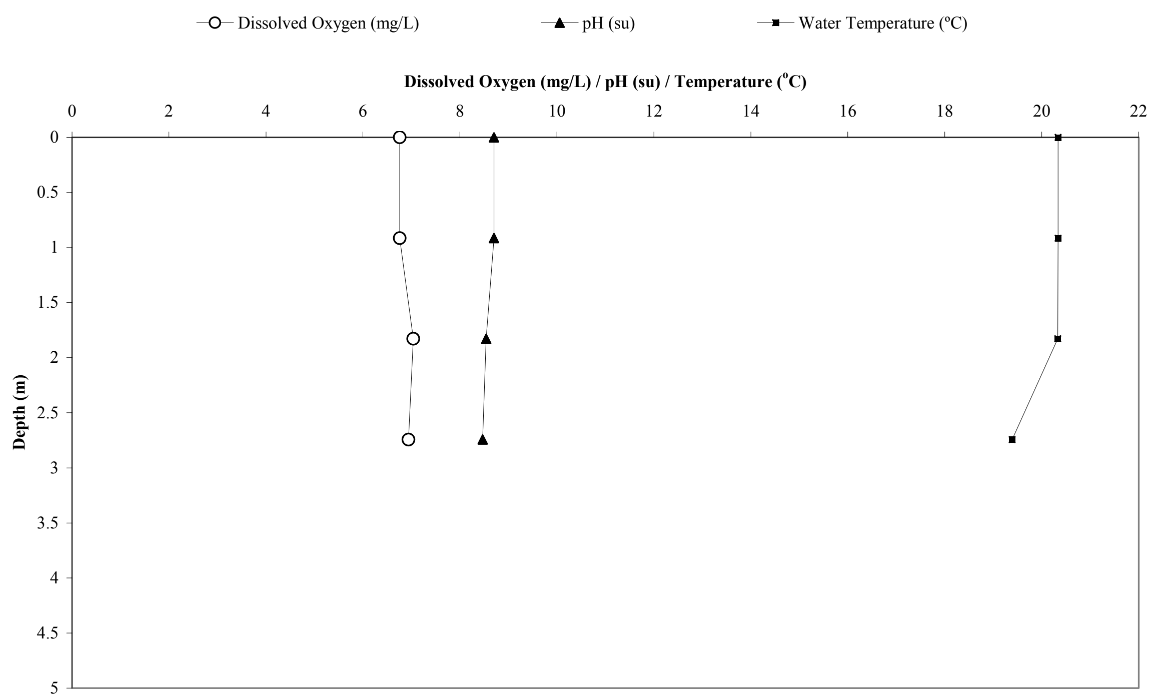


Brakke Dam Profiles 2001 (BL-2)

Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at BD-2 for Brakke Dam, Lyman County, South Dakota in April 2001



Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) Profiles at BD-2 for Brakke Dam, Lyman County, South Dakota in May 2001



APPENDIX F

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

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102 - F-21-R-34

Name: Brakke Lake **County:** Lyman
Legal Description: Sections 16, 21 & 22, Township 105, Range 76
Location From Nearest Town: 5 miles east of Presho

Date of Present Survey: June 6-8, 2001
Date Last Surveyed: June 22-24, 1998
Most Recent Lake Management Plan: F-21-R-30 **Date:** 1998
Management Classification: Warm Water Permanent

Contour Mapped: Yes **Date:** 1968

Primary Species: (game and forage)
1. Largemouth Bass
2. Walleye
3. Bluegill

Secondary and Other Species:
1. Yellow Perch
2. Channel Catfish
3. Black Bullhead

PHYSICAL CHARACTERISTICS

Surface Area: 130 acres **Watershed:** 10,240 acres
Maximum Depth: 17 feet **Mean Depth:** 5 feet

Lake Elevation at Survey (from known benchmark): Full

1. Describe ownership of lake and adjacent lakeshore property:

The Game, Fish and Parks own approximately one third of the land surrounding the lake and the remaining two thirds is privately owned.

2. Describe watershed condition and percentages of land use:

Approximately 75% of the watershed is cultivated for small grains and row crops, with pasture and CRP making up the balance.

3. Describe aquatic vegetative condition:

Cattails create a barrier to shoreline fishing except on the face of the dam and the boat ramp area.

4. Describe pollution problems:

Heavy sedimentation from nearby agricultural land is the primary pollution concern.

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

The spillway, dam grade and boat ramp are all in good condition.

CHEMICAL DATA

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

Water quality characteristics were analyzed on June 6, 2001, with a Hach Water Quality Kit. Results are on Table 1.

2. **Thermocline:** no **Location from surface ft.**

3. **Secchi disc reading:** 1.5 ft.

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

Table 1. Water chemistry results from Brakke Lake, Lyman County, June 6, 2001.

Station number	Depth feet	Temp F	DO PPM	CO2 PPM	ALK MG\L	Hardness MG\L	pH
A	surface	63	11.1	32.8	129	190	8.0
A	16	63	9.0	13.0	128	143	7.5

BIOLOGICAL DATA

Methods:

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

Brakke Lake was sampled using eight frame-net sets from June 6-8, 2001. Frame-nets were constructed with 3x5ft frames, 3/4-inch mesh and sixty-foot leads. Brakke Lake was also electrofished on Oct. 22, 2001, using pulsed AC current. Conductivity was 200 Uhmos and water temperature was 52 degrees. A sample of each species was weighed and measured. Fish indices were calculated using the Winfin computer program.

Results and Discussion:

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

Table 2. Total catch of six, 10-minute transects of nighttime electrofishing at Brakke Lake, Lyman County, Oct.22, 2001.

Spec.	#	%	CPUE fish/hr (80%CI)	PSD (90%CI)	Stock Mean Wr (90%CI)
LMB	54	77.1	54.0(24.2)	87(8)	108.4(1.2)
WAE	16	22.9	16.0(10.4)	47(23)	83.0(1.2)
Total	70				

Table 3. Total catch of eight, 24 hour, 3/4 inch frame nets at Brakke Lake, Lyman County, June 6-8, 2001.

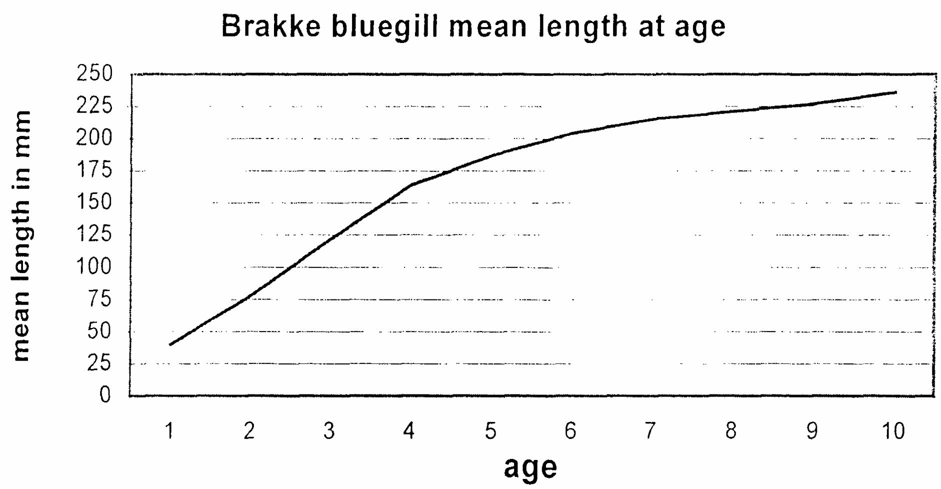
Spec.	#	%	CPUE (80%CI)	PSD (90%CI)	Stock Mean Wr (90%CI)
BLB	1	0.7	0.1(0.2)	--	--
BLC	5	3.7	0.6(0.9)	--	--
BLG	106	78.5	13.3(6.4)	94(4)	98.2(1.1)
NOP	2	1.5	0.3(0.4)	--	--
WAE	20	14.8	2.5(1.5)	89(13)	84.3(4.2)
YEP	1	0.7	0.1(0.2)	--	--
Total	135				

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

Bluegill

The bluegill population in Brakke Lake has declined to a CPUE of 13.3. This is an alarming 89% reduction from 1998, when CPUE was 121.0. PSD was 94 with an RSD-P of 89; this shows there are very few young bluegill coming up to replace the aging population. Condition was good with a Wr of 98.2 for stock length and greater fish. Table 4 shows bluegill growth, which was right at the state and regional average.

Table 4. Weighted mean back-calculated length at age for the Bluegill population at Brakke Lake, Lyman County, 2001.



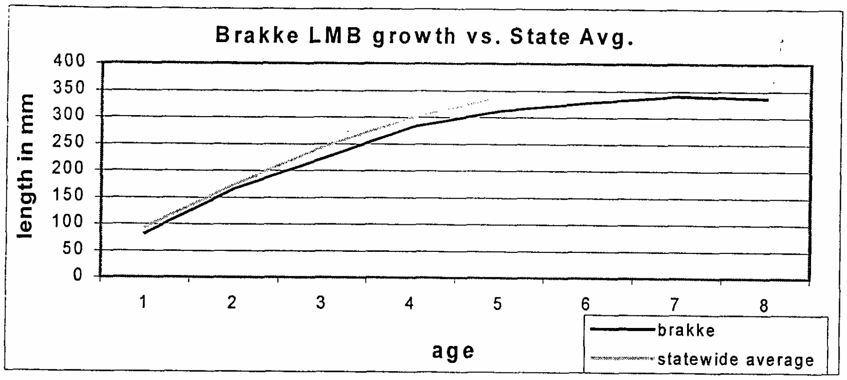
Largemouth Bass

Electrofishing yielded a bass CPUE of 54.0 bass per hour. Eighty-seven percent of bass over stock length were over quality length with an RSD-P of 9. Condition for stock length and larger fish was 108.4. Table 5 shows decreasing fish condition as fish length increases. Table 6 graphs the below average growth of Brakke Lake bass. It appears there may an excessively high density of predators in this system for the available forage.

Table 5. Weighted mean relative weight by length category for Largemouth Bass in Brakke Lake, Lyman County, 2001.

Description	Weighted mean Wr(90%CI)
Stock	108.4(1.2)
Stock to Quality	117.6(3.6)
Quality to Preferred	107.9(0.7)
Preferred to Memorable	99.6(1.1)

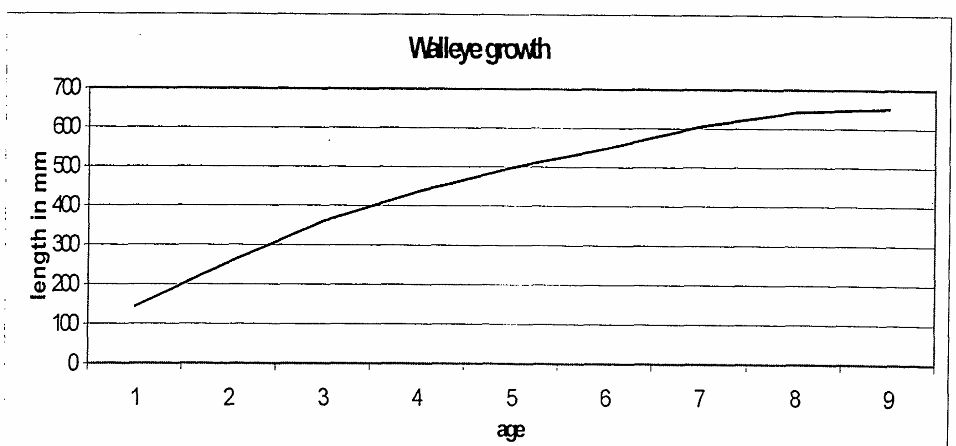
Table 6. **Weighted mean back-calculated length at age for the Largemouth Bass population verses the state average at Brakke Lake, Lyman County, 2001.**



Walleye

Walleye numbers remained similar to the 1998 survey. Frame net CPUE was 2.5. Last survey CPUE was 3.6. The population was dominated by larger fish with a PSD of 89 and an RSD-P of 39. RSD-M was 17. Overall, stock length and larger fish had a Wr of 84. Table 7 shows walleye growth, which was right at the state average.

Table 7. **Weighted mean back-calculated length at age for the Walleye population at Brakke Lake, Lyman County, 2001.**



Other Fish

Frame nets also sampled very small numbers of black bullhead, black crappie, northern pike and yellow perch. During fall electrofishing several large channel catfish were observed.

RECOMMENDATIONS

1. Describe management approach.

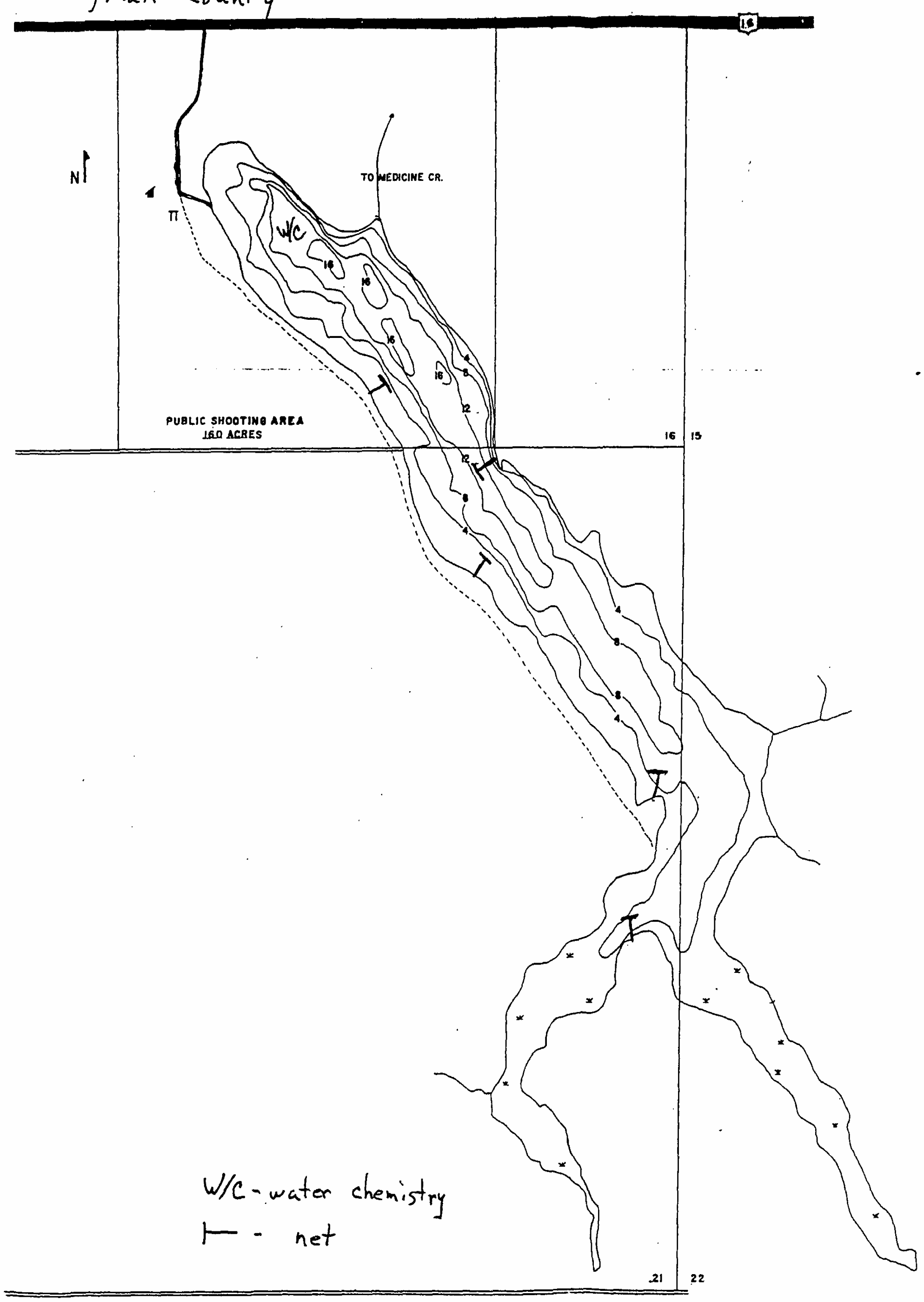
1. If a source of over-populated bluegill is located, transfer adult fish to Brakke Lake to increase number of smaller fish in this aging population.

2. Discontinue walleye stocking until bluegill numbers and size structure improve.

Stocking record for Brakke Lake, Lyman County, 2001.

Year	**Number**	**Species**	**Size**
1991	5,000	LMB	Fingerling
1992	6,750	LMB	Fingerling
1993	1,400	WAE	Fingerling
1997	3,250	WAE	Fingerling
1999	1,970	WAE	Fingerling

Brakke Lake
Lyman County



DE

AERIAL

APPENDIX G

Rare, Threatened and Endangered Species Documented in the Brakke 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 Brakke Dam Watershed 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 H

Brakke Dam Total Maximum Daily Load Document

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

TOTAL PHOSPHORUS (TSI)

In

BRAKKE DAM WATERSHED

(HUC 10140104)

LYMAN COUNTY,
SOUTH DAKOTA

**SOUTH DAKOTA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES**

APRIL, 2004

Brakke Dam Total Maximum Daily Load April, 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. Irrigation water
Size of Waterbody:	52.6 hectare (130 acres)
Size of Watershed:	4,568.1 hectare (11,288 acres)
Water Quality Standards:	Narrative and numeric
Indicators:	Average TSI
Analytical Approach:	BATHTUB, FLUX and AnnAGNPS
Location:	HUC Code: 10140104
TMDL Goal	
Total Phosphorus:	18.9% reduction in total phosphorus (117 kg/yr.)
TMDL Target	
Total Phosphorus:	TSI 63.72, mean TSI 64.51 (501kg/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. Brakke Dam watershed location in South Dakota

Brakke Dam is a 52.6 hectare (130-acre) man-made impoundment located in central Lyman County, South Dakota (Figure 1). Brakke Dam is listed in the 2002 South Dakota 303(d) Waterbody List; however the 2004 Brakke Dam watershed assessment report identified Brakke Dam as not meeting the ecoregional based TSI criteria. Watershed and in-lake modeling indicated that only under extreme conditions (unattainable), Brakke Dam could meet current ecoregional TSI targets. However, this condition is unattainable due to logistical, financial and technical constraints. AnnAGNPS modeling data was used to develop watershed/site specific TSI target criteria for Brakke Dam. Brakke Dam was identified for TMDL development for trophic state index (TSI), increased eutrophication.

The Brakke Dam watershed encompasses approximately 4,568 ha (11,288 acres) and is drained by an unnamed tributary (henceforth, Brakke Creek) (Figure 2). The damming of Brakke Creek near the town of Kennebec, South Dakota created the lake, which has an average depth of 2.08 meters (6.84 feet) and over 5.9 kilometers (3.7 miles) of shoreline. The lake has a maximum depth of 5.8 meters (19 feet) and holds 1,300 acre-feet of water. The outlet for the lake empties back into Brakke Creek, which empties into Medicine Creek and eventually reaches the Missouri River.

Problem Identification

Brakke Creek drains predominantly agricultural land (approximately 49.3 percent cropland and 50.7 percent pastureland) and flows into Brakke Dam. The stream carries nutrients (total nitrogen and total phosphorus) and sediment loads, which degrade the water quality of the lake, 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). Currently, the target for full support in ecoregion 43 is a mean TSI values ≤ 55.00. However, current ecoregional (ecoregion 43) target criteria appear not to fit Brakke 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) indicate the maximum phosphorus reduction in this watershed would be 88.2 percent (Appendix B). BATHTUB was then used to model AnnAGNPS phosphorus reduction to in-lake trophic response under ideal conditions. Data indicate under ideal (extreme conditions (mean TSI 64.37); Brakke Dam could meet ecoregional-based beneficial use criteria based on current targets. However, this condition is unattainable due to logistical, financial and technical constraints.

Current watershed conditions (loading) result in a modeled mean in-lake TSI value of 65.49 (Table 50, Assessment Report page 140). The Brakke Dam/Brakke Creek watershed can not feasibly meet current ecoregional based beneficial use criteria which are unrealistic and unachievable for Brakke Dam. Alternative site specific (watershed specific) evaluation criteria (fully supporting, mean TSI ≤ 65.00) is proposed based on AnnAGNPS modeling, BMPs and watershed specific phosphorus reduction attainability.

Currently, the total phosphorus load to Brakke Dam is 618 kg/year (0.68 tons/year). Annual total phosphorus loads need to be reduced by 117 kilograms (18.9 %), resulting in a total phosphorus TMDL of 501 kilogram per year, including background, producing a modeled mean Trophic State Index (TSI) of 64.51.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Brakke 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 and

Individual parameters, including the lake's mean TSI value, determine the support of beneficial uses and compliance with standards. Brakke Dam experiences nutrient enrichment and some nuisance algal blooms, which are typical signs of the eutrophication process. Brakke Dam was identified in the 2003 Brakke Dam/Brakke 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 Brakke Dam.

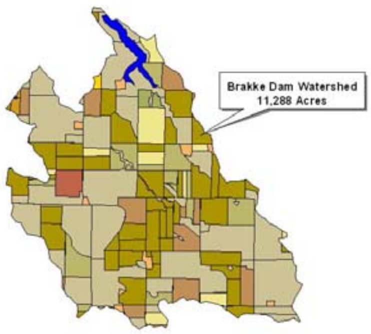


Figure 2. Brakke Dam and Brakke Creek watershed.

Brakke Dam currently has a modeled total phosphorus TSI of 65.33, an adjusted chlorophyll-*a* TSI of 62.17 and a Secchi TSI of 68.97 which translates to an average TSI of 65.49, which is indicative of increased levels of primary productivity (assessment final report, page 140). 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 Brakke Dam. The TMDL numeric target established to reduce total phosphorus loading to Brakke Dam will lower the mean TSI to 64.51 (assessment final report, Table 50).

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 Brakke Dam/Brakke Creek Watershed were estimated using FLUX and AnnAGNPS modeling.

Under current conditions, total nonpoint source loading of total phosphorus from the watershed to Brakke Dam was estimated to be 618 kg/yr and were attributed to agricultural sources. Nonpoint source/background load allocation of total phosphorus (501 kg/yr).

Linkage Analysis

Water quality data was collected from 3 monitoring sites within the Brakke Dam/Brakke Creek watershed. Samples collected at each site were taken 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 9 through 10, pages 18 through 21, 61 through 63 and 130 through 133 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 section of the final report, Appendix B.

In-lake (aluminum sulfate treatment) BMPs were also used to estimate total phosphorus reductions. 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 an implicit margin of safety. All estimates were based on conservative percent reductions applied to priority subwatersheds (assessment final report, pages 131 through 134).

Reducing the current total phosphorus load (618 kg/yr) a minimum of 18.9% (117 kg/yr) will reduce the average TSI value from 65.49 to 64.51. This can be accomplished by implementing tributary BMPs with an implicit margin of safety to support the TMDL target.

TMDL and Allocations

TMDL

Total phosphorus (kg) = 18.9% reduction

	0 kg/yr	(WLA)
+	501 kg/yr	(LA)
+	Implicit	(MOS)
	501 kg/yr	(TMDL) [1]

[1] = TMDL Equation implies an 18.9% based on BMP attainability in total phosphorus reduction with all modeled tributary BMP implementations.

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 0.3% (2 kg/yr) reduction and reduced fertilizer application could achieve a 5.2% (32 kg/yr) reduction in total phosphorus loading to Brakke Dam.

Tributary total phosphorus reductions for grazing management 8.9% (55 kg/yr.) and buffer strips 4.5% (28 kg/yr.) were estimated AnnAGNPS.

In-lake total phosphorus reductions in TSI were also estimated for Brakke Dam. They include and an aluminum sulfate treatment, 30% reduction in in-lake phosphorus concentrations resulting in a 4.2% reduction in in-lake total phosphorus TSI values.

A total phosphorus reduction of 18.9% (117 kg/yr) is needed to improve the mean TSI of Brakke Dam to 64.51.

The 18.9 percent modeled reduction is based on AnnAGNPS watershed modeling and consisted of: (1) all phosphorus fertilized fields with moderate to low fertilizer rates (29.4 percent) reduced one level (moderate to low or low to none) or 5.2 percent phosphorus reduction; (2) converting all current pastures from fair condition to good condition or 8.9 percent reduction; (3) applying conservation tillage to all priority-one and priority-two phosphorus critical cells (4-critical cells) or 0.3 percent and (4) converting tilled/cropped priority-one and priority-two phosphorus critical cells to all grass and results were again reduced 50 percent to better simulate typical phosphorus reduction or 4.5 percent. Combining all reductions the best estimated phosphorus reduction for Brakke Dam watershed is 18.9 percent (assessment final report, page and 138). AnnAGNPS modeling indicated that implementing only modeled BMPs in the Brakke Dam/Brakke Creek watershed would meet watershed specific beneficial use criteria set for Brakke Dam.

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, Brakke Dam samples were separated into winter (January-March, spring (April-June), summer (July-September) and fall (October-December). The spring 2001 sampling season had the highest loading for all parameters.

Margin of Safety

All modeled total phosphorus reductions were calculated based on extremely 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 are incorporated into the TMDL calculation in an implicit margin of safety (assessment final report, page and 141). Brakke Dam needs an 18.9% total phosphorus reduction to improve average TSI values.

Critical Conditions

Based upon the 2000 through 2001 assessment data, nutrient loading to Brakke Dam are most severe during the spring (runoff events) and impairments to Brakke Dam are most severe during the late summer and early fall. This is the result of warm water temperatures and increased algal growth.

Follow-Up Monitoring

Brakke 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 Brakke Dam watershed assessment project was initiated during the spring of 2000 with EPA Section 319 funds. Brakke Dam is on the priority list of Section 319 Nonpoint Source Pollution Control projects; based on watershed assessment data Brakke Dam partially supports TSI criteria. American Creek Conservation District agreed to sponsor the project. Federal grant funds totaled $101,796 of which, Brakke Dam was assessed. Funds were used for water quality analyses, equipment, supplies, travel, and wages for the local coordinator.

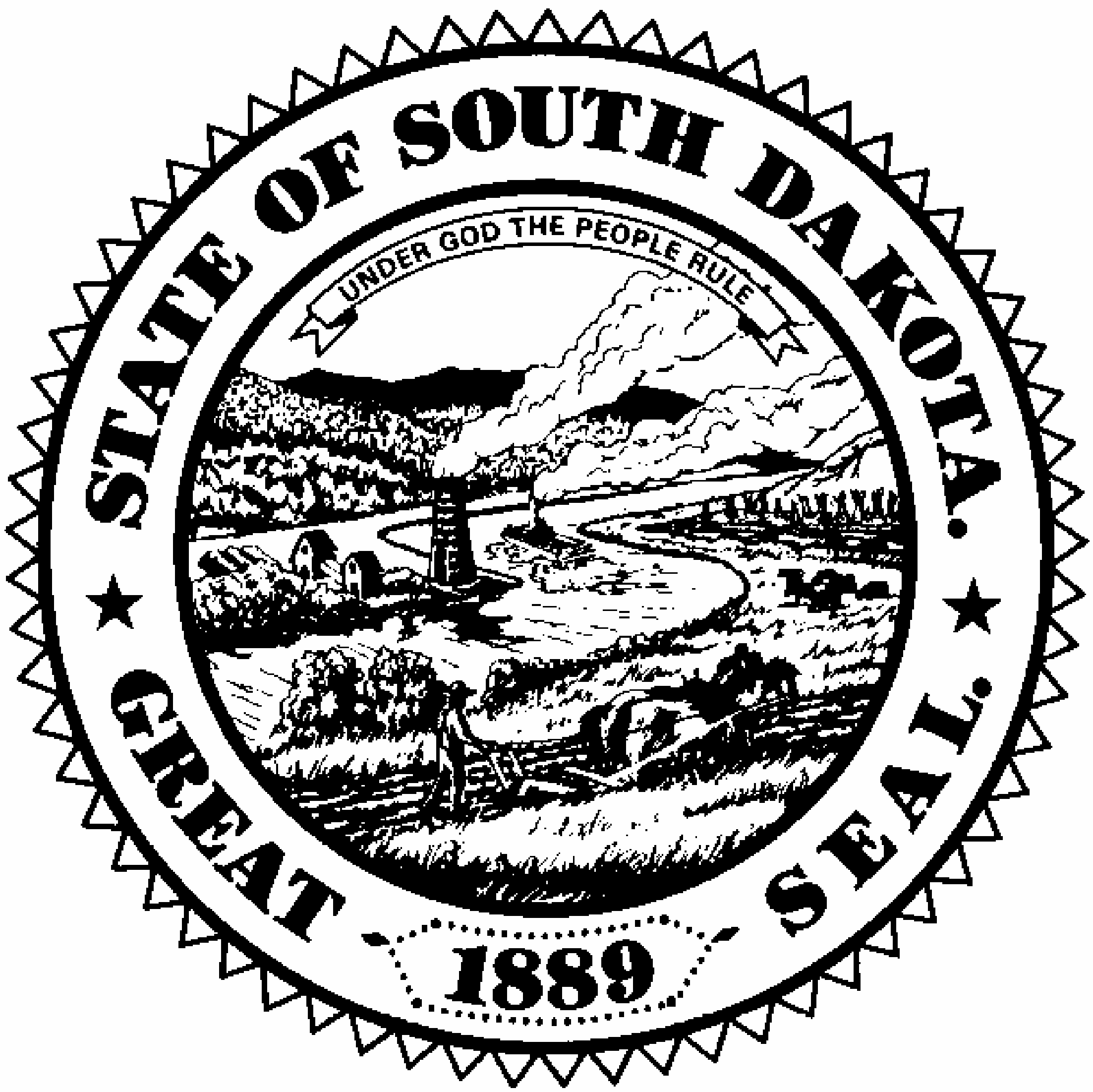
Efforts taken to gain public education, review, and comment during development of the TMDL involved:

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/pamphlets sent to landowners in the watershed (3)
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 Brakke Dam TMDL.

Implementation Plan

The South Dakota DENR is working with the American Creek Conservation District to initiate an implementation project in the future.


STATE OF SOUTH DAKOTA.
UNDER GOD THE PEOPLE RULE
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September 29, 2004

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
Brakke Dam
Fish Lake
Hayes Lake
Lake Herman

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 Fed. Reg. 33040 for July 24, 1992). Further, EPA states that "*...in some situations water quality standards –*

particulary designated uses and biocriteria – can only be attained if nonchemical factors such as hydrology, channel morphology, and habitat are also addressed. EPA recognizes that it is appropriate to use the TMDL process to establish control measures for quantifiable non-chemical parameters that are preventing the attainment of water quality standards." (see Guidance for Water Quality-based Decisions: The TMDL Process; USEPA; EPA 440/4-91-001, April 1991; pg. 4). We feel the State has developed TMDLs that are consistent with this guidance, taking a comprehensive view of the sources and causes of water quality impairment within each of the watersheds. For example, in several of the TMDLs, the State considered nonchemical factors such as trophic state index (TSI) and its relationship to the impaired uses. Further, we feel it is reasonable to use factors such as TSI as surrogates to express the final endpoint of the TMDL.

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

Sincerely,

/s/ by 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)
Brakke Dam*	phosphorus	TSI mean < 64.51	501 kg/yr total phosphorous load to the lake (18.9% reduction in average annual total phosphorus load)	Section 303(d)(1)	# Phase I Watershed Assessment and TMDL Final Report, Brakke Dam, Lyman County, South Dakota (SD DENR, April 2004)
Fish Lake*	phosphorus	TSI mean ≤ 66.3	1,864 kg/yr total phosphorous load to the lake (25% reduction in average annual total phosphorus load)	Section 303(d)(1)	# Phase I Watershed Assessment Final Report and TMDL, Fish Lake, Deuel County, South Dakota (SD DENR, January 2004)
Hayes Lake*	phosphorus	TSI mean ≤ 64.8	25,264 kg/yr total phosphorous load to the lake (24% reduction of average annual watershed load, and 25% reduction of internal load)	Section 303(d)(1)	# Watershed Assessment and TMDL Final Report, Hayes Lake / Frozen Man Creek, Stanley County, South Dakota (SD DENR, March 2004)
Lake Herman*	phosphorus	TSI mean ≤ 73.93	3,417 kg/yr total phosphorous load to the lake (45% reduction in average annual total phosphorus load)	Section 303(d)(1)	# Total Maximum Daily Load for Total Phosphorous in Lake Herman, Lake County, South Dakota (SD DENR, September 2004)

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