PHASE I
WATERSHED ASSESSMENT FINAL REPORT
AND TMDL

MINA LAKE / SNAKE CREEK
BROWN, EDMUNDS AND MCPHERSON COUNTIES, 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

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Prepared By

Robert L. Smith, Environmental Program Scientist

State of South Dakota
William J. Janklow, Governor

March, 2002

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

MINA LAKE WATERSHED ASSESSMENT AND TMDL

by:
Robert L. Smith

Project Sponsor:
Edmunds County Conservation District

March 2002

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

EPA Grant # C9998185-93

Executive Summary

Project Title: Mina Lake Assessment Project

Project Start Date: June 29, 1999 **Project Completion Date:** May 31, 2000

Funding: **Total Budget:** $ 68,446

Total EPA Budget:	$ 68,446
Total Expenditures of EPA Funds:	$ 68,446
Total Section 319 Match Accrued:	$ 0
Budget Revisions:	No Revisions
Total Expenditures:	$ 68,446

Summary of Accomplishments

Mina Lake is listed on the 1998 303(d) Impaired Waterbody List for Trophic State Index (TSI) trend (SD DENR 1998). Snake Creek, the major tributary to Mina Lake, is a natural stream that drains portions of McPherson, Edmunds and Brown counties in South Dakota. The east and west tributaries of Snake Creek drain a watershed of approximately 63,924.4 ha (157,960 acres) and are impounded at their confluence by Mina Lake. Mina Lake is a recreational lake of approximately 326.3 ha (806 acres) and has been impacted by excessive nutrient loads resulting in an increasing Trophic State Index (TSI) trend since 1979 and is in need of a Total Maximum Daily Loads (TMDL) evaluation. The Edmunds County Conservation District (ECCD) sponsored the watershed project.

A total of 53 tributary and 12 in-lake samples were collected by the sponsor from June 1999 through April 2000. Water quality and hydrologic data from Mina Lake was modeled using the FLUX model. FLUX data was used to calculate the annual sediment and nutrient loading to Mina Lake. 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 Mina Lake.

Landuse data was also collected from the watershed by the project sponsor. The watershed was modeled using the Agricultural Non-Point Source Pollution (AGNPS) model. The AGNPS model divides the watershed into 40-acre cells and predicts sediment and nutrient delivery from each cell, routes and estimates delivery at the outlet of the watershed. The model was used to identify critical areas in the watershed for sediment erosion and nutrient runoff for targeting during implementation. AGNPS was also used to estimate/model Best Management Practice (BMP) reductions in sediment and nutrient loads.

Modeling results calculated sediment and nutrient loading and budgets, identified critical and priority areas for sediment and nutrients in the Mina Lake watershed. Water quality loading and AGNPS data were sufficient to develop a TMDL for Mina Lake.

Mina Lake appears not to fit ecoregion-based beneficial use criteria based on the large reduction in total phosphorus needed to meet current ecoregional targets. Economic and technical limitations preclude the realization of a 94.4 percent reduction in total phosphorus. Economically, such reductions would severely alter or eliminated most agriculture in the watershed. Technically, internal loading of in-lake total phosphorous resulting in elevated year round phosphorus concentrations impede reduction attainability even if extensive BMPs are implemented throughout the watershed. Drastic and unrealistic changes in land use and management would have to occur in the watershed in order to achieve ecoregional based beneficial uses. The TMDL should be based on realistic criteria using watershed specific BMP reductions within the Mina Lake watershed resulting in watershed specific criteria.

Current data indicate that a 38.8 percent reduction in phosphorus can be achieved in this watershed to meet the TMDL goal of 9,366 kg/yr or a mean in-lake TSI of 79.18. Reductions beyond 38.8 percent would severely alter most agriculture in the watershed and past this point nutrient reductions would be cost prohibitive on a percent reduction basis. The recommended reductions will improve compliance with South Dakota's narrative criteria and the designated beneficial uses of the watershed, specifically, domestic water supply, warmwater permanent fish life propagation water, immersion recreation, limited contact recreation water and fish and wildlife propagation, recreation, and stock watering. Based upon data from this assessment, a phase II implementation project should be designed and initiated in this watershed to achieve this goal.

The TMDL for phosphorus in Mina Lake is 9,366 kg/yr producing a mean TSI of 79.18. The load allocation for phosphorus is 5,938 kg/yr and the background load for phosphorus is 3,428 kg/yr based on 1999 through 2000 assessment data.

The increasing TSI values observed in Mina Lake from 1979 through 2000 is the result of increased nutrients from the tributary and in-lake internal loading. Decreasing sediment (erosion) and nutrients (nitrogen and phosphorus) inputs from Snake Creek and the ungauged portion of the watershed will improve (lower) TSI values. This can be accomplished by implementing recommended tributary and in-lake BMPs in priority areas identified in the watershed assessment and Agricultural Non- Point Source pollution (AGNPS) model within the watershed.

Acknowledgements

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

US EPA Non-Point Source Program
Edmunds County
Edmunds County Conservation District
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Kevin Goyer- Department of Environment and Natural Resources - Executive Intern

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Appendix B. Snake Creek Tributary Stage Discharge Regression Graphs and Equations 1999 trough 2000.

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Appendix E. Mina Lake Algae Data for 1999 and 2000.

Appendix F. Mina Lake Surface and Bottom In-lake Chemical Data Tables 1999 through 2000.

Appendix G. Mina Lake In-lake Temperature and Dissolved Oxygen Profiles 1999 and 2000.

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Appendix I. Rare, Threatened or Endangered Species Documented in the Mina Lake Watershed, Edmunds, McPherson and Brown Counties, South Dakota.

Appendix J. Mina Lake Total Maximum Daily Load Summary Document.

Waterbody Type:	Lake
Pollutant:	Trophic State Index (TSI) Tend – Total phosphorus.
Designated Uses:	Domestic water supply, warmwater permanent fish life propagation, immersion recreation, limited contact recreation, wildlife propagation and stock watering waters.
Size of Waterbody:	Mina Lake - 326.3 hectares (806 acres).
Size of Watershed:	63,924.4 ha (157,960 acres), HUC Code: 101600008.
Water Quality Standards:	Numeric: TSI.
Indicators:	Nutrient enrichment, water clarity and algal blooms.
Analytical Approach:	Effects of nutrients and sediment on Mina Lake and the Snake Creek watershed.

1.0 Introduction

Mina Lake is a reservoir located in the Northern Glaciated Plains (46) ecoregion (level III) in northeastern South Dakota. The official name for Mina Lake was “Shake Maza” which is the Sioux name for “horseshoe” which describes its shape (WWP, 1941), however, the name was never accepted. The lake has also been known as Lake Parmley. J. C. Parmley was an avid supporter of the Works Projects Administration (WPA) project. The 1978 edition of the United States Geological Survey (USGS) 1:24,000 quad maps have Mina Lake listed as Lake Parmley.

Mina Lake is listed on the 1998 303(d) Impaired Waterbody List (SD DENR 1998). Snake Creek is a natural stream that drains portions of McPherson, Edmunds and Brown counties in South Dakota (Figure 1). The east and west tributaries of Snake Creek drain a watershed of approximately 63,924.4 ha (157,960 acres) and are impounded at their confluence by Mina Lake. Mina Lake is a recreational lake of approximately 326.3 ha (806 acres) and has been impacted by excessive nutrient loads resulting in an increasing TSI trend since 1979. A previous study has been completed on the Mina Lake watershed by South Dakota Department of Environment and Natural Resources (SD DENR) in 1992; however, watershed data was inadequate to develop a Total Maximum Daily Load (TMDL) for Mina Lake (Appendix A). The Edmunds County Conservation District (ECCD) sponsored this project.

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

Mina Lake is located at 45.441667° Latitude and 98.731667° Longitude (SW NE SEC. 25-T123N-R66W). The lake is owned and managed by the South Dakota Department of Game, Fish and Parks (SD GF&P). The dam is 109.7 meters wide (360 feet), 9.8 meters high (32 feet) and has a 45.7 meter-wide spillway (150 feet). The dam was designed by WPA and final construction was completed on February 4, 1934. The primary spillway was repaired and renovated in 1994, and in the spring of 2000, and the outlet reach above the dam was cleared of debris.

Land use in the watershed is primarily agricultural. Approximately 46.7 percent of the landuse is cropland (cultivated and non-cultivated) and 39.4 percent is range and pastureland. Seventy-six animal feeding areas/operations are located in the Mina Lake watershed.

Major soil associations found in the watershed include Niobell-Noonan, Bryant, Williams-Vida and Williams-Bowbells associations.

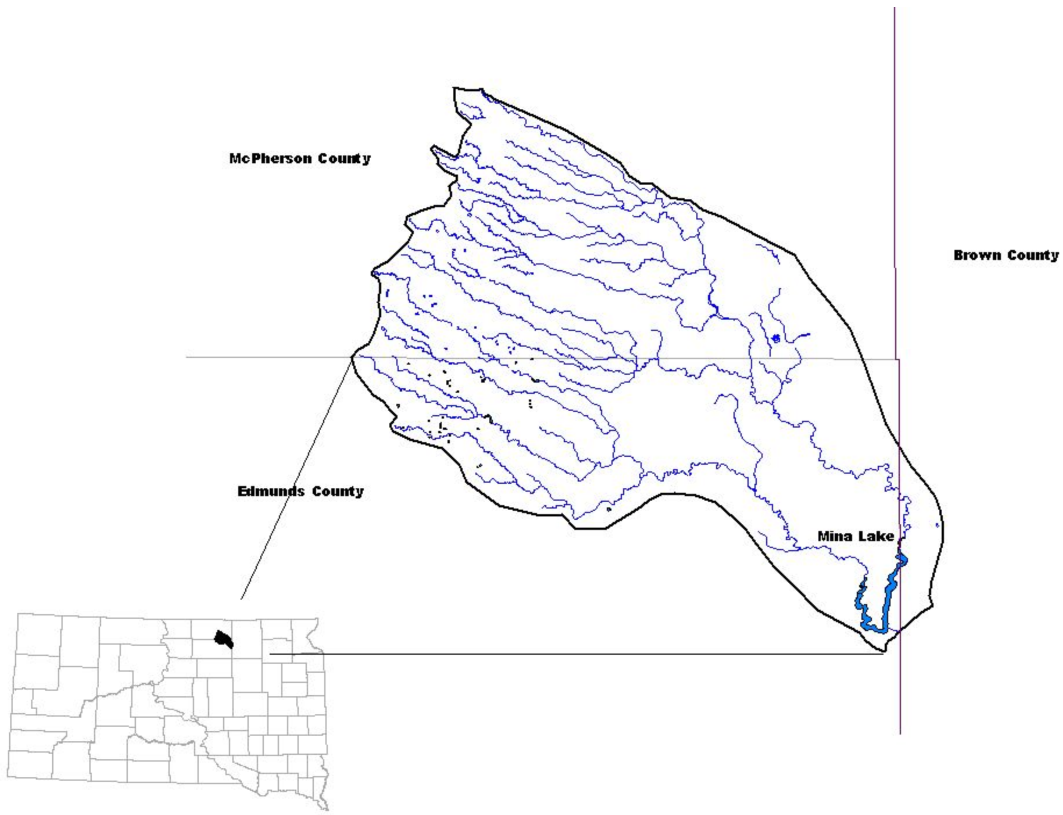


Figure 1. The Mina Lake watershed and its location in the State of South Dakota.

The average annual precipitation in the watershed is 18.3 inches of which 80% usually falls in April through September. 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 27.4 inches per year (USDA, 1977).

The landscape in the watershed is characterized by an upland plain that is moderately dissected by streams and entrenched drainageways. Land elevation ranges from about 1,968 feet msl in the west and north parts of the watershed to about 1,413 msl in the eastern part.

Mina Lake in South Dakota was listed in The 1998 South Dakota 303(d) Waterbody List as nonsupporting beneficial uses due to nutrients. Excessive nutrient loads from Snake Creek and internal loading in Mina Lake resulted in the listing (SD DENR, 1998). In addition, ecoregion targeting of impaired lakes in South Dakota modified the criteria for support categories by ecoregion (SD DENR, 2000a). Previous data indicated that the Mina Lake watershed has had nutrient problems in the past (Appendix A).

The 1998 305(b) report to the U.S. Congress reported the 5-year water quality trend in Mina Lake as improving, while the 2000 305(b) report (the most current) reported Mina Lake water quality as stable (SD DENR, 1998a and SD DENR, 2000b).

Most of the Mina Lake watershed is in the Northern Glaciated Plains (46) ecoregion (Level III) with the extreme eastern edge of the watershed in the Northwestern Glaciated Plains (42) ecoregion (Level III). Level III ecoregions can be refined to Level IV to elicit more resolution and landscape conditions. The Mina Lake watershed is also located in two Level IV ecoregions one, the Drift Plains (46i), is located within the Northern Glaciated Plains (46) ecoregion and the other is the Missouri Coteau (42a) located within the Northwestern Glaciated Plains (42) ecoregion (Bryce et al., 1997).

In the 1998 South Dakota Unified Watershed Assessment, the Snake Creek Hydrologic Unit Code (HUC # 10160008) 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 ranking for Snake Creek was 15 out of a total 39 HU (watersheds) assessed in this manner (SD DENR, 1998b).

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

South Dakota Department of Environment and Natural Resources (SD DENR) has monitored Mina Lake periodically since 1979, as part of the statewide lakes assessment. Monitoring data indicated a long-term increase in the Trophic State Index (TSI). The lake was placed on the 1998 South Dakota Waterbody List (303(d)) (SD DENR, 1998).

2.0 Project Goals, Objectives and Activities

Goals

The long-term goal of the Mina Lake Watershed Assessment Project is to locate and document sources of point and nonpoint source pollution in the watershed and produce feasible restoration alternatives in order to provide adequate background information needed to develop a TMDL and to drive a watershed implementation project to improve water quality.

Objectives and Activities

OBJECTIVE 1:

Determine current conditions in Mina Lake and calculate the present trophic state of Mina Lake. This information will be used to determine nutrient loading and the amount of nutrients and sediment to be reduced to improve the trophic condition of Mina Lake.

TASK 1. Lake Sampling:

Nutrient and solids parameters were sampled at two in-lake sites and one outlet site on Mina Lake. The in-lake samples consisted of composite surface and bottom samples. In addition, chlorophyll-*a* concentrations were determined from in-lake surface samples. Nutrient/solids parameters were analyzed by the South Dakota State Health Laboratory in Pierre. Chlorophyll-*a* concentrations will be determined at the DENR Matthews Training Center laboratory. Samples were collected monthly from June 1999 through April 2000.

The purpose of in-lake sampling was to assess ambient nutrient concentrations, identify present lake trophic status, and calculate a nutrient/sediment budget. Water column dissolved oxygen and temperature profiles were collected on a monthly basis. Water samples were collected with a Van Dorn sampler and sample bottles were iced and shipped to the lab by the most rapid means available.

All samples were collected using the methods described in the *Standard Operating Procedures for Field Samplers* manual prepared by the State of South Dakota Water Resources Assistance Program (SD DENR, 2000). Sampling site locations were as follows:

Lake Sampling Locations:

SITE	LOCATION
SC-3 (Outlet)	Lat. 45° 26’ 29” Long. 98° 43’ 48”
ML-4	Lat. 45° 27’ 15” Long. 98° 44’ 15”
ML-5	Lat. 45° 26’ 43” Long. 98° 44’ 53”

All samples were collected, iced, and shipped to the lab using the methods described in *Standard Operating Procedures for Field Samplers*. Nutrient and solids parameters were sampled at two surface and two bottom in-lake monitoring sites in Mina Lake. The tributary water quality data will be integrated with hydrologic loadings to provide a complete analysis of the Mina Lake hydrologic system.

OBJECTIVE 2:

Estimate through hydrologic and chemical monitoring the sediment and nutrient loadings to Mina Lake from its two major tributaries, the east and west branches of Snake Creek. The information will be used to locate critical areas and sub-watersheds in the Mina Lake watershed to be targeted for implementation.

TASK 1. Stream Gauging:

Install water level recorders on 5 tributary monitoring sites and the Mina Lake outlet (site SC-3). Maintain a continuous stage record for the project period, with the exception of winter months after freeze-up (Figure 2).

Site	Location	
SC-1	Lat.	45^{o} 29’ 11”
	Long.	98^{o} 47’ 01”
SC-2	Lat.	45^{o} 31’ 08”
	Long.	98^{o} 43’ 22”
SC-6	Lat.	45^{o} 34’ 20”
	Long.	98^{o} 58’ 24”
SC-7	Lat.	45^{o} 34’ 46”
	Long.	98^{o} 53’ 27”
SC-8	Lat.	45^{o} 34’ 46”
	Long.	98^{o} 47’ 17”

Discrete discharge measurements were taken on a regular schedule and during storm surges. Discharge measurements were taken with a hand-held current velocity meter.

Discharge measurements and water level data will be used to calculate a hydrologic budget for Mina Lake and its two major tributaries. This information will be used with concentrations of sediment and nutrients to calculate loadings from the watershed.

TASK 2. Water Quality Sampling:

Collect water quality samples from five tributary monitoring sites. Samples were collected during spring runoff, storm events, and monthly base flows.

Samples were collected twice weekly during the first week of spring snowmelt runoff and once a week thereafter until flow was no longer detectable. Storm events and base flows were sampled throughout the project period.

Water samples were collected with a suspended sediment sampler when possible. All sample bottles were iced and shipped to the lab. Samples were collected using methods described in the *Standard Operating Procedures for Field Samplers.* Nutrient and solids parameters were sampled at five tributary sites in the Mina Lake watershed. All samples were analyzed by the South Dakota State Health Laboratory in Pierre, SD. The watershed water quality data were integrated together with the hydrologic loadings to provide a complete analysis of the Mina Lake hydrologic system.

A tributary water quality report was to be written which would include a comparison of tributary and Mina Lake water quality characteristics. Hydrologic, sediment, and nutrient loads would also be calculated for the entire watershed.

OBJECTIVE 3:

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

TASK 1. QA/QC Sampling:

All QA/QC activities were conducted in accordance with the Nonpoint Source Program Quality Assurance Project Plan

The collection of all field water quality data was accomplished in accordance with the *Standard Operating Procedures for Field Samplers* manual prepared by South Dakota Water Resources Assistance Program.

A minimum of 10 percent of all in-lake and tributary water quality samples collected were QA/QC samples. QA/QC samples consisted of field blanks and field duplicate samples.

TASK 2. QA/QC Reporting:

The activities involved with QA/QC procedures and the results of QA/QC monitoring were compiled and reported in a section of the final project report and in all project reports.

Approved QA/QC procedures were followed in the course of all sampling and field data collection during the Mina Lake Assessment Project. Please refer to the South Dakota Watershed Protection Program Quality Assurance Plan and the South Dakota Watershed Protection Program *Standard Operation Procedures for Field Samplers* for details of the procedures to be followed (SD DENR, 1998c and SD DENR, 2000).

OBJECTIVE 4:

Evaluation of agricultural impacts on the water quality of the watershed through the use of the Agricultural Nonpoint Source (AGNPS) computer model.

TASK 1. Watershed Analysis:

The Mina Lake watershed was modeled using the Agricultural Nonpoint Source (AGNPS) model. AGNPS is a comprehensive land use model which estimates soil and nutrient loss and delivery and evaluates the impact of livestock feeding areas. The watershed is divided into 40-acre cells. Twenty-one separate parameters are collected for each watershed cell with additional information collected for animal feeding operations.

This model was used to identify critical areas of nonpoint source pollution to the surface waters in the watershed. Major contributors of nutrients and sediments to surface water in the Mina Lake watershed will be identified.

OBJECTIVE 5:

Public participation and involvement was provided for and encouraged.

TASK 1. Public Meetings:

Informational meetings were held for the public and were used to inform stakeholders and involved parties on the status of the project. These meetings provide an avenue for input from the residents in the area.

OBJECTIVE 6:

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

TASK 1. Final Report:

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

Summarize the results of the AGNPS model for the watershed and report locations of critical areas.

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

Based on data, evaluate the hydrology of Mina Lake and Snake Creek and the chemical and physical condition of the stream.

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

Write a description of feasible restoration alternatives for use in planning a watershed nonpoint source implementation project. Data was managed by the South Dakota Department of Environment and Natural Resources and maintained in a computer database. All sample data was entered in the US EPA STORET Program. This data will be used as the foundation of a Section 319 Watershed Implementation Project proposal.

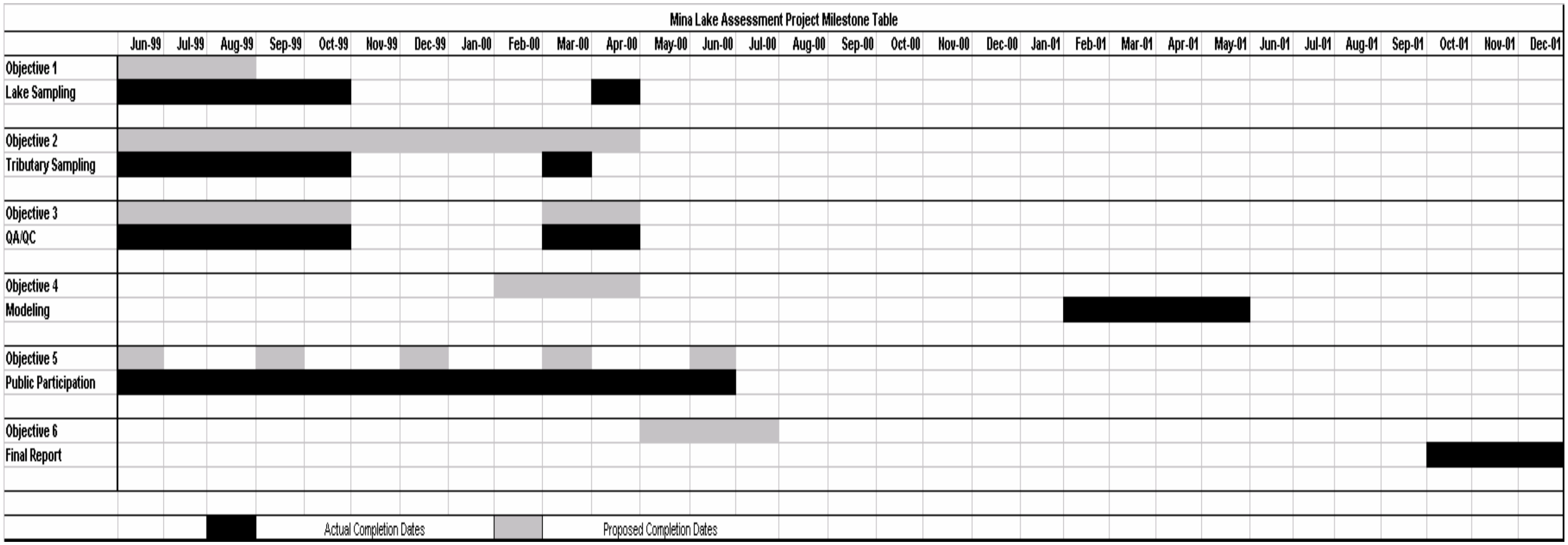
Statistical evaluation was performed on all water quality and field data produced during the course of the study.

Review and compilation of current and historical data was completed. Restoration alternatives were developed and graphic presentations of the information were produced.

2.1 Planned and Actual Milestones, Products and Completion Dates

The Mina Lake Assessment Project was scheduled to start in March 1999, however funds were not secured until mid June 1999, this delayed the start of the project until late June 1999. The sampling effort was extended through April 2000. Logistical difficulty was encountered in the collection of Agricultural Nonpoint Source Model (AGNPS) landuse data which was not completed until spring 2001. These situations resulted in a delay in watershed modeling and report generation. See the attached Mina Lake Assessment Project milestone table (Table 1).

Table 1. Proposed and actual completion dates for the Mina Lake Assessment Project, 1999 through 2000.



2.2 Evaluation of Goal Achievement

Mina Lake is listed on the State of South Dakota's 303(d) list of impaired waterbodies as a priority one waterbody for increasing Trophic State Index (TSI) trend caused by increased nutrients. This study assessed Mina Lake, Snake Creek and its watershed for background data to develop a TMDL, identified targeted areas of increased nutrient and sediment load impacting Mina Lake and recommend specific Best Management Practices (BMPs) for targeted areas in the watershed. 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 proposal is planned in the near future.

2.3 Supplemental Information

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

3.0 Monitoring Results

Tributary Methods

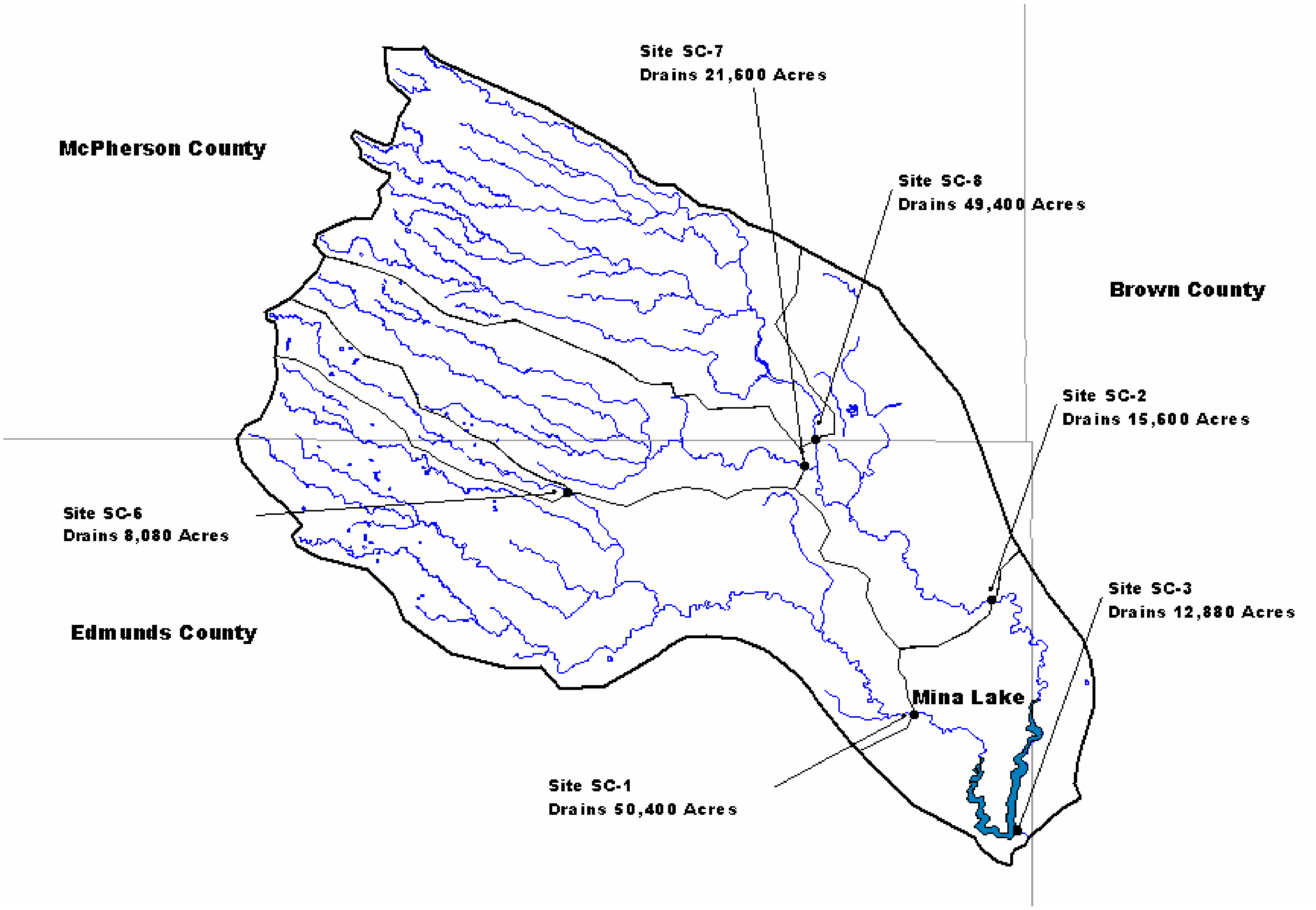


Figure 2. Snake Creek sampling sites and sub-watersheds for 1999 and 2000.

Five tributary locations were chosen for collecting hydrologic and nutrient information from the Mina Lake watershed (Figure 2). Tributary site locations were chosen that would best show watershed managers which sub-watersheds were contributing the largest nutrient and sediment loads. A Steven's Type F paper graph recorder was placed at the outlet site (SC-3) to record lake level (stage). The recorder was checked weekly to change the graph paper and reset the chart. After the chart was changed, daily stage height averages were calculated to the nearest 1/100th of a foot. Sites SC-1, SC-2, SC-6, SC-7 and SC-8 had ISCO GLS (Great Little Sampler) samplers installed with ISCO model 4230 bubbler stage recorders. All discharge data was collected according to South Dakota's *Standard Operating Procedures for Field Samples* (SD DENR 2000). Actual stage and discharge measurements were used to calculate a regression equation for each site (Appendix B). These equations were used to calculate average daily loading for each site. Daily loadings were then totaled for an annual load for each parameter.

Outlet data for the Mina Lake spillway was calculated by using the following standard equation:

Equation 1. Mina Lake spillway discharge equation.

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

Where: Q = Flow 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 each monitoring site were used to develop a stage/discharge table that was used to calculate average daily loadings for each site. The individual discharge equations and data for each monitoring site can be found in Appendix B.

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.

Table 2. Tributary physical, chemical and biological parameters analyzed in Snake Creek, Edmunds and Mc Pherson Counties, South Dakota in 1999 and 2000.

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

Tributary Modeling Methods

Tributary Loading Calculations

The FLUX program was used to develop nutrient and sediment loadings for Snake 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 method was used on all five tributary sites and the outlet of Mina Lake 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.

Landuse Modeling - 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. The AGNPS model was developed by the United States Department of Agriculture (Young et al., 1986) to give comparative parameter values for every forty-acre cell in a given watershed. Twenty-one parameters were collected per 40-acre cell in the Mina Lake watershed.

The twenty-one main parameters included:

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.

If one cell contains two different values for the same parameter, such as soil curve number (4), the local coordinator takes the value that covers the majority of the cell. Each 40-acre cell is given a modeled export value for phosphorus, nitrogen, and suspended solids. After the report is completed, the cells with high export values are field-checked to make sure the model highlights the correct problem areas in the watershed. The export values of each sub-watershed are compared to each other and to the water quality monitoring data on a relative basis only.

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

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 3. 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 3. 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.

Snake Creek in Edmunds County has been also assigned the beneficial uses of (6) warmwater marginal fish life propagation water, and (8) limited contact recreation water (Table 4).

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 4. Assigned beneficial uses for Snake Creek, Edmunds County South Dakota.

Water Body	From	To	Beneficial Uses*	County
Snake Creek	Confluence with the South Fork of Snake Creek	S26, T124N, R66E	6,8	Edmunds
All Streams	Entire State	Entire State	9,10	All

*** = See Table 3 above**

Each beneficial use classification has a set of numeric standards uniquely associated with that specific category. Water quality values that exceed those standards, applicable to specific beneficial uses, impair beneficial use and violate water quality standards. Table 5 lists the most stringent water quality parameters for Snake Creek. Five of the fourteen parameters (total petroleum hydrocarbon, oil and grease, un-disassociated hydrogen sulfide, conductivity and sodium adsorption ratio) listed for Snake Creek beneficial use classification were not sampled during this project.

Table 5. The most stringent water quality standards for Snake Creek based on beneficial use classifications.

Water Body	Beneficial Uses	Parameter	Standard Value
Snake Creek	6,8,9,10	Un-ionized ammonia nitrogen as N [1]	≤ 0.05 mg/L
		Dissolved oxygen	≥ 5.0 mg/L
		pH	≥ 6.0 - ≤ 9.0
		Total Suspended Solids [2]	≤ 263 mg/L
		Temperature (°C)	≤ 32.2°C
		Fecal coliform [3]	≤ 2,000 colonies/100mL
		Total alkalinity as calcium carbonate [4]	≤ 1313 mg/L
		Total dissolved solids [5]	≤ 4,375 mg/L
		Conductivity at 25° C [8, 6]	≤ 4,375 μmhos/cm
		Nitrates as N [7]	≤ 88 mg/L
		Undisassociated hydrogen sulfide [8]	≤ 0.002 mg/L
		Total petroleum hydrocarbon [8]	≤ 10 mg/L
		Oil and grease [8]	≤ 10 mg/L
		Sodium adsorption ratio [8, 9]	≤ 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 ≤ 0.05 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 ≤ 263 mg/L or ≤ 150 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 ≤ 2,000 counts/100 ml is for a single sample or ≤ 1,000 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 ≤ 1313 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 mg/L or ≤ 4,000 mg/L 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.
[9] = 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 2. Sodium Absorption Ratio (SAR) (Gapon Equation)

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

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

Snake Creek Water Quality Exceedance

Three water quality parameters; dissolved oxygen, fecal coliform and total suspended solids exceeded tributary water quality standards in Snake Creek during the project. All Snake Creek water quality monitoring sites above Mina Lake (SC-1, SC-2, SC-6, SC-7 and SC-8) had at least one violation of water quality standards. The outlet from Mina Lake to Snake Creek (SC-3) was the only tributary site to meet all water quality standards during this project. Any exceedances in water quality standards upstream of Mina Lake were mitigated by hydrologic residence time and dilution in Mina Lake before being discharged back into Snake Creek.

Table 6. Dissolved oxygen water quality standards exceedances in Snake Creek above Mina Lake in 1999.

Site	Date	Hydrologic Event	Temperature °C	Dissolved Oxygen mg/L
SC-1	7/19/99	Base Flow	21.9	3.4
SC-1	7/23/99	Increasing	25.4	3.4
SC-1	7/27/99	Decreasing	26.3	4.2
SC-2	7/07/99	Slightly Increasing	23.4	3.2
SC-2	7/08/99	Slightly Increasing	23.8	3.6
SC-2	7/19/99	Decreasing	21.9	1.6
SC-2	7/23/99	Decreasing	29.8	4.2
SC-2	7/27/99	Increasing	25.4	4.3
SC-6	7/08/99	Increasing	23.5	4.6
SC-6	7/23/99	Base Flow	21.6	3.2
SC-7	7/08/99	Increasing	23.8	3.8
SC-7	7/13/99	Decreasing	24.1	2.0
SC-7	7/19/99	Base Flow	24.3	3.2
SC-7	7/23/99	Peak	23.8	1.6
SC-7	7/27/99	Decreasing	24.0	1.0
SC-8	7/08/99	Slightly Increasing	24.1	3.9
SC-8	7/13/99	Peak	24.9	2.8
SC-8	7/19/99	Base Flow	26.1	4.8
SC-8	7/23/99	Base Flow	24.9	2.3
SC-8	7/27/99	Slightly Increasing	24.1	2.2

All five tributary sampling sites above Mina Lake exceeded water quality standards for dissolved oxygen in July 1999 (Table 6). Dissolved oxygen exceedances in July occurred at water temperatures greater than 20° C and covered a wide range of hydrologic conditions. Warmer water does not hold as much oxygen as cold water so decreased values were expected. However, dissolved oxygen at the observed water temperatures was well below expected solubility values and minimum water quality standards. Low dissolved oxygen readings were detected over the entire range of the hydrologic curve (increasing, peak and decreasing flows). Many exceedances coincided with increased fecal coliform, ammonia, organic nitrogen and volatile total suspended solids concentrations. Fecal coliform at sites SC-2, SC-6, SC-7 and SC-8 on July, 8 1999 exceeded water quality standards (Table 7) and both SC-2 and SC-7 exceeded total suspended solids (SC-2,584 mg/L, of that 60 mg/L was volatile organic and SC-7, 1,850 mg/L) standards on the same date (Table 8). This may indicate that increased organic loading in warmer waters increases Biochemical and Sediment Oxygen Demand (BOD and SOD) in the Snake Creek system

Table 7. Fecal coliform water quality standards exceedances in Snake Creek above Mina Lake in 1999.

Site	Date	Hydrologic Event	Fecal Coliform (Colonies/100 ml)
SC-1	6/30/99	Base	7,400
SC-2	7/08/99	Slightly Increasing	15,100
SC-6	7/08/99	Increasing	25,000
SC-7	7/08/99	Increasing	51,000
SC-8	7/08/99	Slightly Increasing	6,100

Fecal coliform bacteria standards are in effect from May 1 through September 30 each year. All sampling sites upstream of Mina Lake had at least one fecal coliform count in excess of 2,000 colonies/100 ml, the standard for Snake Creek (Table 7). Most high fecal coliform counts were collected during increasing flow conditions in early summer of 1999. One other sample collected at SC-7 on June 30, 1999 had coliform counts greater than 1000 colonies/100 ml (Appendix D). Runoff from land-applied manure, animal feeding areas, cattle pastured in the riparian areas or poor manure management may be responsible for the high fecal concentrations. Since the majority of the Mina Lake/Snake Creek watershed is agricultural, most fecal coliform standard violations can be attributed to agricultural runoff.

Table 8. Total suspended solids water quality standards exceedances in Snake Creek above Mina Lake in 1999.

Site	Date	Hydrologic Event	Total Suspended Solids (mg/L)
SC-2	7/08/99	Slightly Increasing	584
SC-2	9/03/99	Base	1,020
SC-7	7/08/99	Increasing	1,850
SC-8	10/21/99	Slowly Decreasing	286

Total suspended solids standards were exceeded on four sampling occasions, two samples in July sampled during increasing flows and September and October samples on base or decreasing flows (Table 8). Both samples collected in July during increasing flows indicate event-based loading to Snake Creek. The September and October samples collected at low or base flows may suggest sampling-specific irregularities.

Seasonal Tributary Water Quality

Typically, water quality parameters will vary depending upon season due to changes in temperature, precipitation and agricultural practices. Fifty-three tributary water quality samples were collected during the project. These data were separated seasonally: summer (June – August), and fall (September – November) and spring (March – May). During the project, approximately 38 discrete samples were collected in the summer, 10 in the fall and 5 samples in the spring. Tributary summer and fall samples were collected after heavy rainfall that occurred in scattered areas of the watershed. Not all sites were sampled during every runoff event in the summer and fall due to scattered rains and intermittent flow.

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 Snake Creek by specific tributary input are provided in Table 9.

Tributary Concentrations

Table 9. Average seasonal tributary concentrations from Snake Creek, Edmunds County, South Dakota[1] for 1999 and 2000 by tributary.

	Summer				Fall				Spring			
	West Tributary (SC-1)		East Tributary (SC-2)		West Tributary (SC-1)		East Tributary (SC-2)		West Tributary (SC-1)		East Tributary (SC-2)	
Parameter	**Sample Count**	**Average**	**Sample Count**	**Average**	**Sample Count**	**Average**	**Sample Count**	**Average**	**Sample Count**	**Average**	**Sample Count**	**Average**
Water Temperature (°C)	18	23.4	19	24.6	4	10.5	6	11.9	2	5.1	3	6.3
Field pH (su)	18	7.74	19	7.46	4	7.93	6	7.90	2	8.62	3	8.37
Dissolved Oxygen (mg/L)	18	5.01	19	3.75	4	7.75	6	7.13	2	9.70	3	9.53
Fecal Coliform (# Colonies/ 100 ml)	15	3913	17	4453	2	30	3	43.3	2	20	3	10
Alkalinity(mg/L)	18	276.89	20	200.90	4	187.75	6	201.50	2	248.00	3	184.33
Total Solids (mg/L)	18	988.44	20	877.10	4	1355.25	6	1039.00	2	1884.00	3	1456.00
Total Dissolved Solids (mg/L)	18	951.06	20	712.55	4	1318.00	6	795.67	2	1855.00	3	1435.33
Total Suspended Solids (mg/L)	18	37.39	20	164.55	4	37.25	6	243.33	2	29.00	3	20.67
Volatile Total Suspended Solids (mg/L)	18	6.06	20	21.45	4	4.50	6	13.83	2	8.00	3	7.67
Total Nitrogen (mg/L)	18	3.29	20	3.79	4	3.15	6	1.96	2	3.69	3	3.02
Organic Nitrogen(mg/L)	18	2.66	20	2.22	4	1.83	6	1.55	2	3.07	3	2.70
Ammonia-N (mg/L)	18	0.09	20	0.09	4	0.02	6	0.06	2	0.02	3	0.02
Un-ionized Ammonia (mg/L)	18	0.003	20	0.001	4	0.0004	6	0.001	2	0.001	3	0.0006
Nitrate-Nitrite-N (mg/L)	18	0.54	20	1.49	4	1.30	6	0.35	2	0.60	3	0.30
Total Kjeldahl-N (mg/L)	18	2.75	20	2.31	4	1.85	6	1.61	2	3.09	3	2.72
Total Phosphorus (mg/L)	18	1.79	20	1.72	4	0.77	6	0.83	2	0.64	3	0.49
Total Dissolved Phosphorus (mg/L)	18	1.65	20	1.44	4	0.64	6	0.55	2	0.44	3	0.30
Total Nitrogen : Total Phosphorus Ratio	18	1.90	20	2.59	4	4.91	6	3.75	2	6.04	3	6.79

[1] = Highlighted areas are the highest recorded average concentrations by tributary for a given parameter.

Average dissolved oxygen concentrations were highest in the spring for both the east and west tributary of Snake Creek. It is likely that cooler water (cooler water can hold more oxygen) and higher flows and water turbulence in the spring agitates and aerates the water as it moves along the stream. Lower dissolved oxygen concentrations occurred in the summer (exceeded water quality standards in July) and were most likely due to decomposition of organic matter increasing Biochemical Oxygen Demand (BOD) and Sediment Oxygen Demand (SOD) in the system and warmer water temperatures.

Alkalinity seems to be related to surface and groundwater runoff. The highest concentration in the west tributary was in the summer and in the fall for the east tributary, when theoretically, groundwater influence was most likely the highest. Groundwater typically has higher alkalinity than rainwater because of the soluble minerals in the soil.

Higher total and dissolved solids concentrations were observed for both tributaries in the spring. The east tributary had the highest average concentration of total suspended solids in the fall and was six times higher than the highest average value from the west tributary, which occurred in the summer. Intense rains on agricultural lands and harvested crops typically cause higher erosion and higher total suspended solids in streams.

Average total nitrogen concentrations were higher in the summer on the east tributary and higher in the spring for the west tributary. Ammonia and un-ionized ammonia concentrations were highest in the summer for both tributaries. Sources for high ammonia concentrations could be animal feeding areas, decomposition of organic matter, or runoff from land applied fertilizer and/or manure.

Total Kjeldahl Nitrogen (TKN) and organic nitrogen had the highest average concentrations in the spring for both the east and west tributaries of Snake Creek. TKN is composed of mostly organic nitrogen.

Nitrate-nitrite showed more seasonal variability than other forms of nitrogen. The summer season had the highest average nitrate-nitrite concentration in the east tributary (1.49 mg/L) and the west tributary had the highest average concentration in the fall (1.30 mg/L).

Total phosphorus and dissolved phosphorus concentrations were highest in the eastern tributary. The highest average summer concentrations were 1.79 mg/L and 1.65 mg/L for total phosphorus and total dissolved phosphorus, respectively (Table 9). Increased phosphorus concentrations often coincide with higher fecal coliform or suspended solids concentrations. Average fecal coliform, total phosphorus and total dissolved phosphorus concentrations were highest in the summer, suggesting that animal waste loads may contribute to seasonal phosphorus concentrations in both tributaries.

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 summer. Season-long grazing, runoff from animal feeding areas and poor manure management were the most likely sources of increased fecal coliform counts.

Seasonalized Tributary Hydrologic Loadings

Five tributary monitoring sites were set up on Snake Creek and one (SC-3) at the outlet of Mina Lake. All sites were monitored 311 days from June 1999 through April 2000 excluding the winter months. Approximately 12.02 million cubic meters (9,745 acre-feet) of water flowed into Mina Lake from Snake Creek over the project period. The overall tributary export coefficient (amount of water delivered per acre) was 76,095 liters/acre (0.06 acre-foot). Export coefficients and seasonal loading percentages for each gauged sub-watershed are provided in Table 10.

Table 10. Cumulative hydrologic loading and export coefficients for Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

		Hydrologic Loading			Export Coefficient	
Site	**Season**	**Liters**	**Acre-feet**	**Percent**	**Liters/acre**	**Acre-feet/acre**
SC-1	**Summer**	4,191,000,000	3,398	83.99	83,155	0.07
	Fall	666,000,000	540	13.35	13,214	0.01
	Winter	0	0	0		
	Spring	133,000,000	108	2.67	2,639	0.00
	Total	4,990,000,000	4,045	100.00	99,008	0.08
SC-2	**Summer**	3,171,000,000	2,571	67.31	203,269	0.16
	Fall	1,380,000,000	1,119	29.29	88,462	0.07
	Winter	0	0			
	Spring	160,000,000	130	3.40	10,256	0.01
	Total	4,711,000,000	3,819	100.00	301,987	0.24
SC-6	**Summer**	424,000,000	344	53.74	52,475	0.04
	Fall	267,000,000	216	33.84	33,045	0.03
	Winter	0	0			
	Spring	98,000,000	79	12.42	12,129	0.01
	Total	789,000,000	640	100.00	97,649	0.08
SC-7	**Summer**	421,000,000	341	39.46	8,522	0.01
	Fall	613,000,000	497	57.45	12,409	0.01
	Winter	0	0			
	Spring	33,000,000	27	3.09	668	0.00
	Total	1,067,000,000	865	100.00	21,599	0.02
SC-8	**Summer**	890,000,000	722	61.81	41,204	0.03
	Fall	517,000,000	419	35.90	23,935	0.02
	Winter	0	0			
	Spring	33,000,000	27	2.29	1,528	0.00
	Total	1,440,000,000	1,167	100.00	66,667	0.05
SC-3 (ungauged)	**Total**	2,319,000,000	1,880	100.00	180,047	0.15
Watershed	**Total**	**12,020,000,000**	**9,745**	**100.00**	**76,095**	**0.06**

The peak hydrologic load for the majority of the sub-watersheds (SC-1, SC-2, SC-6 and SC-8) occurred during the summer. However, sub-watershed SC-7 had the peak hydrologic load in the fall (Table 10). Approximately three-fourths (75.89 percent) of the gauged water load was delivered to Mina Lake during the summer sampling period. All cumulative hydrologic loads increased downstream. Sub-watershed SC-2 had the highest export coefficient, 0.245 acre-feet/acre/year (Table 11).

Table 11. Hydrologic load percentages[1] and export coefficients by sub-watershed (site) for the Mina Lake watershed.

Site	Hydrologic Load Percent	Export Coefficient (acre-feet)
West Tributary		
SC-6	15.81	0.08
SC–1	41.51	0.08
East Tributary		
SC-8	30.57	0.05
SC-7	22.65	0.02
SC-2	39.19	0.24
Unguaged		
SC-3	19.29	0.15
Watershed	100.00	0.06

[1] = Percentages were calculated within tributaries (SC-6 delivers 15.81 percent of the hydrologic load to SC-1 and both SC-8 and SC-7 deliver 53.22 percent of the hydrologic load to SC-2. Sub-watershed SC-1, SC-2 and SC-3 (ungauged) deliver 100 percent of the hydrologic load to Mina Lake.

All gauged sub-watersheds totaled 157,960 acres or 91.8 percent of the watershed. The remaining 12,880 acres or 8.2 percent was ungauged. The ungauged portion of the watershed incorporates the area downstream of SC-1 and SC-2 and the area near Mina Lake without defined tributaries. An estimated 2.3 million cubic meters (1,880 acre-feet) of water was delivered from the ungauged watershed to Mina Lake from June 1999 through April 2000.

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). Snake Creek dissolved oxygen concentrations averaged 5.80 mg/L (median 5.85 mg/L) during this study.

The maximum dissolved oxygen concentration in Snake Creek was 10.0 mg/L. The sample was collected at site SC-6 on March 27, 2000 (Appendix D). March tributary samples had the highest average dissolved oxygen concentration, which was most likely a product of cooler water temperatures (Figure 3). The minimum dissolved oxygen concentration was 1.0 mg/L at SC-7 on July 27, 1999. Forty-four tributary samples were collected from Snake Creek above Mina Lake in July 1999. Thirty-six of those samples or 81.8 percent of the samples violated (exceeded) water quality standards for Snake Creek based on designated beneficial uses. The average dissolved oxygen concentration of samples that exceeded water quality standards was 3.16 mg/L. Low dissolved oxygen concentrations were observed at all tributary sampling sites (SC-1, SC-2, SC-6, SC-7 and SC-8) in July (Appendix D). No dissolved oxygen exceedances were observed at site SC-3 (outlet of Mina Lake) during the project, indicating that Mina Lake mitigated the low dissolved oxygen concentrations upstream.

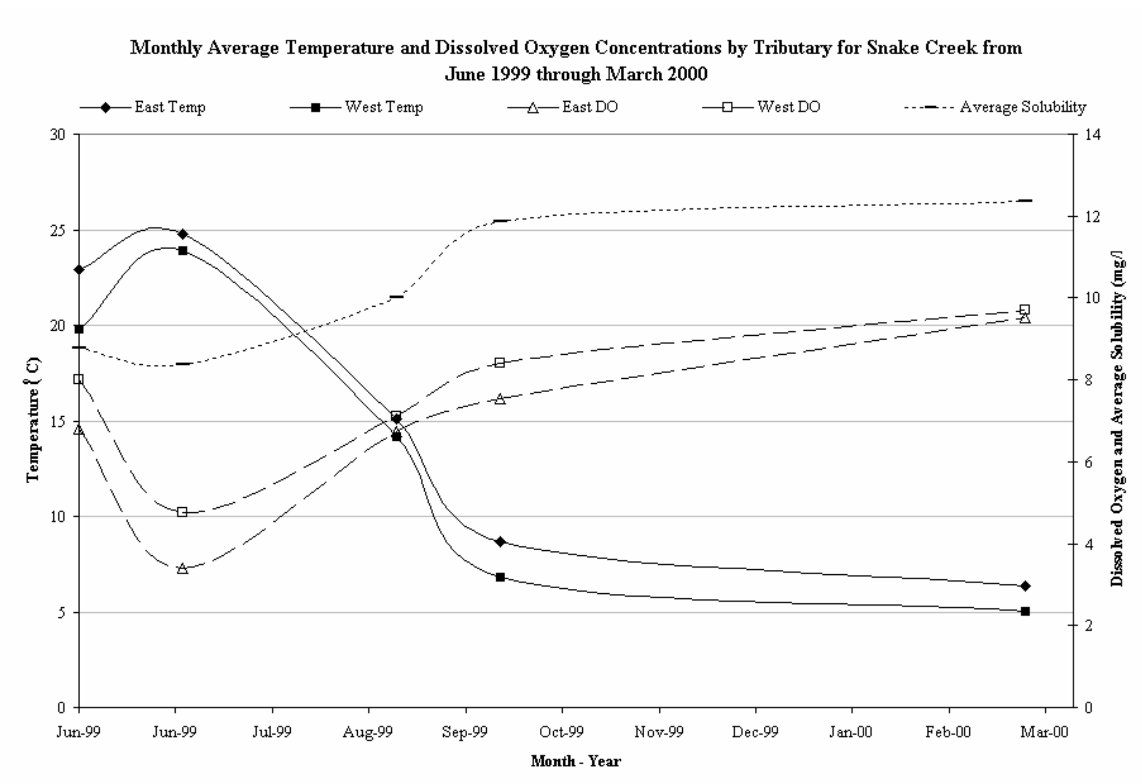


Figure 3. Monthly average dissolved oxygen and solubility concentrations and temperature for Snake Creek, Edmunds County, South Dakota from June 1999 through March 2000.

The relationship of oxygen solubility and temperature was observed during this study. Monthly average dissolved oxygen concentrations were highest during the cooler months of the sampling year (October 1999 through March 2000) were within 72.7 percent saturation (maximum solubility of oxygen in de-ionized water). Oxygen solubility decreased with increasing water temperatures during warmer months (June, July and September 1999) and averaged 56.3 percent saturation (Figure 3).

Table 9 shows seasonal tributary average dissolved oxygen concentrations by tributary for Snake Creek during the project. Seasonal oxygen levels were lowest in the summer (west 5.01 mg/L and east 3.75 mg/L), increase in the fall (west 7.75 mg/L and east 7.13 mg/L) and were the highest in the spring for both tributaries (west 9.70 mg/L and east 9.53 mg/L). Seasonal and daily concentrations of chemicals (biotic and abiotic) in water can also affect dissolved oxygen concentrations. Table 9 indicates that during the summer there were increased average concentrations in ten of the fourteen chemical parameters monitored in Snake Creek. Increased average chemical concentrations and increased temperatures in warmer months appear to contribute to reduced oxygen levels and solubility. 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.

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

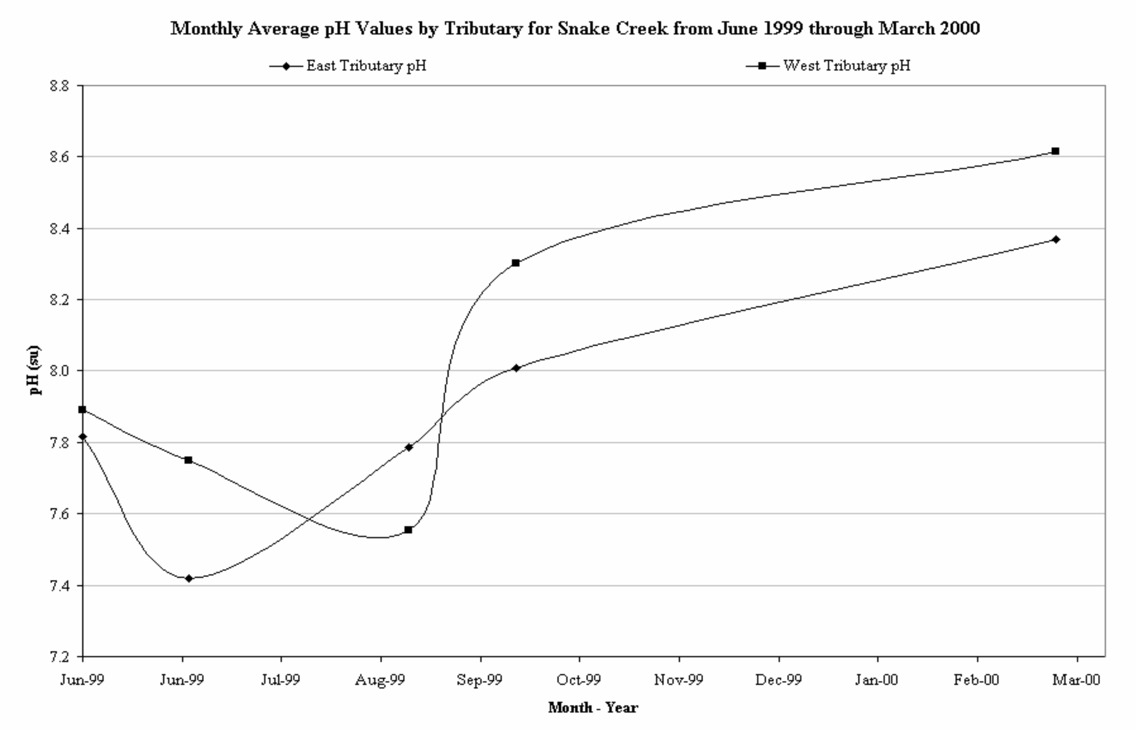


Figure 4. Monthly average pH values for Snake Creek, Edmunds County, South Dakota.

This scenario was seen in Snake Creek during the project. Lower pH values were observed in July and September for both tributaries, which coincides with the highest loading of organic material during the project (Figure 9, Figure 10, Figure 13 and Figure 14). The reduction in pH during increased organic loading may have been buffered by increased loading of bicarbonate and carbonate compounds (alkalinity) during the same time (Figure 5).

The pH concentrations in Snake Creek averaged 7.81 su with a maximum of 8.73 su and a minimum of 7.04 su. Generally, pH concentrations were higher in the spring (Figure 4). Table 9 lists seasonal averages for pH concentrations by tributary. The highest concentrations were in the spring for both tributaries (west 8.62 su and east 8.37 su).

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 12. Snake Creek, 1999 -2000, total alkalinity loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	150,613	150,613	7.87	18.64
SC-1	34.74	38.39	1,065,305	914,692	47.81	18.15
East Tributary						
SC-8	34.05	11.08	225,819	225,819	11.80	4.57
SC-7	14.89	8.21	180,788	180,788	9.45	8.37
SC-2	10.75	36.25	847,940	441,332	23.07	28.29
Total Gauged Load to Mina Lake			**1,913,245**			

The average alkalinity in Snake Creek was 215.7 mg/L with a median of 200 mg/L. The minimum alkalinity concentration was 55 mg/L and was collected at site SC-1 on September 3, 1999 (Appendix D). The maximum alkalinity sample was 402 mg/L collected at site SC-1 on June 30, 1999. Seasonally, Snake Creek average alkalinity concentrations were higher in the summer months for the west tributary and during the fall for the east tributary (Table 9).

Total alkalinity loading by site was highest at site SC-1 with 914,692 kg/year or 47.8 percent of the total alkalinity load (Table 12). Sub-watershed export coefficients (kilograms/acre) were highest in the SC-2 sub-watershed (28.3 kg/acre), which is approximately 1.5 times more alkalinity runoff per acre than the next highest sub-watershed (SC-6). The highest loading to Mina Lake occurred during July 1999 from the west tributary, another spike was recorded in September 1999 with the east tributary contributing the most loading (Figure 5).

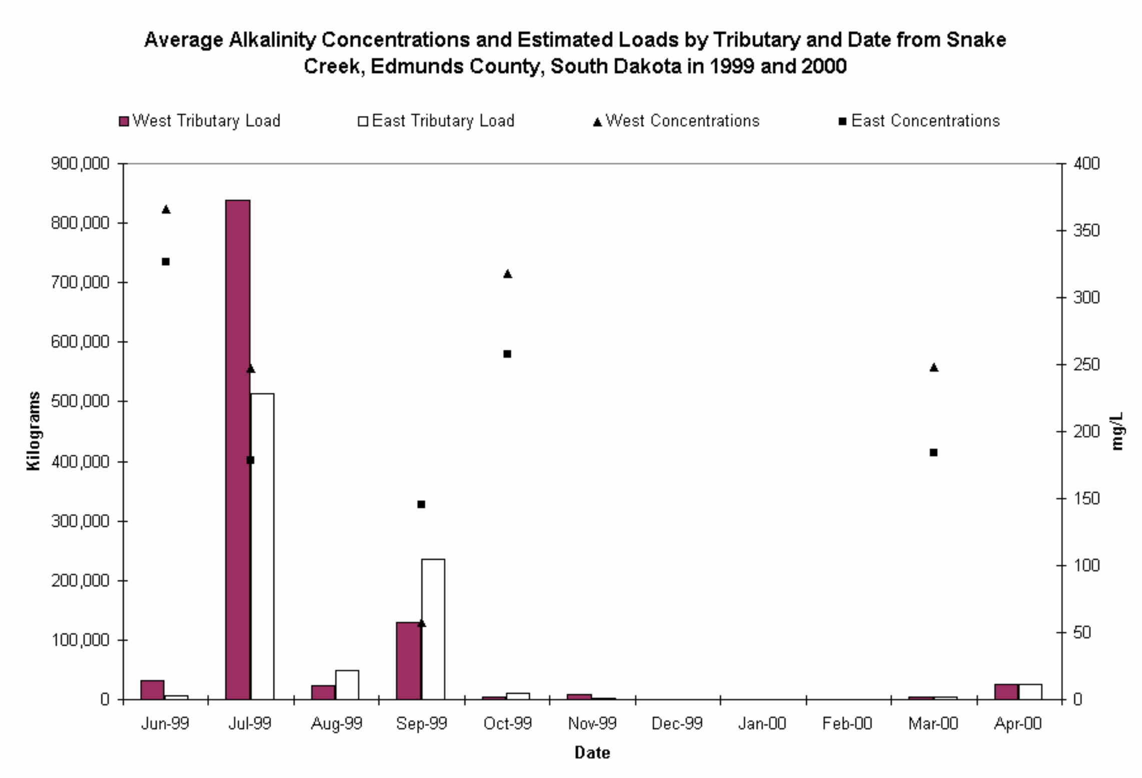


Figure 5. Monthly average total alkalinity concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

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. Suspended volatile 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 Snake Creek averaged 1,025.7 mg/L with a maximum of 2,364.0 mg/L and a minimum of 511.0 mg/L. Total dissolved solids concentrations averaged 918.6 mg/L with a maximum of 2275.0 mg/L and a minimum concentration of 346.0 mg/L. Generally, total and dissolved solids concentrations were lower in the late summer and peaked in the spring and fall, depending on tributary (Figure 6 and Figure 7). Seasonal averages for total and dissolved solids concentrations were highest in the spring (Table 9).

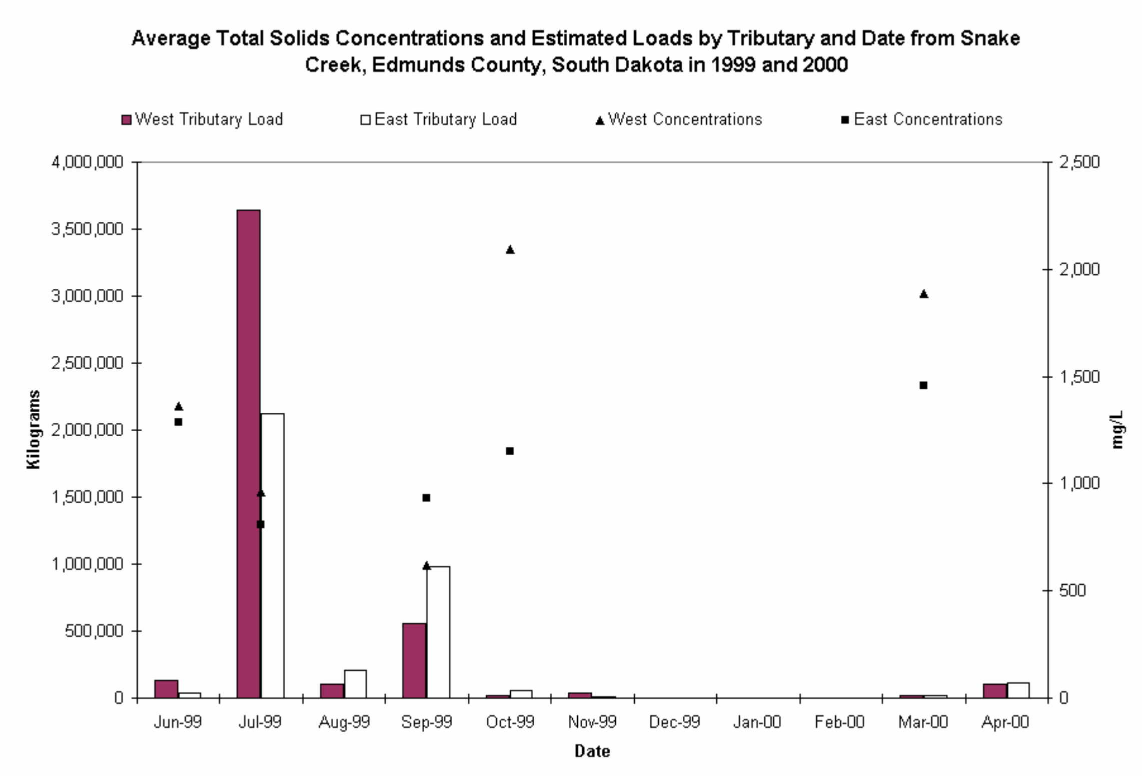


Figure 6. Monthly average total solids concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Table 13. Snake Creek, 1999 - 2000, total solids loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	712,187	712,187	8.72	88.14
SC-1	34.74	38.39	4,619,727	3,907,540	47.84	77.53
East Tributary						
SC-8	34.05	11.08	867,410	867,410	10.62	17.56
SC-7	14.89	8.21	1,536,011	1,536,011	18.81	71.11
SC-2	10.75	36.25	3,548,160	1,144,739	14.02	73.38
Total Gauged Load to Mina Lake			**8,167,887**			

Total solids loading by site was highest at site SC-1 with 3,907,540 kg/year or 47.8 percent of the total solids load (Table 13). Total dissolved solids loadings were also the highest at site SC-1 with 3,527,389 kg/year or 48.7 percent of the total dissolved solids load (Table 14). Sub-watershed export coefficients (kilograms/acre) were highest in the SC-6 sub-watershed (88.1 kg/acre), which is slightly (1.1 times) more solids per acre than the SC-1 sub-watershed, which had the highest percent load. Similarly, total dissolved solids also had the highest export coefficient in the SC-6 sub-watershed (84.3 kg/acre), 1.1 times higher than sub-watershed SC-7 (71.1 kg/acre). The highest loading of both total and dissolved solids to Mina Lake occurred in July 1999 from the west tributary, another increase was observed in September 1999 with the east tributary contributing most of the loading (Figure 6 and Figure 7).

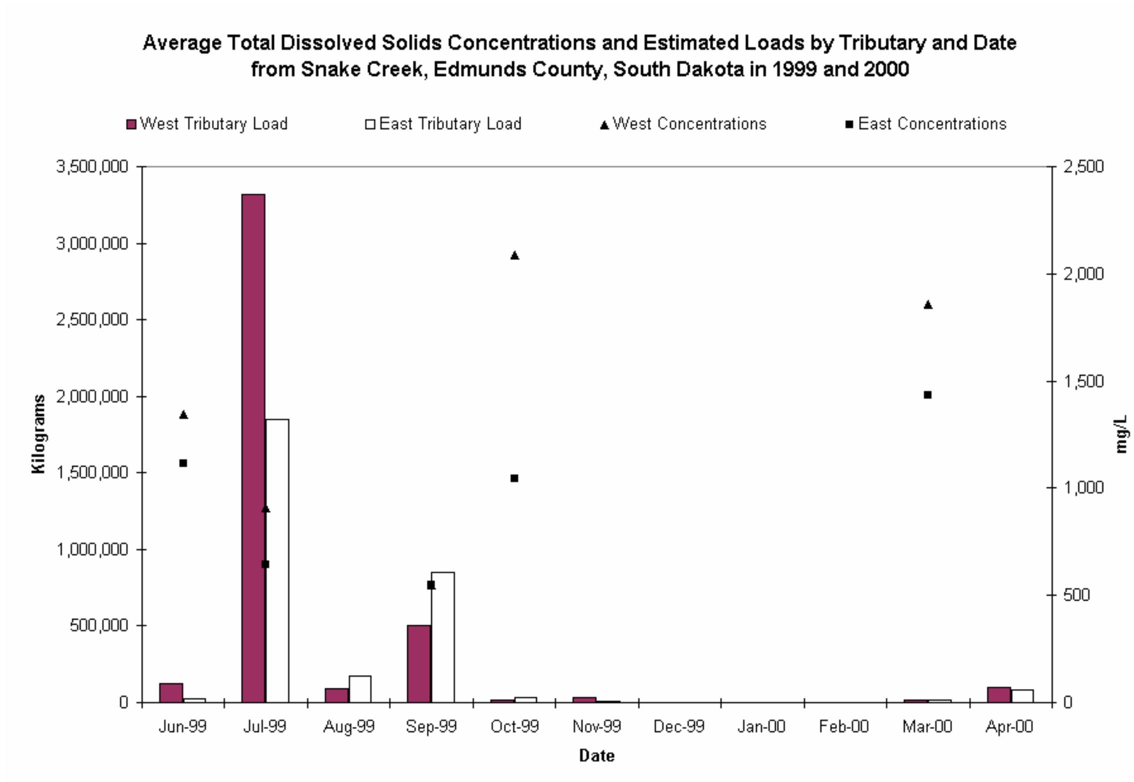


Figure 7. Monthly average total dissolved solids concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Table 14. Snake Creek, 1999 - 2000, total dissolved solids loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	680,827	680,827	9.40	84.26
SC-1	34.74	38.39	4,208,216	3,527,389	48.68	69.99
East Tributary						
SC-8	34.05	11.08	828,650	828,650	11.44	16.77
SC-7	14.89	8.21	1,536,011	1,536,011	21.20	71.11
SC-2	10.75	36.25	3,037,269	672,608	9.28	43.12
Total Gauged Load to Mina Lake			**7,245,485**			

The total suspended solids concentrations in Snake Creek averaged 107.2 mg/L with a maximum of 1,850.0 mg/L and a minimum of 1.0 mg/L. Volatile total suspended solids concentrations averaged 12.7 mg/L with a maximum of 230 mg/L and a minimum concentration of 1.0 mg/L. Generally, average total suspended and volatile total suspended solids concentrations were lower in the spring and peaked in late summer and early fall, depending upon tributary (Figure 8 and Figure 9). Table 9 indicates that seasonal averages for total suspended solids peaked in the summer in the west tributary (37.4 mg/L) and in the fall for the east tributary (243.3 mg/L), while volatile total suspended solids concentrations peaked in the spring in the west tributary (8.0 mg/L) and in the summer for the east (21.4 mg/L).

Table 15. Snake Creek, 1999 - 2000, total suspended solids loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	29,845	29,845	2.26	3.69
SC-1	34.74	38.39	392,939	363,095	27.54	7.20
East Tributary						
SC-8	34.05	11.08	38,760	38,760	2.94	0.78
SC-7	14.89	8.21	886,816	886,816	67.26	41.06
SC-2	10.75	36.25	621,563[1]	0	0.00	0.00 (7.18)[2]
Total Gauged Load to Mina Lake			**1,014,502**			

[1] = Total kilograms/year was reduced at SC-2 by 304,013 kg.

[2] = Estimated export coefficient and kilograms based upon delivered load at site SC-2 divided by acreage drained by east tributary

Total suspended solids loading by site was highest at site SC-7 with 886,816 kg/year or 41.1 percent of the total suspended solids load (Table 15). Volatile total suspended solids loadings were also highest at site SC-7 with 111,805 kg/year or 78.6 percent of the volatile total suspended solids load (Table 16). Sub-watershed export coefficients (kilograms/acre) for total suspended solids were highest in the SC-7 sub-watershed (41.1 kg/acre). Volatile total suspended solids export coefficients were also highest in sub-watershed SC-7 (5.2 kg/acre), 7.5 times higher than sub-watershed SC-6. Similar to total and total dissolved solids loading, the highest total suspended and volatile total suspended solids loads to Mina Lake occurred in July 1999 with another increase in September 1999 (Figure 8 and Figure 9). However, the west tributary contributed the majority of the volatile total suspended solids loads to the lake and the east tributary contributed the highest total suspended solids loads to Mina Lake. The higher total suspended solids load delivered from the east tributary is due to increased cropped acreage in the eastern tributary than in the western tributary.

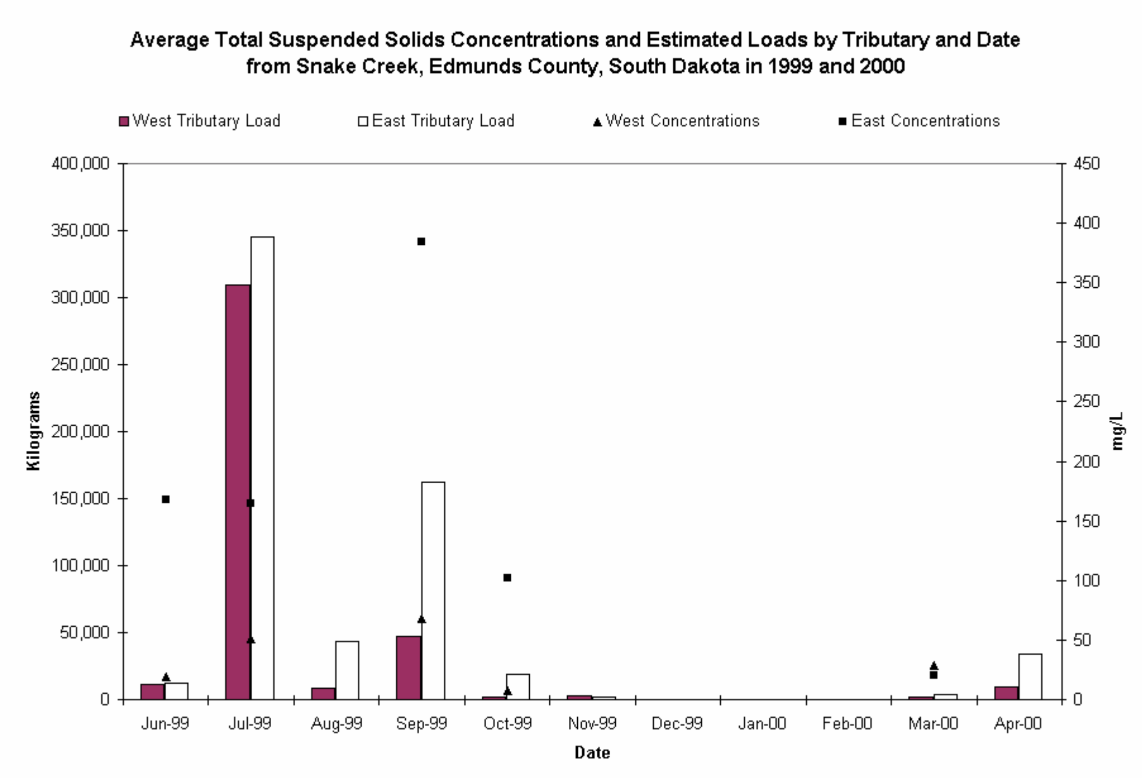


Figure 8. Monthly average total suspended solids concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Table 16. Snake Creek, 1999 - 2000, volatile total suspended solids loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	5,567	5,567	3.91	0.69
SC-1	34.74	38.39	22,219	16,652	11.70	0.33
East Tributary						
SC-8	34.05	11.08	8,310	8,310	5.84	0.17
SC-7	14.89	8.21	111,805	111,805	78.55	5.18
SC-2	10.75	36.25	38,678[1]	0	0.00	0.00 (0.45)[2]
Total Gauged Load to Mina Lake			**60,897**			

[1] = Total kilograms/year was reduced at SC-2 by 81,437 kg.

[2] = Estimated export coefficient and kilograms based upon delivered load at site SC-2 divided by acreage drained by east tributary (86,600 acres)

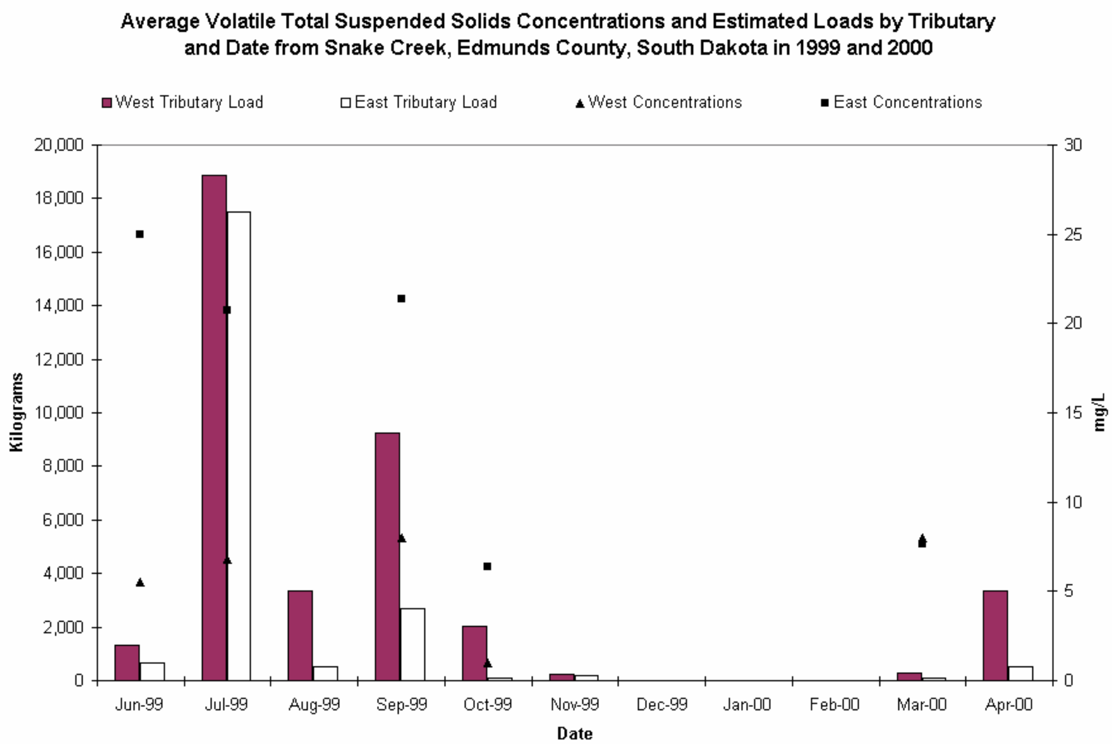


Figure 9. Monthly average volatile total suspended solids concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Mina Lake is on the 303(d) list (impaired waterbody list) because of an increasing TSI trend (Trophic State Index) (SD DENR, 1998). Decreasing sediment (erosion) inputs from Snake Creek and the ungauged sub-watershed 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 Mina Lake, 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 Mina Lake.

Sub-watersheds that should be targeted for sediment (erosion) mitigation, based upon the watershed assessment and AGNPS modeling export coefficients, are presented in priority ranking in Table 17:

Table 17. Snake Creek watershed mitigation priority sub-watersheds for sediment, based on the 1999 and 2000 watershed assessment and AGNPS modeling.

Priority Ranking	Sub-watershed	Total Suspended Solids Export Coefficient (kg/acre)	Total Suspended Solids Kilograms Delivered
1	SC-7	41.06	886,816
2	Ungauged	15.70	202,216
3	SC-2	7.18*	621,563
4	SC-1	7.02	363,095
5	SC-6	3.69	29,845
6	SC-8	0.78	38,760

*** = Estimated export coefficient based upon delivered load at site SC-2 divided by acreage drained by the east tributary.**

Ammonia

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

Table 18. Snake Creek, 1999 - 2000, ammonia loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	70	70	15.70	0.009
SC-1	34.74	38.39	204	134	30.05	0.003
East Tributary						
SC-8	34.05	11.08	130	130	29.11	0.003
SC-7	14.89	8.21	112	112	25.15	0.005
SC-2	10.75	36.25	190[1]	0	0.00	0.000 (0.0021)[2]
Total Gauged Load to Mina Lake			**394**			

[1] = Total kilograms/year was reduced at SC-2 by 52 kg.

[2] = Estimated export coefficient based upon delivered load at site SC-2 divided by acreage drained by east tributary

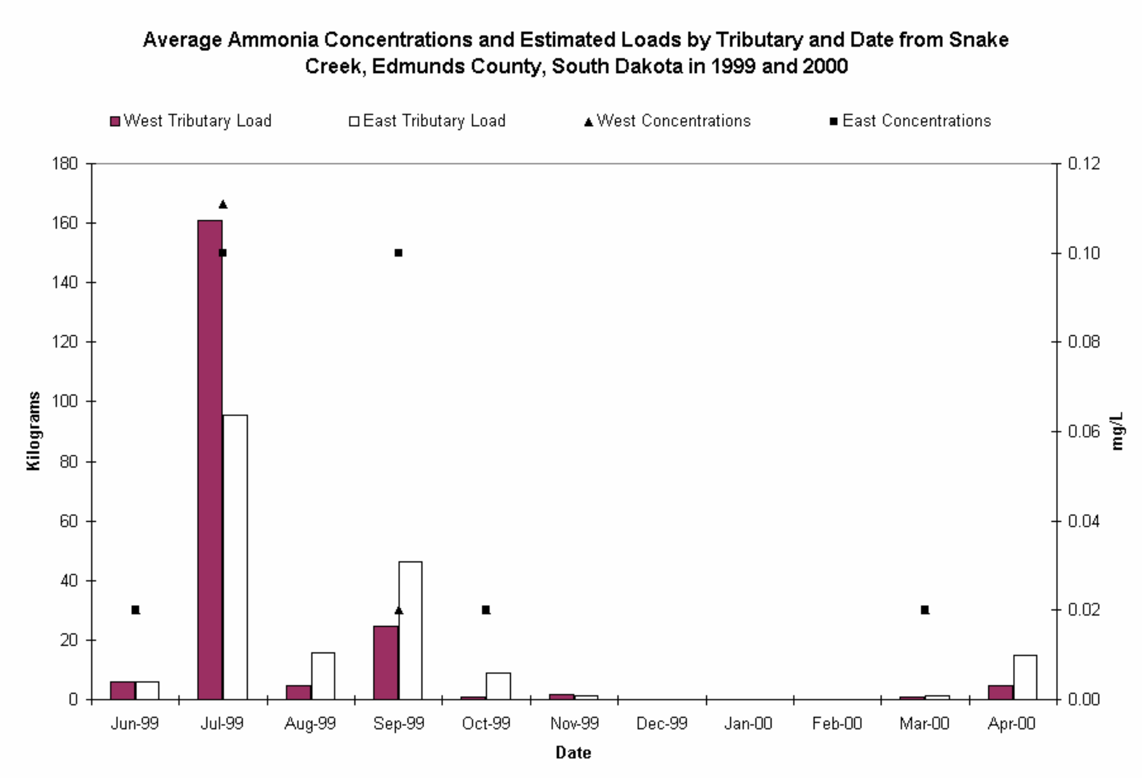


Figure 10. Monthly average ammonia concentrations from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

The mean ammonia concentration in Snake Creek was 0.07 mg/L with a median of 0.02 mg/L. The standard deviation was 0.10 mg/L which indicates a large variation in sample concentrations. Ammonia concentrations rose dramatically after May and returned below the laboratory detection limit (0.02 mg/L) by the end of August (Figure 10). The majority of ammonia samples (75.5 percent) collected in Snake Creek were below the laboratory detection limit. Seasonally the highest concentrations of ammonia occurred in summer for both the east and west tributaries (0.09 mg/L) with average spring concentrations below detection limits (Table 9).

Ammonia loading by site was highest at site SC-6 with 134 kg/year or 30.0 percent of the total ammonia load (Table 18). Sub-watershed export coefficients (kilograms/acre) were also highest in the SC-6 sub-watershed (0.009 kg/acre). Like most parameters, peak ammonia loading occurred in July 1999 and to a lesser extent September 1999. The west tributary contributed the greatest load in July and the east tributary contributed an increased load in September (Figure 10).

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.

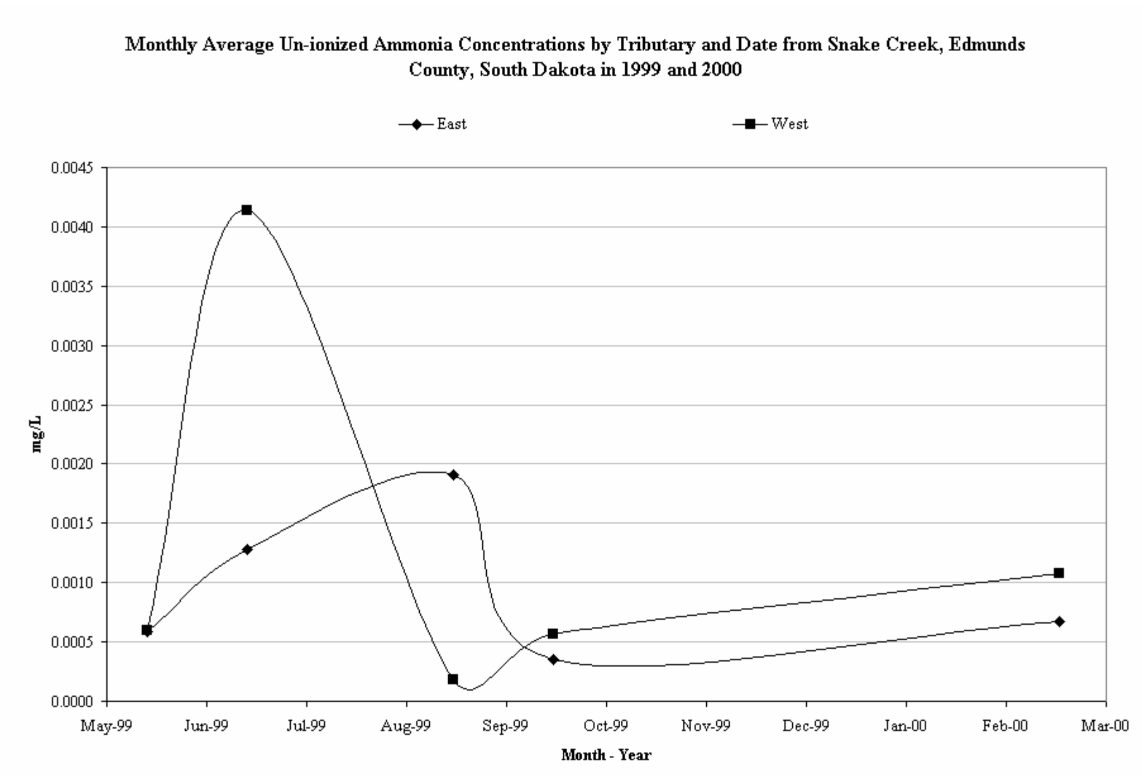


Figure 11. Monthly average un-ionized ammonia concentrations from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

The mean un-ionized ammonia concentration for Snake Creek was 0.002 mg/L. The maximum concentration was 0.026 mg/L and the minimum concentration was 0.0002 mg/L. Average un-ionized ammonia concentrations peaked in July 7, 1999 in the west tributary at 0.0041 mg/L and gradually declined to 0.0002 mg/L by September (Figure 11). The peak value was the result of increased total ammonia concentrations and warmer water temperature increasing the un-ionized ammonia fraction.

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.

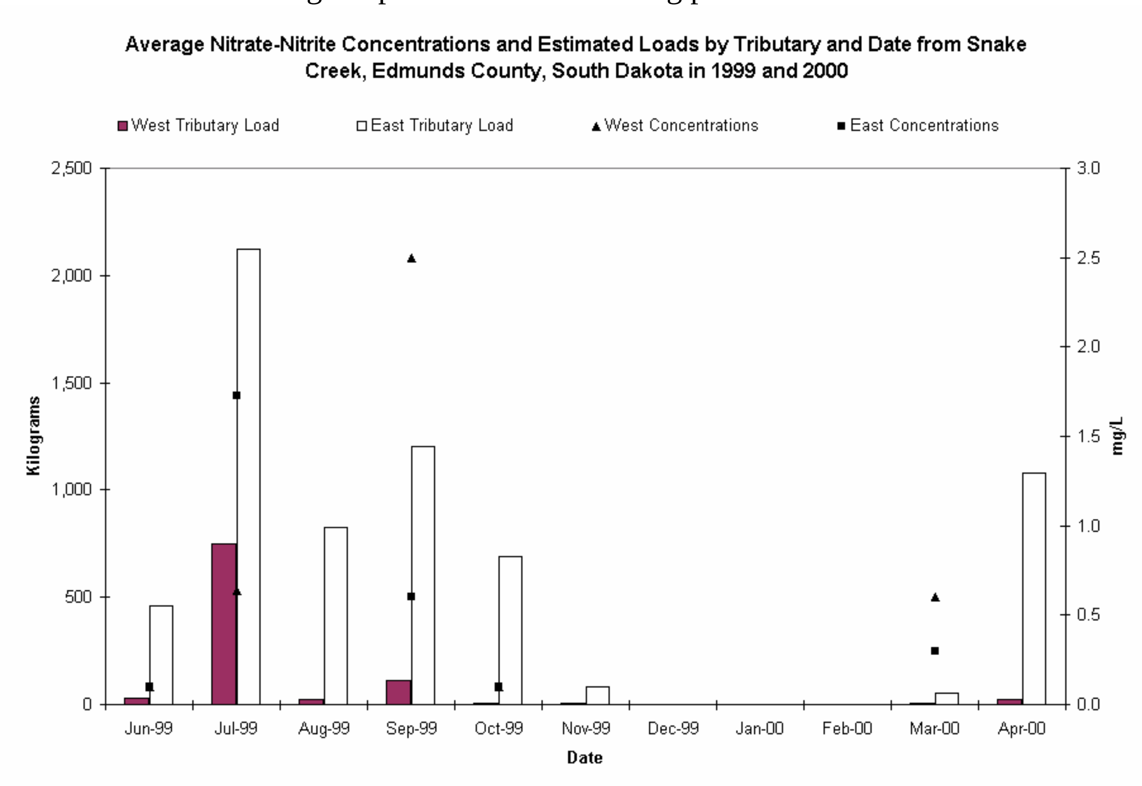


Figure 12. Monthly average nitrate-nitrite concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

The average nitrate-nitrite concentration for Snake Creek was 0.88 mg/L (median 0.10 mg/L) during the project. The maximum concentration of nitrate-nitrite was 23.2 mg/L on July 8, 1999 at SC-2 and a minimum of 0.10 mg/L (laboratory detection limit) in 36 separate samples covering all tributary sampling sites (Appendix D). Two peaks were observed in monthly average nitrate-nitrite concentrations, one in July and one in September (Figure 12). Seasonally, average nitrate-nitrite concentrations were elevated in the summer at 1.49 mg/L on the east tributary and 1.30 mg/L on the west (Table 9). Nitrate-nitrite loading by site was highest at site SC-2 (5,687 kg/year (on the east tributary)) or 71.6 percent of the total load to Mina Lake (Table 19). Sub-watershed export coefficients (kilograms/acre) were also highest in the SC-2 sub-watershed at 0.36 kg/acre. Estimated loads to Mina Lake were significantly higher in the east tributary than the west tributary ($p < 0.05$).

Table 19. Snake Creek, 1999 - 2000, nitrate–nitrite loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	1,428	1,428	17.98	0.18
SC-1	34.74	38.39	948[1]	0	0.00	0.00 (0.016)[2]
East Tributary						
SC-8	34.05	11.08	370	370	4.66	0.01
SC-7	14.89	8.21	458	458	5.77	0.02
SC-2	10.75	36.25	6,515	5,687	71.60	0.36
Total Gauged Load to Mina Lake			**7,463**			

[1] = Total kilograms/year was reduced at SC-1 by 480 kg.
[2] = Estimated export coefficient based upon delivered load at site SC-1 divided by acreage drained by east tributary.

Total Kjeldahl Nitrogen

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

TKN concentrations in Snake Creek averaged 2.26 mg/L (median 2.21 mg/L) with a maximum concentration of 3.74 mg/L and a minimum of 1.19 mg/L. There was a decrease in TKN concentration from early summer (June) through the fall (October) 1999 and an increase in the spring of 2000 (Figure 13). Seasonal TKN concentrations were highest in the spring for both the west and the east tributaries (Table 9).

Table 20. Snake Creek, 1999 - 2000, Total Kjeldahl Nitrogen loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	1,865	1,865	8.11	0.23
SC-1	34.74	38.39	12,586	10,721	46.65	0.21
East Tributary						
SC-8	34.05	11.08	3,013	3,013	13.11	0.06
SC-7	14.89	8.21	2,050	2,050	8.92	0.09
SC-2	10.75	36.25	10,398	5,336	23.22	0.34
Total Gauged Load to Mina Lake			**22,984**			

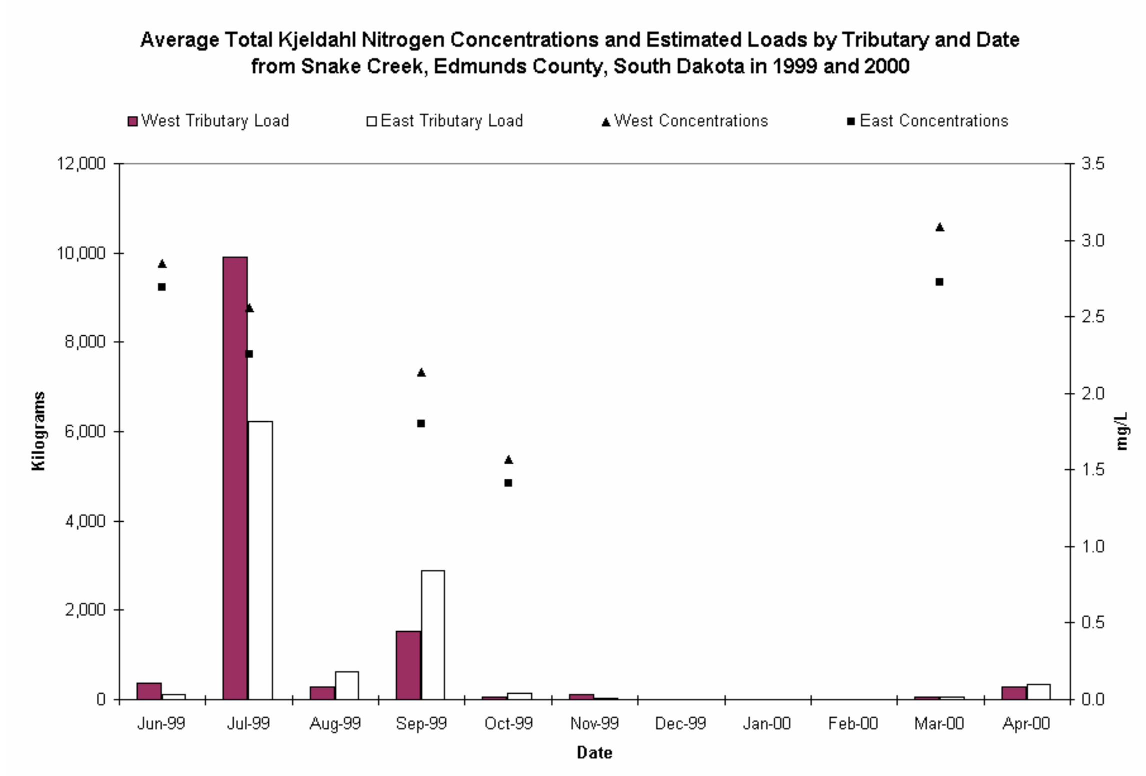


Figure 13. Monthly average Total Kjeldahl Nitrogen concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Monthly TKN loadings were higher in July 1999 for the west tributary and in September 1999 for the east tributary (Figure 13). Sub-watersheds export coefficients (kilograms/acre) for TKN were highest in the east tributary SC-2 (0.34 kg/acre) sub-watershed (Table 20). The SC-2 sub-watershed export coefficient (kg/acre) for TKN were 1.62 times greater than the SC-1 sub-watershed which had the highest percent total load (Table 20).

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.

Organic nitrogen concentrations in Snake Creek averaged 2.19 mg/L (median 2.19 mg/L) with a maximum of 3.32 mg/L and a minimum concentration of 1.07 mg/L. Similar to TKN, average monthly concentrations of organic nitrogen were high in the summer, declined in the fall and peaked in the spring (Figure 14). Since organic nitrogen is calculated from TKN, Figure 13 and Figure 14 are similar. Seasonal averages for organic nitrogen concentrations were also highest in the fall (Table 9).

Table 21. Snake Creek, 1999 - 2000, organic nitrogen loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	1,800	1,800	7.97	0.22
SC-1	34.74	38.39	12,381	10,581	46.84	0.21
East Tributary						
SC-8	34.05	11.08	2,895	2,895	12.81	0.06
SC-7	14.89	8.21	1,937	1,937	8.58	0.09
SC-2	10.75	36.25	10,208	5,376	23.80	0.34
Total Gauged Load to Mina Lake			**22,589**			

Organic nitrogen monthly loading was also similar to TKN with higher loading in July and September 1999 (Figure 14). Sub-watersheds export coefficients (kilograms/acre) for organic nitrogen were highest in the SC-2 (0.34 kg/acre) sub-watershed. The SC-2 sub-watershed export coefficient (kg/acre) was 1.62 times greater than the SC-1 sub-watershed, which had the highest percent total load (Table 21).

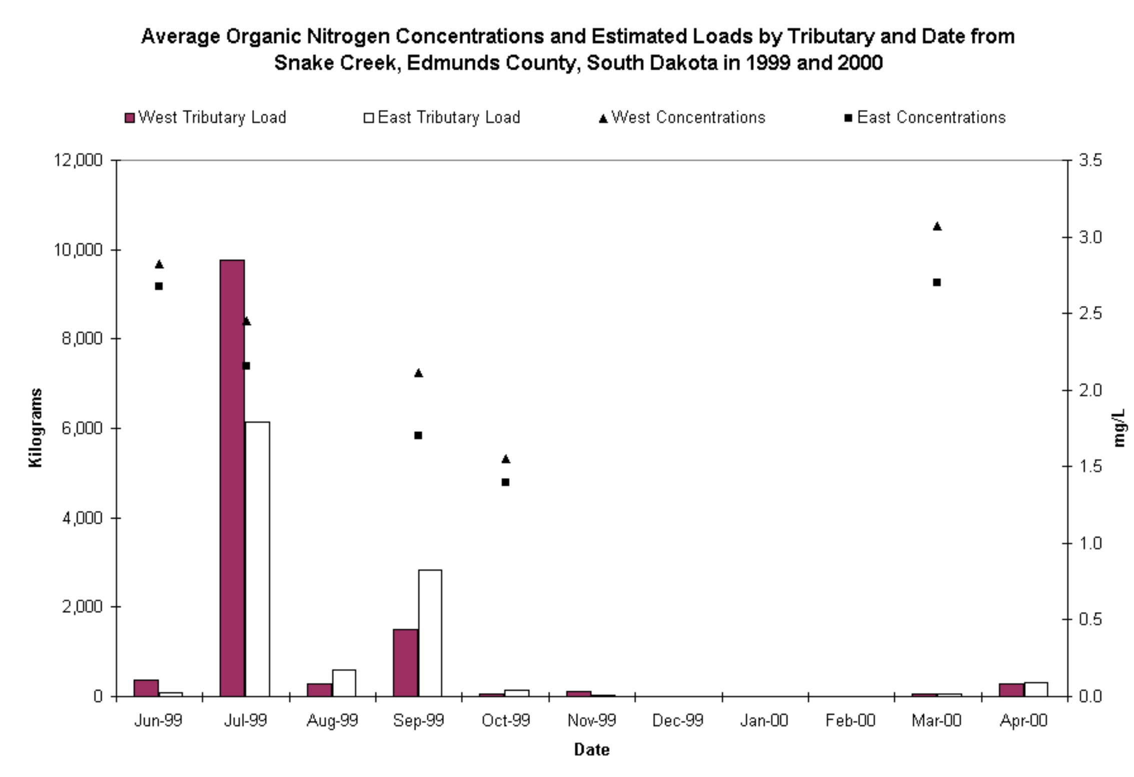


Figure 14. Monthly average organic nitrogen concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used mostly in determining the limiting nutrient (nitrogen or phosphorus) and will be discussed later in this section and in the lake section of this report. The maximum total nitrogen concentration found in Snake Creek was 26.1 mg/L at SC-2 on July 8, 1999 (Appendix D). Average monthly total nitrogen concentrations peaked in September 1999 for the west tributary and July 1999 for the east tributary (Figure 15). The mean concentration for the entire project was 3.14 mg/L and the standard deviation for total nitrogen was 3.43 mg/L. The organic nitrogen fraction (percent of organic nitrogen in total nitrogen (concentrations)) ranged from 11.2 to 97.4 percent and averaged 71.9 percent.

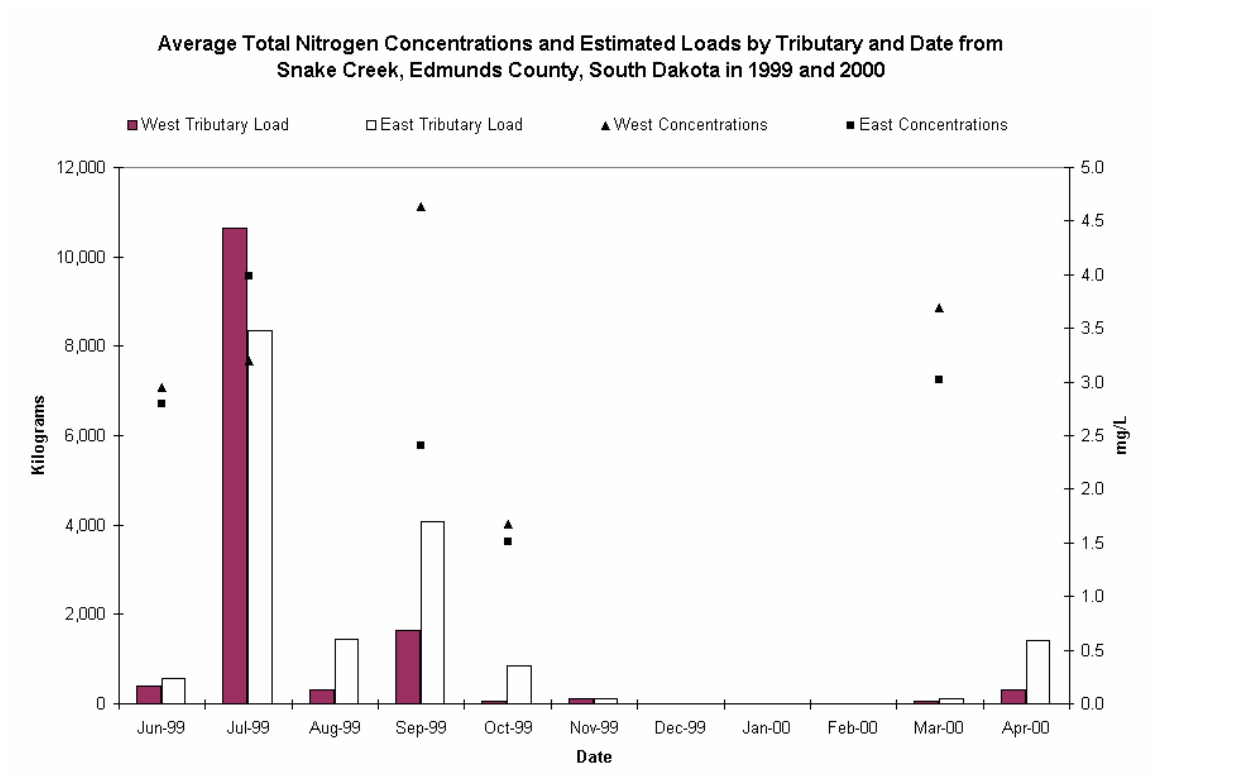


Figure 15. Monthly average total nitrogen concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Seasonally, average total nitrogen concentrations were higher in the summer (3.79 mg/L for the east tributary and 3.69 mg/L for the west tributary (Table 9).

Total nitrogen loading by site was highest at site SC-2 (east tributary) with 16,914 kg/year or 36.2 percent of the total nitrogen load to Mina Lake (Table 22). Sub-watershed export coefficients (kilograms/acre) were also highest in the SC-2 sub-watershed (0.71 kg/acre).

Table 22. Snake Creek, 1999, total nitrogen loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	3,293	3,293	10.83	0.41
SC-1	34.74	38.39	13,498	10,205	33.56	0.20
East Tributary						
SC-8	34.05	11.08	3,383	3,383	11.12	0.07
SC-7	14.89	8.21	2,508	2,508	8.25	0.12
SC-2	10.75	36.25	16,914	11,023	36.25	0.71
Total Gauged Load to Mina Lake			**30,411**			

Decreasing nitrogen inputs from Snake Creek and the ungauged sub-watershed may improve (lower) in-lake TSI values. Reducing nitrogen (especially organic nitrogen) could improve non-algal turbidity, which would decrease Secchi TSI values. Increasing transparency could increase the growth of submerged macrophytes, which would increase the uptake of nitrogen and phosphorus, reducing available nutrients that could cause algal blooms in Mina Lake. A dramatic reduction in both nitrogen and phosphorus is needed to reduce algal growth in Mina Lake. 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 Mina Lake 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 watershed assessment export coefficients and AGNPS modeling are presented by priority ranking in Table 23.

Table 23. Snake Creek watershed mitigation priority sub-watersheds for total nitrogen based on 1999 – 2000 watershed assessment and AGNPS modeling.

Priority Ranking	Sub-watershed	Total Nitrogen Export Coefficient (kg/acre)	Total Nitrogen Kilograms Delivered
1	SC-2	0.71	11,023
2	Ungauged	0.48	6,182
3	SC-6	0.41	3,293
4	SC-1	0.20	10,205
5	SC-7	0.12	2,508
6	SC-8	0.07	3,383

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 Mina Lake 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 Snake 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 Snake Creek.

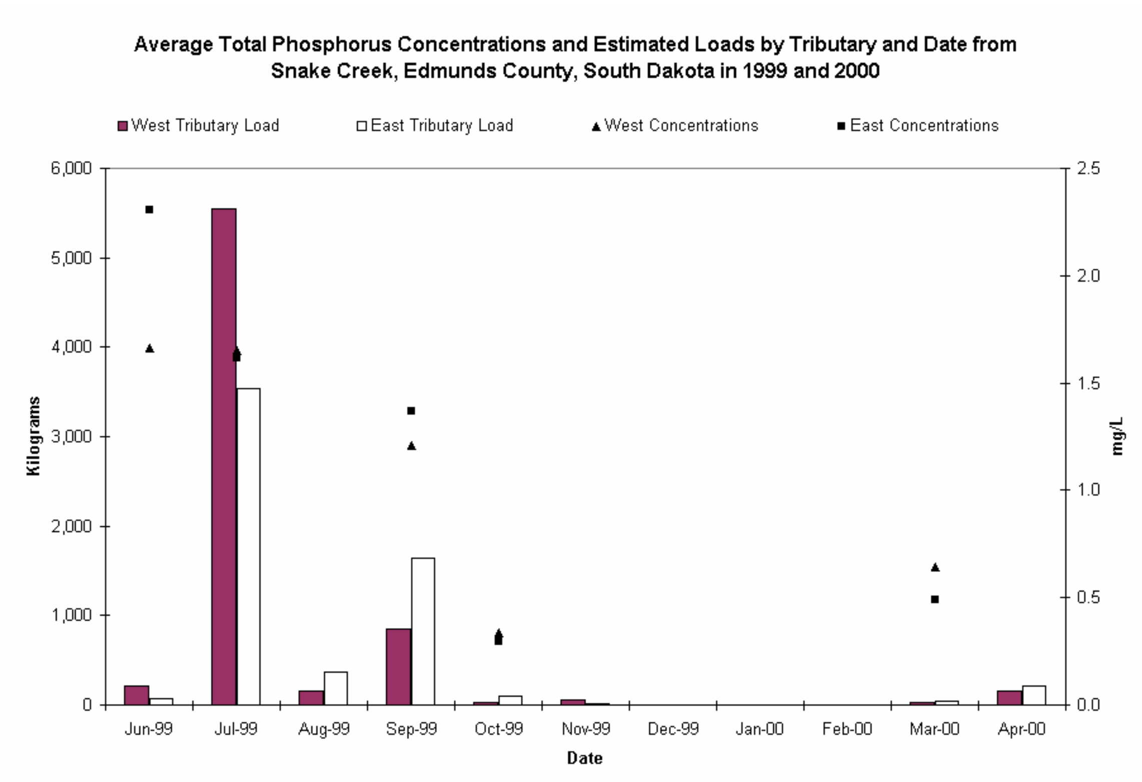


Figure 16. Monthly average total phosphorus concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

The average total phosphorus concentration for Snake Creek was 1.34 mg/L (median 1.36 mg/L) during the project. The maximum concentration of total phosphorus was 3.17 mg/L on July 8, 1999 at SC8 and a minimum of 0.204 mg/L at SC-1 on October 21, 1999 (Appendix D). Since algae/periphyton only need 0.02 mg/L of phosphorus to produce algal blooms in lakes (Wetzel, 2001), Snake Creek average delivery concentration was 67 times the phosphorus needed to produce algal blooms in Mina Lake.

Table 24. Snake Creek, 1999 - 2000, total phosphorus loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	1,193	1,193	9.17	0.15
SC-1	34.74	38.39	7,034	5,841	44.87	0.12
East Tributary						
SC-8	34.05	11.08	1,727	1,727	13.27	0.03
SC-7	14.89	8.21	1,610	1,610	12.37	0.07
SC-2	10.75	36.25	5,983	2,646	20.33	0.17
Total Gauged Load to Mina Lake			**13,016**			

Figure 16 indicates decreases in monthly average total phosphorus concentrations from June 1999 through October 1999 and a gradual increase in March 2000. Seasonally, average total phosphorus concentrations were elevated (peaked) in the summer for both the west (1.79 mg/L) and the east (1.72 mg/L) tributaries (Table 9).

Total phosphorus loading by site was highest at site SC-1 with 5,841 kg/year or 44.9 percent of the total phosphorus load to Mina Lake. However, sub-watershed export coefficients (kilograms/acre) were highest in the SC-2 sub-watershed (0.17 kg/acre). This is 1.42 times more total phosphorus per acre than sub-watershed SC-1 (0.12 kg/acre) which had the highest percent total load (Table 24). Monthly total phosphorus loading was similar to most other parameter observations in Snake Creek. The greatest monthly total phosphorus loading occurred in July and was higher in the west tributary (Figure 16).

Significant reductions in total phosphorus loads are needed to improve TSI values in Mina Lake. However, tributary total phosphorus reductions of the magnitude needed to achieve dramatic in-lake TSI reductions will be difficult to achieve. Considerable alterations should be implemented in existing management practices to improve current conditions in both the watershed and Mina Lake. Limitations exist in the reduction of total phosphorus needed to meet ecoregion based beneficial use criteria and a realistic achievable reduction of total phosphorus in this watershed; however, every effort should be made to reduce total phosphorus loads to Snake Creek and Mina Lake.

Decreasing total phosphorus inputs from the Snake Creek and the ungauged watershed will improve (lower) TSI values. Dramatically 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 the increasing TSI trend observed in Mina Lake.

Sub-watersheds that should be targeted for phosphorus mitigation based upon watershed assessment export coefficients by priority ranking are presented in Table 25.

Table 25. Snake Creek watershed mitigation priority sub-watersheds for total phosphorus based on 1999 – 2000 watershed assessment and AGNPS modeling.

Priority Ranking	Sub-watershed	Total Phosphorus Export Coefficient (kg/acre)	Total Phosphorus Kilograms Delivered
1	Ungauged	0.19	2,447
2	SC-2	0.17	2,646
3	SC-6	0.15	1,193
4	SC-1	0.12	5,841
5	SC-7	0.07	1,610
6	SC-8	0.03	1,727

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 average total dissolved phosphorus concentration for Snake Creek was 1.13 mg/L (median 1.09 mg/L). The maximum concentration of total phosphorus was 2.57 mg/L on June 30, 1999 at SC-7 and a minimum of 0.137 mg/L at SC-8 on March 27, 2000 (Appendix D). During this study, the percentage of total dissolved phosphorus to total phosphorus ranged from 39.7 percent in the summer to 98.6 percent in spring and averaged 84.6 percent over the project.

Table 26. Snake Creek, 1999 - 2000, total dissolved phosphorus loading per year by site.

Station	Percent Watershed (gauged)	Percent Hydrologic Load	Total Kilograms (cumulative)	Kilograms by site	Percent Total Load by site	Export Coefficient (kg/acre)
West Tributary						
SC-6	5.57	6.07	1,066	1,066	9.48	0.13
SC-1	34.74	38.39	6,323	5,256	46.72	0.10
East Tributary						
SC-8	34.05	11.08	1,503	1,503	13.36	0.03
SC-7	14.89	8.21	846	846	7.52	0.04
SC-2	10.75	36.25	4,928	2,579	22.92	0.17
Total Gauged Load to Mina Lake			**11,251**			

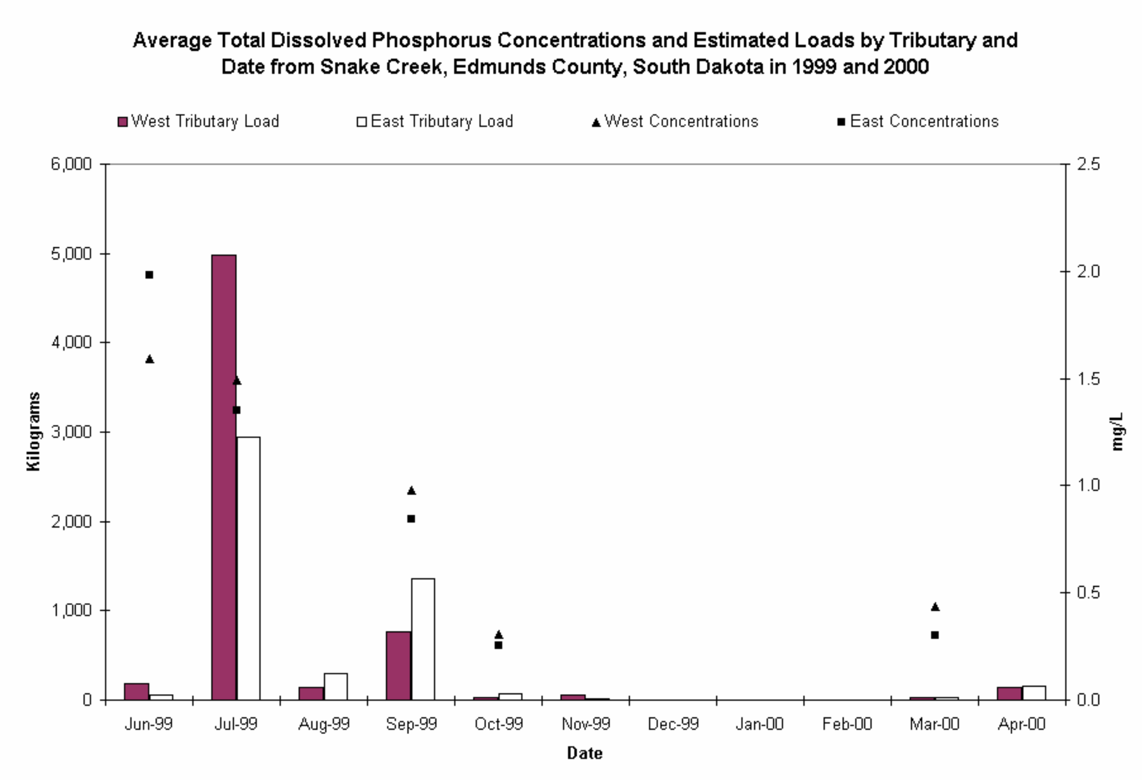


Figure 17. Monthly average total dissolved phosphorus concentrations and estimated loads by tributary to Mina Lake from Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Average total dissolved phosphorus concentrations were similar to total phosphorus with decreases in monthly average total dissolved phosphorus concentrations from June 1999 through October 1999 and a gradual increase in March 2000 (Figure 17). Seasonally, total dissolved phosphorus concentrations were elevated (peaked) in the summer for both the west (1.65 mg/L) and the east (1.44 mg/L) tributaries (Table 9).

Total dissolved phosphorus loading by site was highest at site SC-1 with 6,323 kg/year or 46.7 percent of the total dissolved phosphorus load to Mina Lake. However, sub-watershed export coefficients (kilograms/acre) were highest in the SC-2 sub-watershed (0.17 kg/acre). This is 1.70 times more total dissolved phosphorus per acre than sub-watershed SC-1 (0.10 kg/acre) which had the highest percent total load (Table 26). Again, monthly total dissolved phosphorus loading was similar to most other parameter observations in Snake Creek, with the greatest monthly total phosphorus loading occurring in July and was greatest in the west tributary (Figure 17).

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.

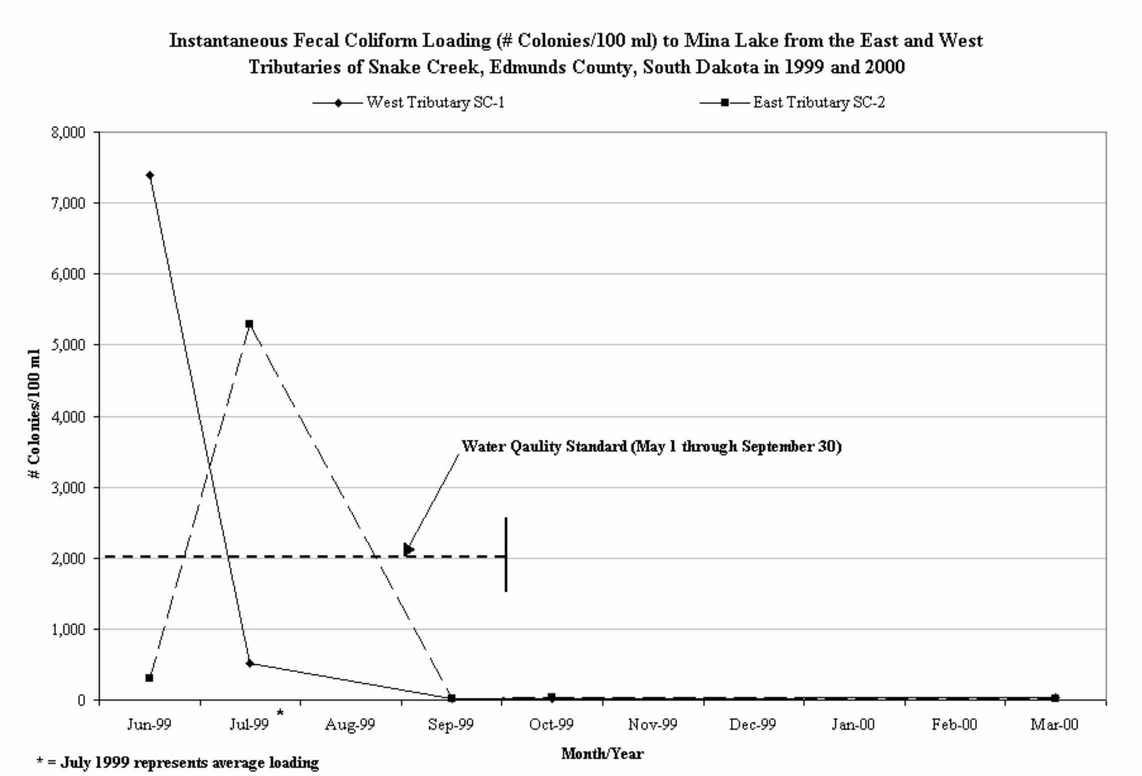


Figure 18. Monthly fecal coliform concentrations (# colonies/100 ml) to Mina Lake from the east and west tributaries of Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Table 7 identifies five samples collected in late June and early July of 1999 in Snake Creek as exceeding water quality standards for fecal coliform. Figure 18 indicates tributary loading from the east and west tributaries of Snake Creek into Mina Lake exceeded fecal coliform standards, even when averaging the multiple samples collected at SC-1 (west tributary) and SC-2 (east tributary) in July. All fecal coliform water quality violations in July occurred during increasing flows. This suggests that elevated fecal coliform concentrations/loadings may be related to watershed runoff events. However, in-lake and swimming beach fecal coliform samples during this period were at or below laboratory detection limits (Figure 40 and Table 36). This indicates that fecal decay rate, sunlight and in-lake dilution affect tributary fecal coliform loading to Mina Lake. Water quality standards violations for fecal coliform are a concern in Snake Creek; and, implementing suggested tributary Best Management Practices (BMPs) will reduce tributary fecal coliform concentrations.

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 syreams. 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).

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), Snake Creek would still be nitrogen-limited.

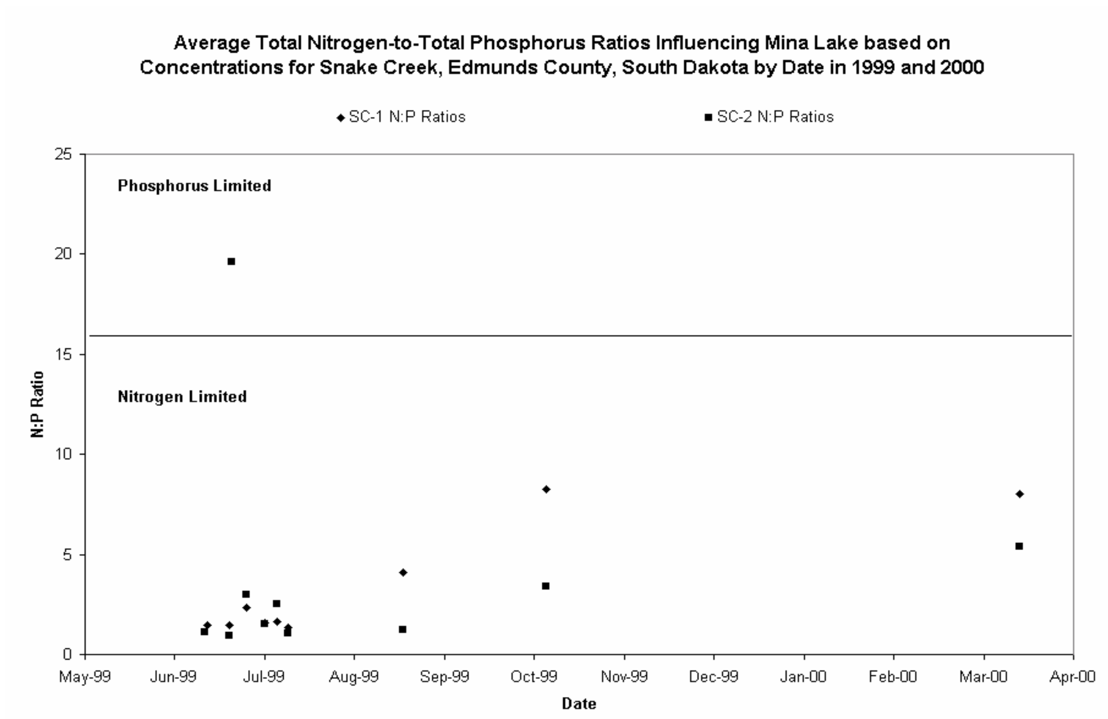


Figure 19. Total nitrogen-to-total phosphorus ratios based on concentrations at SC-1 and SC-2 for Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Table 27. Seasonal average total nitrogen-to-total phosphorus ratios based on sample concentrations for Snake Creek and SC-1 and SC-2.

Season	Snake Creek (all sites)	Inlets SC-1	Inlets SC-2	Site SC-1 and SC-2 Season Average
Summer	3.0	1.6	4.3	3.0
Fall	4.2	6.2	2.3	4.3
Spring	6.5	8.0 [1]	5.4 [1]	6.7
Overall Average	**3.0**	**3.4**	**4.0**	
Average N : P ratio influencing Mina Lake		**3.7**		

1 = not an average, only one sample taken

Nitrogen and phosphorus ratios were calculated for all tributary samples (53 samples), however, only data from SC-1 and SC-2 was evaluated because those concentrations (ratios) influence Mina Lake directly. Individual ratios for SC-1 and SC-2 are shown in Figure 19. Over the project, both tributaries tended to be more nitrogen limited during the growing season (June through September).

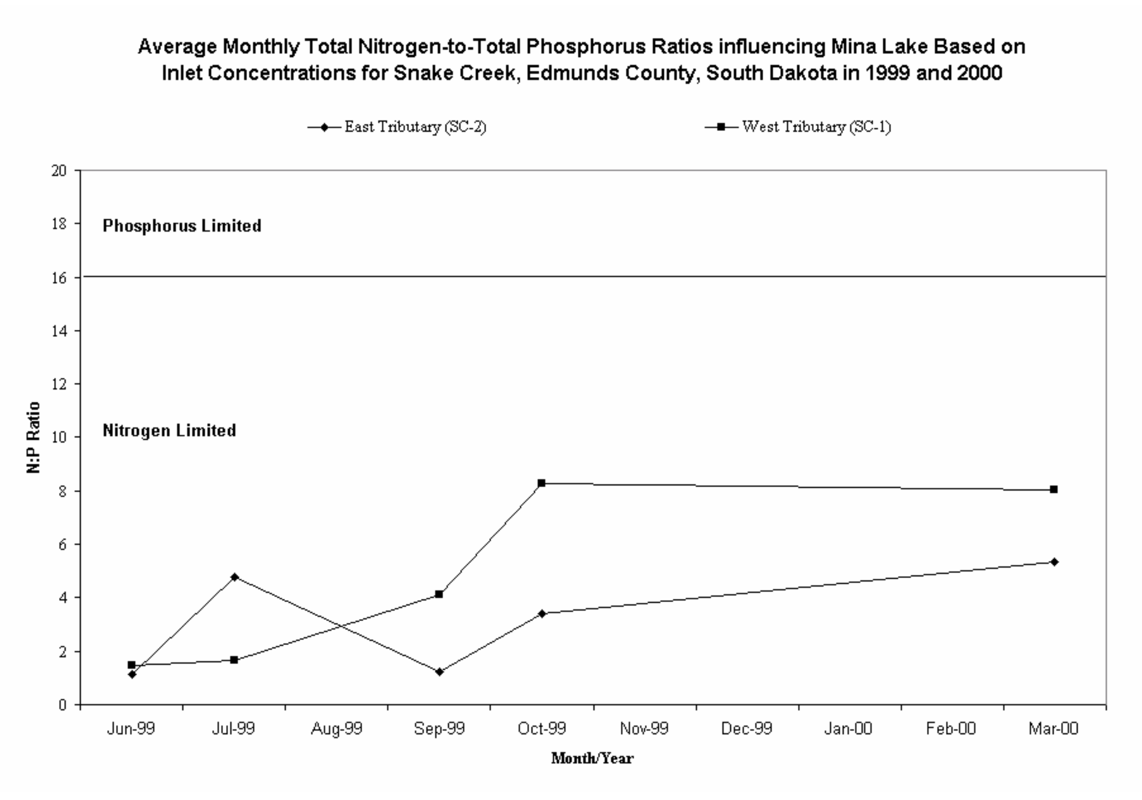


Figure 20. Monthly average total nitrogen/total phosphorus ratios based on concentrations for Snake Creek, Edmunds County, South Dakota in 1999 and 2000.

Average seasonal tributary total nitrogen-to-total phosphorus ratios were generally lower and slightly erratic during increased hydrologic events in the summer and early fall (Figure 20 and Table 27). The average seasonal ratios increased from the summer (3.0) through the fall (6.7). Most tributary total nitrogen-to-total phosphorus ratios (both individually and seasonally) indicate that the Snake Creek system in the Mina Lake watershed is nitrogen-limited (Figure 19, figure 20 and Table 27). The sample collected on July 8, 1999 at SC-2 had a tributary total nitrogen-to-total phosphorus ratio of 19.6 or phosphorus-limited (Figure 19).

Total nitrogen-to-total phosphorus ratios calculated from concentration and modeled loading data by water quality monitoring site were similar and shows nitrogen limitation (Table 28).

Based on the criteria previously proposed, metabolic activity and community structure based on nutrient limitations was a factor in Snake Creek due to nitrogen limitation (indicating excess phosphorus in the watershed).

Table 28. Snake Creek annual total nitrogen-to-total phosphorus loading and concentration ratios by site for 1999 and 2000.

Site	Gauged Hydrologic Load Percent	Load Ratio	Concentration Ratio
SC–1	41.51	2:1	2:1
SC-2	39.19	4:1	3:1
SC-6	6.56	3:1	3:1
SC-7	8.88	2:1	2:1
SC-8	11.96	2:1	2:1

Ungauged Portion of Watershed

The ungauged portion of the project is comprised of the area immediately around the lake and portions of the watershed to the north and northwest of Mina Lake (portion of the watershed downstream of SC-1 and SC-2 to the outlet of Mina Lake). It was estimated from the AGNPS model, that approximately eight percent of the watershed was not gauged (Appendix C). To determine hydrologic loading of the ungauged portion of the watershed a conservative export coefficient was used (0.15 acre-feet) based partially on export coefficients from FLUX modeling for both SC-1, SC-2 and SC-3 sub-watersheds. After the total from the ungauged sites was added to the loading total, it was found that the ungauged area contributed an additional 19.3 percent of the hydrologic load to the lake. AGNPS data was used to estimate the additional percent of phosphorus, sediment and nitrogen loadings to the lake. AGNPS-calculated export coefficients were adjusted using export coefficients derived from water quality loading data. A simple ratio was used to modify AGNPS export coefficients. This ratio was the average AGNPS gauged export coefficient over the AGNPS ungauged export coefficient compared to the average gauged water quality export coefficient over the unknown ungauged export coefficient. Modified export coefficients are listed in Table 29. The ungauged portion of the watershed contributed an additional 15.7 percent of the phosphorus, 15.7 percent of the sediment and 16.9 percent of the total nitrogen using adjusted export coefficients (Table 29).

In the ungauged portion of the watershed, AGNPS identified 31 critical cells for erosion (sediment), 31 critical cells for nitrogen and 26 critical cells for phosphorus. Critical cells for erosion were targeted/selected as delivering greater than 1,654 kg (1.82 tons) of sediment per acre. Nitrogen critical cells were targeted as delivering greater than 1.78 kg (3.93 pounds) per acre of total nitrogen and critical cells for phosphorus delivering more than 0.66 kg (1.47 pounds) of total phosphorus per acre. The percentage of critical cells in the ungauged portion of the watershed was 9.63 percent for sediment, 9.63 percent for nitrogen and 8.07 percent for phosphorus.

There were two animal feeding areas within the ungauged portion of the watershed that rated over 40 and are in need of mitigation. AGNPS ranked the feedlots within the ungauged watershed from zero to 62. The feeding areas, along with improper manure management, and overgrazed pastures in the ungauged portion of the watershed were the most likely sources of nutrients and sediment to Mina Lake. The estimated loads for the ungauged section of the watershed are significant and will be considered in tributary loading (Table 29) and watershed mitigation.

Table 29. Estimated ungauged (site) percent loading and adjusted export coefficients for Snake Creek, Edmunds County, South Dakota.

Ungauged Parameter	Percent Total Load [1]	Export Coefficient
Percent Watershed	8.1	NA
Hydrologic (Acre-feet)	19.3	0.15
Total Suspended Solids (kg)	15.7	14.7
Total Nitrogen (kg)	16.9	0.48
Total Phosphorus (kg)	15.7	0.19

[1] = Ungauged load was calculated and added to gauged load to determine estimated percent load.

In-lake Methods

Two in-lake sample locations were chosen for collecting nutrient, biological and sediment data from Mina Lake during the study. The locations of the in-lake sampling sites are shown in Figure 21. A sample set consisted of one surface and one bottom sample collected from each site (ML-4 and ML-5) each month. Additional in-lake data were collected in 1989, 1991, 1992 and 1998 for the state-sponsored annual Statewide Lake Assessment. These samples were used to analyze water quality trends over time. Statewide Lake Assessment samples were collected by compositing three widely separated sample sites for both surface and bottom samples in each lake (Stueven and Stewart, 1996).

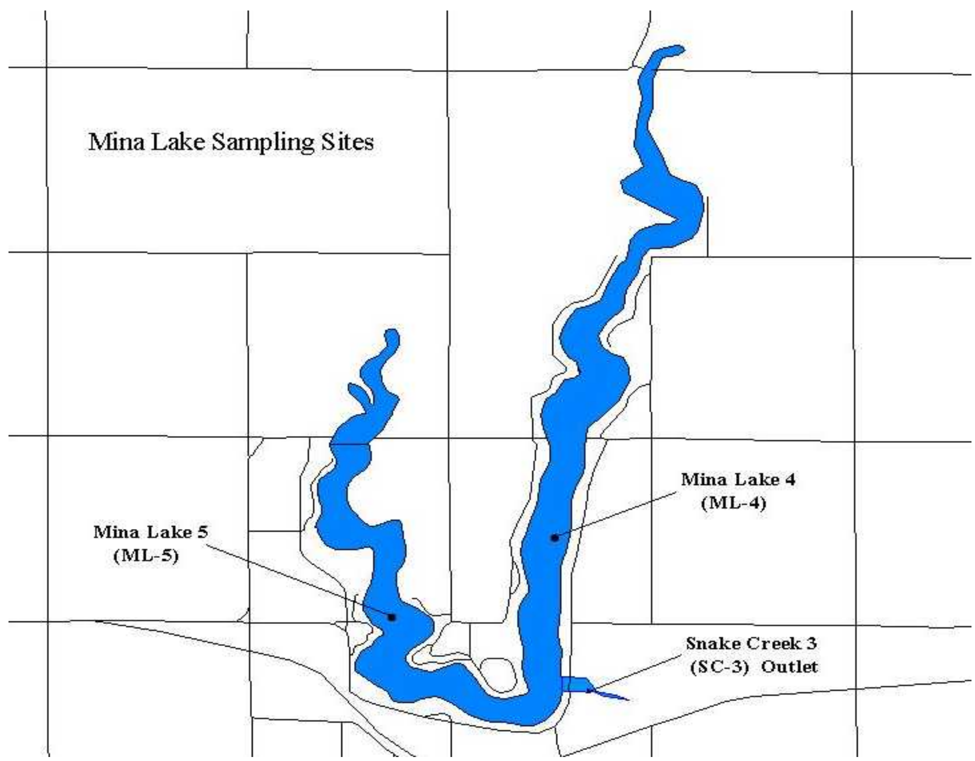


Figure 21. Mina Lake in-lake sampling sites for 1999 and 2000.

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

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 30. 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.

Table 30. In-lake physical, chemical and biological parameters analyzed in Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Physical	Chemical	Biological
Air Temperature	Total Alkalinity	Fecal Coliform
Water Temperature	Field pH	Chlorophyll-*a*
Secchi Transparency	Dissolved Oxygen	Aquatic Macrophytes
Total Depth	Total Solids	Algae
Visual Observations	Total Suspended Solids	
	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 Aquatic Analysts, Wilsonville, Oregon and enumeration results were entered into a database to be analyzed. Aquatic Analysts provided identification, enumeration and biovolume data: however, biovolume was re-calculated using local biovolume values and all algal analysis was based on these values. Original data provided by Aquatic Analysts is presented in Appendix E.

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 Snake Creek from 1999 through 2000.

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 31. 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 31. 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.

Mina Lake in Edmunds County has been also assigned the beneficial uses of (1) Domestic water supply water, (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 32).

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 32. Assigned beneficial uses for Snake Creek, Edmunds County, South Dakota.

Water Body	To	Beneficial Uses*	County
Mina Lake	S26, T124N, R66E	1, 4, 7, 8	Edmunds
All Lakes	Entire State	9	All

*** = See Table 31 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 33 lists the most stringent water quality parameters for Mina Lake. Seven of the seventeen parameters (conductivity, un-disassociated hydrogen sulfide, barium, fluoride, sulfate, total petroleum hydrocarbon and oil and grease) listed for Mina Lake beneficial use classifications were not in the scope of this project and were not sampled.

Table 33. The most stringent water quality standards for Mina Lake based on beneficial use classifications.

Water Body	Beneficial Uses	Parameter	Standard Value
Mina Lake	1, 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]	≤ 1,750 mg/L
		Conductivity at 25° C [6, 10]	≤ 7,000 μmhos/cm
		Nitrates as N [7]	≤ 10 mg/L
		Undissociated hydrogen sulfide [10]	≤ 0.002 mg/L
		Barium [10]	≤ 1.0 mg/L
		Chloride [8]	≤ 438 mg/L
		Fluoride [10]	≤ 4.0 mg/L
		Sulfate [9, 10]	≤ 875 mg/L
		Total petroleum hydrocarbon [10]	≤ 1 mg/L
		Oil and grease [10]	≤ 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 ≤ 1313 mg/L or ≤ 750 mg/L for a 30-day average.
[5] = The daily maximum for total dissolved solids is ≤ 1,750 mg/L or ≤ 1,000 mg/L for a 30-day average.
[6] = The daily maximum for conductivity at 25° C is ≤ 7,000 mg/L or ≤ 4,000 mg/L for a 30-day average.
[7] = The daily maximum for nitrates is ≤ 10 mg/L.
[8] = The daily maximum for chloride is ≤ 438 mg/L or ≤ 250 mg/L for a 30-day average.
[9] = The daily maximum for sulfate is ≤ 875 mg/L or ≤ 500 mg/L for a 30-day average.
[10] = Parameters not measured during this project.

Mina Lake Water Quality Exceedance

One water quality parameter, pH, exceeded in-lake water quality standards in Mina Lake during the project. The surface sample at site ML-5 in the west arm of Mina Lake exceeded in-lake water quality standards for pH on October 12, 1999 (Table 34).

Table 34. pH water quality standards exceedances in Mina Lake in 1999.

Site	Date	Season	pH (s u)	In-lake Water Quality Standard
ML-5	10/12/99	Fall	9.14	≥ 6.5 - ≤ 9.0

The water quality standard violation in pH at site ML-5 of 9.14 su in the west arm was the highest surface pH value recorded at that site during the project. The pH sample collected on the same date from the east arm (site ML-4) also had the highest pH value (8.93 su) recorded from that site (Appendix F).

Seasonal In-lake Water Quality

Typically, water quality parameters will vary with season due to changes in temperature, precipitation and agricultural practices. Twenty-four in-lake water quality samples were collected during the project (12 surface and 12 bottom samples). These data were separated seasonally into spring (March – May), summer (June – August), and fall (September – November). During the project, six discrete surface samples were collected in the summer, four samples in the fall and two samples in the spring of 2000 (Table 35).

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; however, based on Stueven and Stewart (1996) and current project profiles, Mina Lake does not usually stratify. Average concentrations of in-lake sampling sites and sampling parameters by season and are listed in Table 35.

Dissolved oxygen concentrations were highest in the spring due to cooler water temperatures (cooler water can hold more oxygen). The lower oxygen concentrations in the summer were most likely due to warm water temperatures and decomposition of organic matter.

Table 35. Average[1] seasonal surface water concentrations of measured parameters by site from Mina Lake, Edmunds County, South Dakota for 1999 and 2000 [2].

	Summer 1999				Fall 1999				Spring 2000			
	Mina Lake 4 (East Arm)		Mina Lake 5 (West Arm)		Mina Lake 4 (East Arm)		Mina Lake 5 (West Arm)		Mina Lake 4 (East Arm)		Mina Lake 5 (West Arm)	
Parameter	Sample Count	Average	Sample Count	Average	Sample Count	Average	Sample Count	Average	Sample Count	Value	Sample Count	Value
Water Temperature (°C)	3	23.13	3	23.20	2	14.65	2	14.30	1	8.20	1	8.30
Field pH (su)	3	8.54	3	8.62	2	8.75	2	8.56	1	8.65	1	8.75
Dissolved Oxygen (mg/L)	3	6.97	3	8.33	2	9.00	2	10.10	1	11.20	1	11.40
Fecal Coliform (# Colonies/ 100 ml)	3	6.67	3	5.00	2	7.50	2	5.00	1	5.00	1	5.00
Alkalinity(mg/L)	3	191.33	3	204.33	2	197.50	2	183.50	1	197.00	1	197.00
Total Solids (mg/L)	3	688.67	3	745.67	2	718.00	2	723.00	1	761.00	1	847.00
Total Dissolved Solids (mg/L)	3	674.33	3	722.33	2	704.50	2	702.50	1	750.00	1	828.00
Total Suspended Solids (mg/L)	3	14.33	3	23.33	2	13.50	2	20.50	1	11.00	1	19.00
Volatile Total Suspended Solids (mg/L)	3	3.67	3	8.67	2	4.00	2	5.50	1	2.00	1	3.00
Total Nitrogen (mg/L)	3	1.87	3	2.62	2	1.98	2	2.28	1	1.25	1	1.39
Organic Nitrogen(mg/L)	3	1.73	3	2.53	2	1.91	2	2.22	1	1.19	1	2.53
Ammonia-N (mg/L)	3	0.06	3	0.01	2	0.01	2	0.01	1	0.01	1	0.18
Un-ionized Ammonia (mg/L)	3	0.0073	3	0.0017	2	0.0013	2	0.0013	1	0.0007	1	0.0151
Nitrate-Nitrite-N (mg/L)	3	0.08	3	0.08	2	0.05	2	0.05	1	0.05	1	0.05
Total Kjeldahl-N (mg/L)	3	1.79	3	2.54	2	1.93	2	2.23	1	1.20	1	1.34
Total Phosphorus (mg/L)	3	0.98	3	1.01	2	1.12	2	0.96	1	0.64	1	0.57
Total Dissolved Phosphorus (mg/L)	3	0.91	3	0.93	2	1.00	2	0.88	1	0.58	1	0.45
Total Nitrogen : Total Phosphorus Ratio	3	1.99	3	2.60	2	1.76	2	2.39	1	1.99	1	2.42
Chlorophyll-a (mg/m3)	3	35.17	3	50.16	2	12.46	2	38.55	0	0	1	11.01
Secchi Depth (meters)	3	1.01	3	0.61	2	0.98	2	0.65	1	0.91	1	0.63
TSI-S (Secchi)	3	60.60	3	67.36	2	60.53	2	66.29	1	61.29	1	66.55
TSI-P (Phosphorus)	3	103.30	3	103.78	2	105.44	2	103.19	1	97.48	1	95.80
TSI-C (Chlorophyll-a)	3	68.88	3	77.96	2	64.32	2	74.55	0	0	1	63.13
Mean TSI	3	77.60	3	83.04	2	76.76	2	81.34	1	79.39	1	75.16

[1] = Only one sample was collected from each in-lake monitoring site spring 2000, values are not average

[2] = Highlighted areas are the seasons that recorded the highest concentrations or values for a given parameter.

The water quality standard violation of pH at site ML-5 of 9.14 su in the west arm was the highest surface pH value recorded at that site during the project. The pH sample collected on the same date from the east arm (site ML-4) also had the highest pH value (8.93 su) recorded from that site (Appendix F).

Average seasonal alkalinity concentrations were highest in the summer for ML-5 (west arm) and ML-4 (east arm) had highest average concentrations in the fall.

Total solids and total dissolved solids average concentrations were highest in the spring for both arms of Mina Lake and were similar to average concentrations for tributary loading. Average total suspended solids concentrations were highest in the summer for both arms, while average volatile total suspended solids were highest in the summer for ML-5 (west arm) and in the fall for the east arm (ML-4).

Average total nitrogen, Total Kjeldahl Nitrogen (TKN) and organic nitrogen concentrations were highest in the summer at ML-5 (west arm) and in the fall for the east arm (ML-4).

Ammonia concentrations were highest at ML-4 (east arm) in the summer and correlated with the highest average tributary concentrations in the east tributary (Table 35 and Table 9). Average ammonia concentrations were highest in the fall for the west arm (ML-5). Un-ionized ammonia (NH_4-OH) is the fraction of ammonia that is toxic to aquatic organisms. The highest un-ionized ammonia fractions paralleled total ammonia concentrations and were higher in the east arm (ML-4) in the summer and in the fall for the west arm (ML-5). 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).

Average seasonal in-lake concentrations of nitrate-nitrite for both arms were lower than average tributary seasonal concentrations (Table 35 and Table 9). Concentrations of nitrate–nitrite were highest in the summer for both ML-4 and ML-5.

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 fall for both ML-4 and ML-5.

Average total phosphorus and total dissolved phosphorus concentrations were highest in the summer for the west arm (ML-5) and in the fall for the east arm (ML-4) of Mina Lake (Table 35). Chlorophyll-*a* is a pigment in plants that may be used to estimate the biomass of algae found in water samples (Brower, 1984). Average chlorophyll-*a* concentrations were highest in the summer for both arms of Mina Lake. That coincided with increased algal densities observed in the summer of 1999 (Table 35 and Figure 63).

All average Trophic State Index (TSI) values (Secchi, phosphorus, chlorophyll-*a* and mean TSI) were highest in the summer for ML-5 (west arm). The highest values for ML-4 (east arm) showed no consistent pattern in that chlorophyll-*a* TSI was highest in the summer, phosphorus TSI in the fall, and Secchi TSI in the spring (Table 35).

In-lake Water Quality

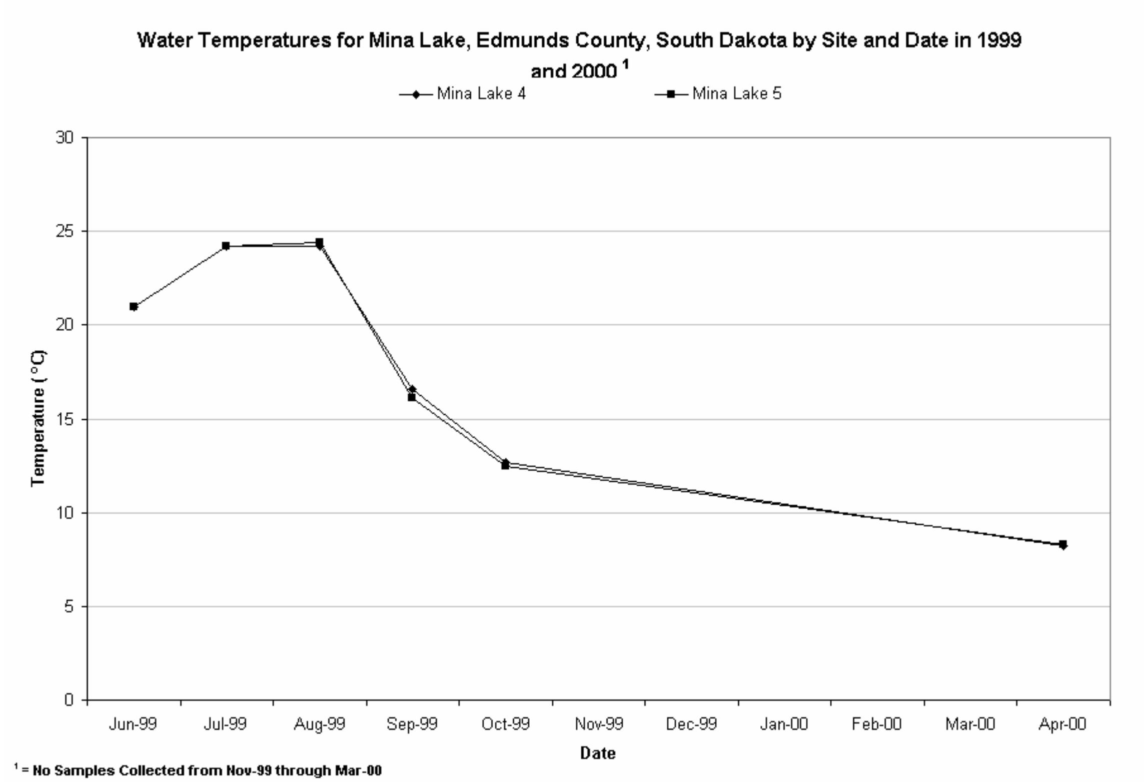


Figure 22. Surface water temperatures by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999.

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.

The mean surface water temperature in Mina Lake over the sampling season was 17.8° C. Figure 22 shows surface water temperatures throughout the project period for both in-lake sampling sites. No significant differences were detected within or between sampling sites ($p>0.05$). The maximum surface water temperature measured during the sampling season was 24.4 ^{o}C taken in mid-July, 1999.

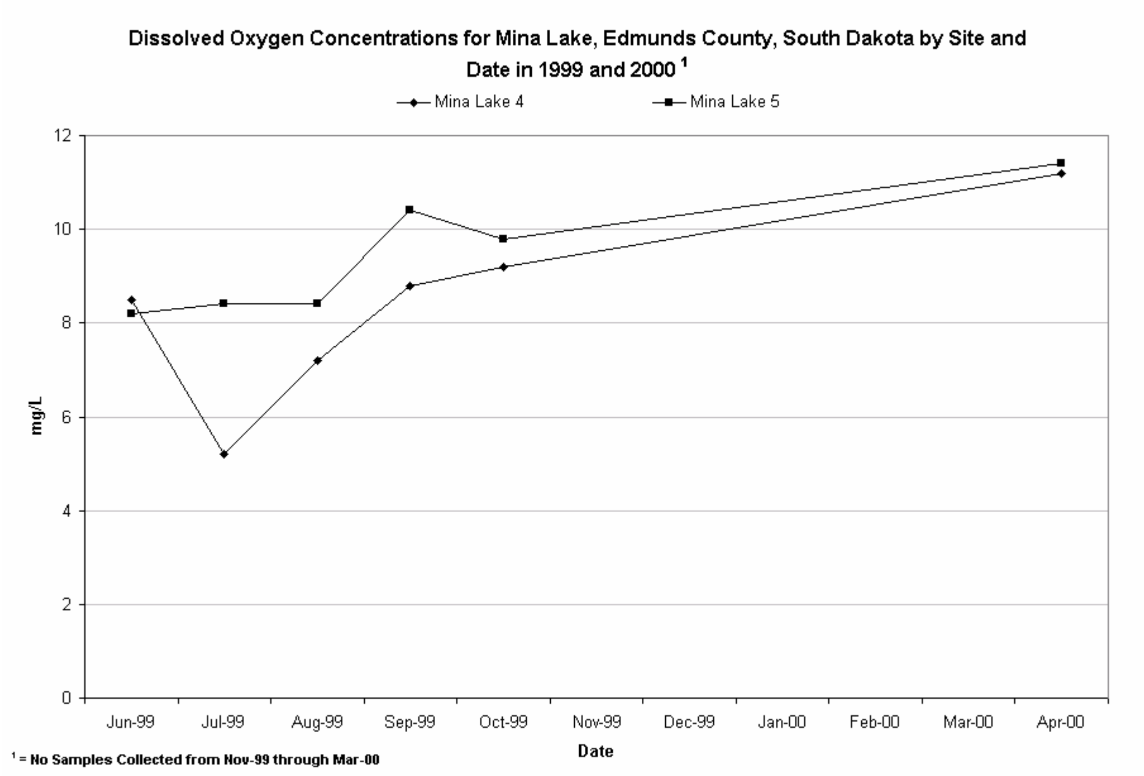


Figure 23. Average surface dissolved oxygen concentrations by sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

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 increase surface oxygen levels of a lake. Surface water dissolved oxygen averaged 8.9 mg/L (median 8.6 mg/L) over the entire duration of the study (Appendix F). The maximum surface-water oxygen concentration in Mina Lake was 11.4 mg/L. That sample was collected at ML-5 on April 6, 2000. At site, ML-5, high dissolved oxygen concentrations were most likely a product of water temperature. Cool water temperatures increase the solubility of oxygen (cool water can hold more oxygen). The minimum dissolved oxygen concentration was 5.2 mg/L at the surface of ML-4 on July 19, 1999 (Figure 23). 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 not observed in the water column at either site. Surface water dissolved oxygen samples were statistically similar between sites and between surface and bottom dissolved oxygen concentrations ($p>0.05$). Current and previous in-lake profile data indicate that Mina Lake tends not to stratify (Appendix G and Stueven and Stewart, 1996). Appendix G has all the dissolved oxygen profiles collected in Mina Lake in 1999 and 2000.

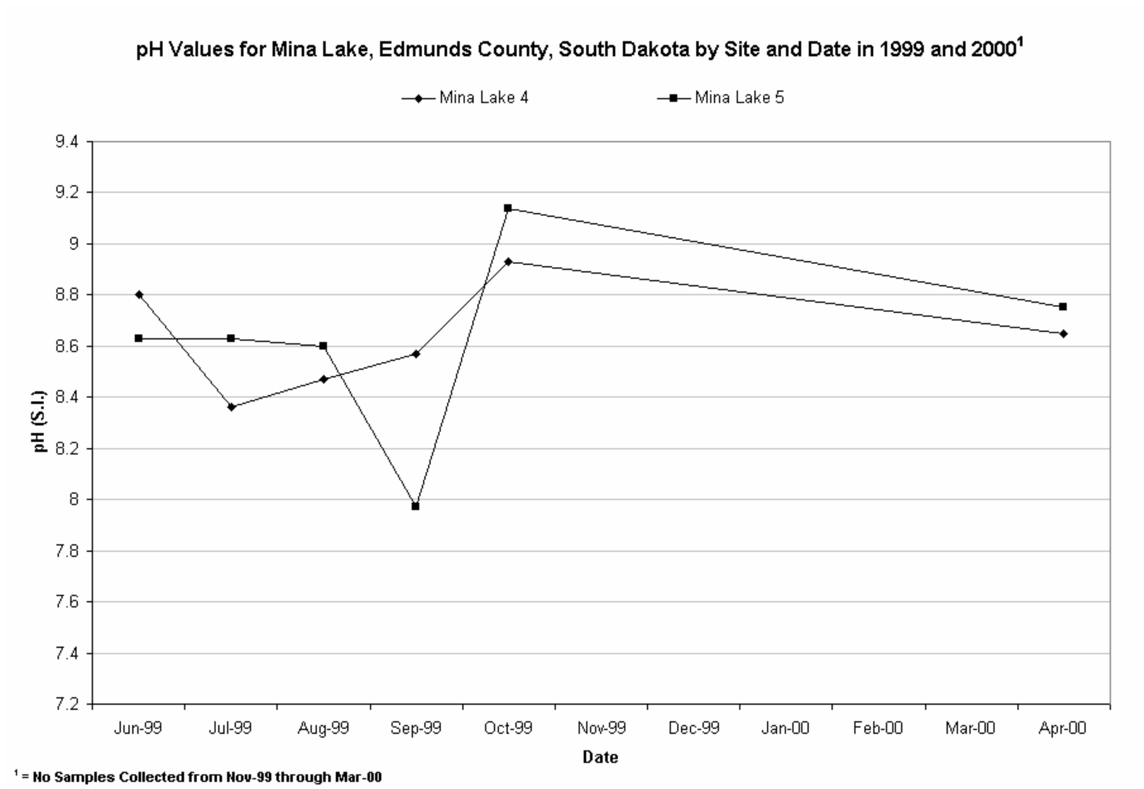


Figure 24. Monthly pH concentrations by date and sampling site for Mina Lake Edmunds County, South Dakota in 1999 and 2000.

pH

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

The pH concentrations declined in the summer and increased in the fall (Figure 24). ML-5 trend was more erratic than ML-4, especially in September and October 1999. During this period, the pH concentration went from 7.97 su in September to 9.14 su in October. One water quality standard violation in pH occurred at site ML-5 (9.14 su) in the west arm of Mina Lake and was the highest surface pH value recorded. The pH sample collected on the same date from the east arm (site ML-4) also had the highest pH value (8.93 su) recorded from that site (Appendix F). This seems to indicate that the increased readings in October were an event and not an anomaly. Even with the erratic monthly changes in ML-5, both sites were statistically similar ($p>0.05$) with an average pH concentration of 8.6 su and a median of 8.6 su. One possible cause of the observed changes in pH may have been the growth and decay of seasonal algae populations. Seasonal changes in pH and algae populations were more extreme at site ML-5. For example, the sharp decrease in pH at ML-5 in September may have been caused by the decline and decay of the large summer algal bloom at this site (figure 65 and Figure 66, pages 114 and 115).

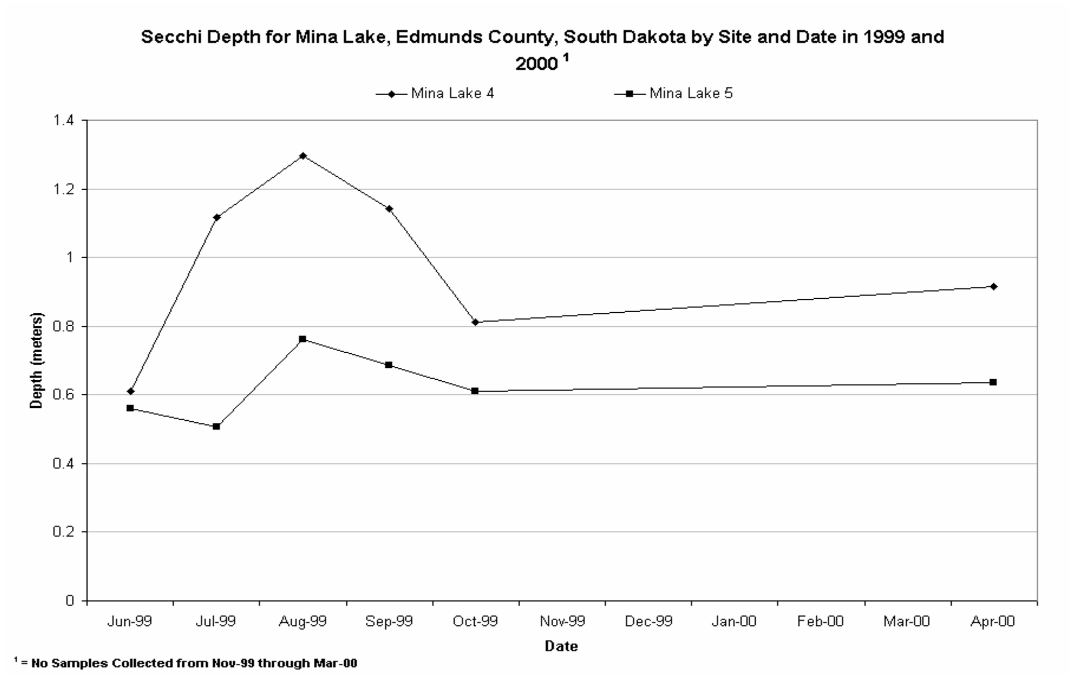


Figure 25. Monthly Secchi depth by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

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-eutrophy because of suspended sediments and/or high algal biomass.

Figure 25 shows lower Secchi depth readings in late summer and fall, especially at site ML-5 (west arm). The highest Secchi disk reading was 1.3 meters (4.25 feet) at ML-4 on August 25, 1999. This relates to the lower numbers of algae at site ML-4 increasing the Secchi depth during this study (Figure 65, page 114). Total suspended solids, volatile total suspended solids and chlorophyll-*a* concentrations were also lower at ML-4, which resulted in increased transparency. Secchi transparency in the east arm (ML-4) was significantly deeper than the west arm in Mina Lake ($p<0.05$). Average seasonal Secchi depths were highest in the summer months particularly at ML-5 (Figure 25 and Table 35). Secchi depth readings were significantly different between in-lake sampling sites ($p<0.05$). Since Secchi transparency depth is one parameter used in measuring trophic state, Secchi TSI values between sites were also statistically different ($p<0.05$).

Alkalinity

As discussed previously, alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7.00 su). The average alkalinity in Mina Lake was 195.2 mg/L with a median of 196.0 mg/L. The maximum alkalinity concentration (215.0 mg/L) was collected at ML-5 in August while the minimum alkalinity concentration (177 mg/L) was collected at ML-4 in June of 1999.

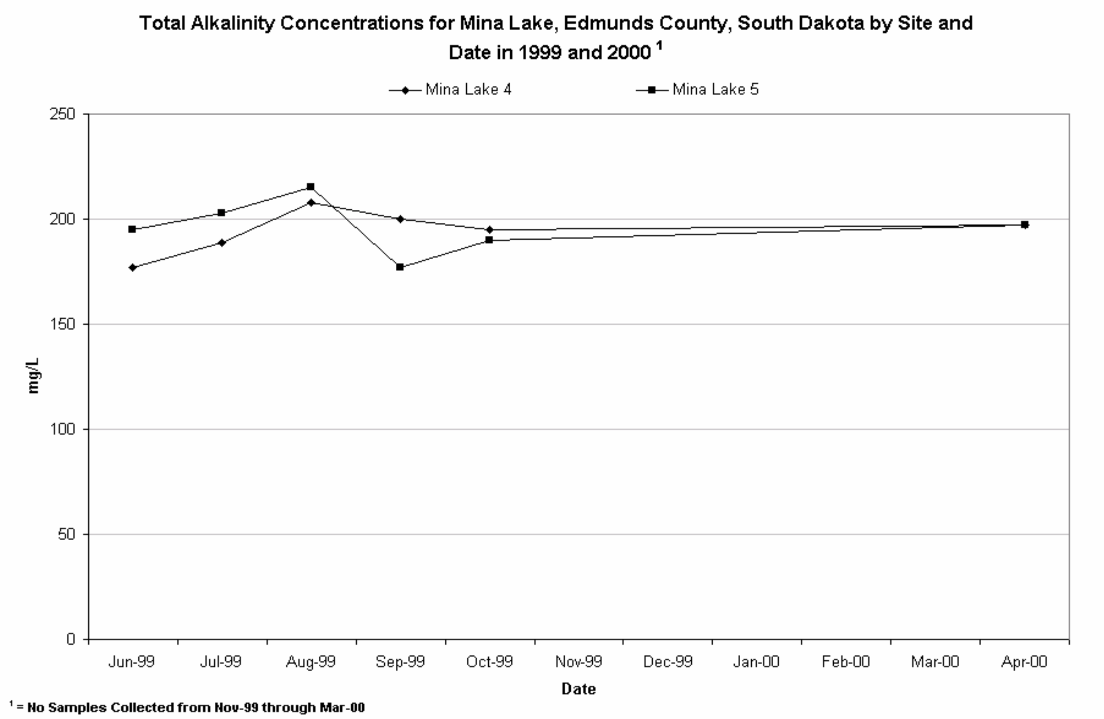


Figure 26. Monthly alkalinity concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Generally, alkalinity concentrations were consistent throughout the sampling period and were not statistically significant between ML-4 and ML-5 (>0.05). However, in-lake pH concentrations fluctuated during the sampling period (decreasing in the summer and increasing in the fall), indicating other conditions (increased phytoplankton densities, decomposition or respiration rates) affected (varied) pH concentrations. Seasonally, the highest average concentration occurred in the summer for ML-5 (west arm) and in the fall for ML-4 (Figure 26).

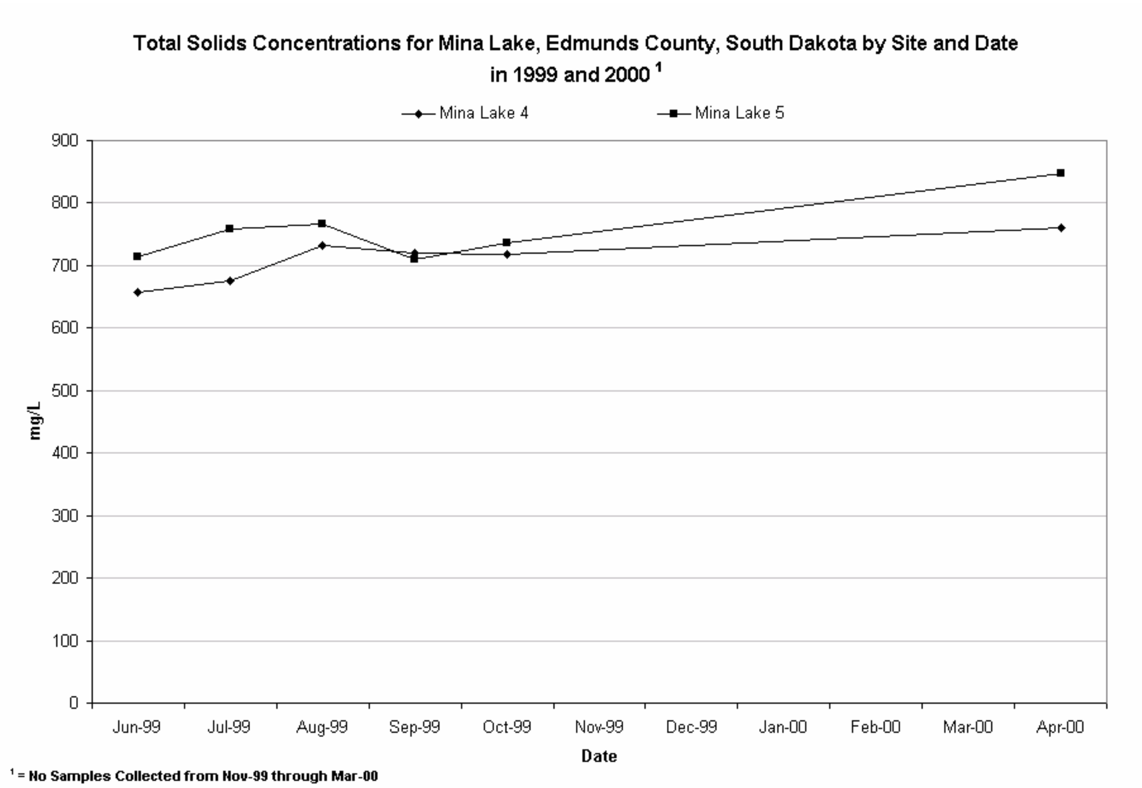


Figure 27. Monthly total solids concentration by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Total Solids

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

The total solids concentrations in Mina Lake averaged 723.7 mg/L (median 726.0 mg/L) with a maximum of 847.0 mg/L and a minimum of 658.0 mg/L. Generally, total solids concentrations were lower in the summer and peaked in the spring (Figure 27). Seasonal averages for total solids concentrations were highest in the spring (Table 35). Total solids concentrations were statistically similar between sites ($p>0.05$).

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.

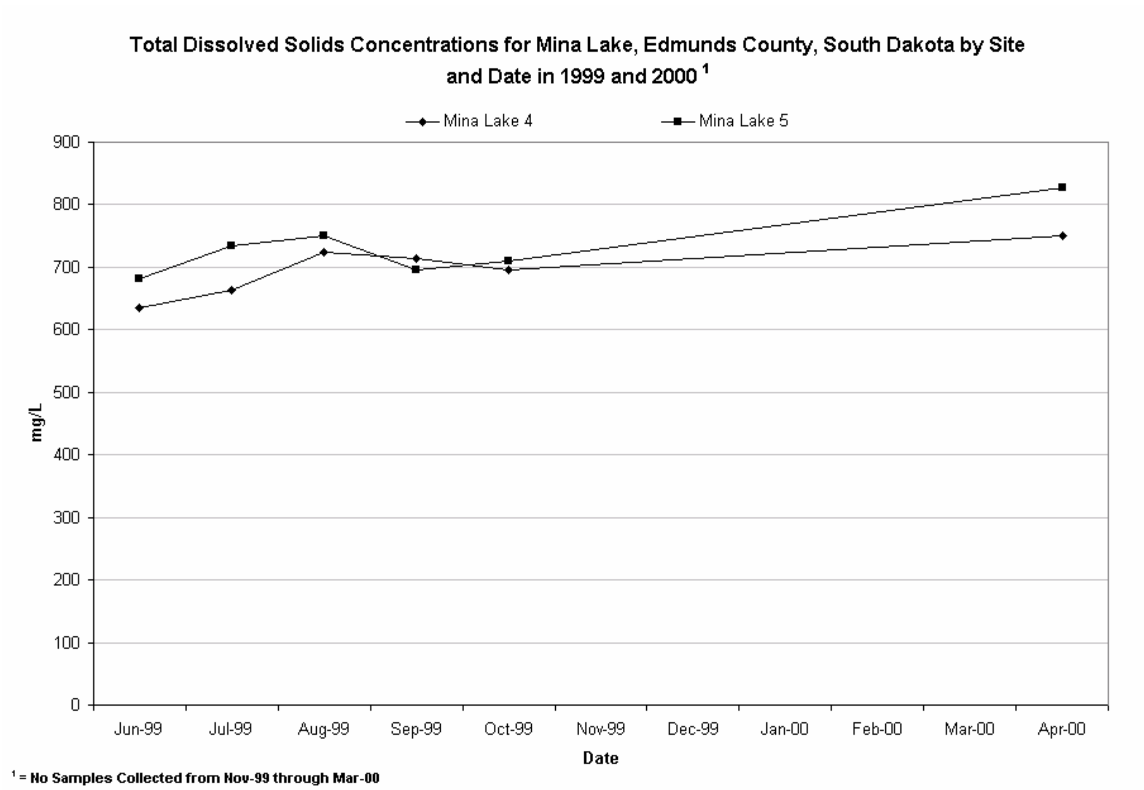


Figure 28. Monthly total dissolved solids concentration by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

The total dissolved solids concentrations in Mina Lake averaged 715.2 mg/L (median 711.5 mg/L) with a maximum of 828.0 mg/L and a minimum of 636.0 mg/L. Similar to total solids, total dissolved solids concentrations were lower in the summer and peaked in the spring (Figure 28). Total dissolved solids concentrations comprised between 95.7 percent and 99.1 percent of total solids concentrations. Total dissolved solids concentrations between ML-4 and ML-5 were statistically similar ($p>0.05$).

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.

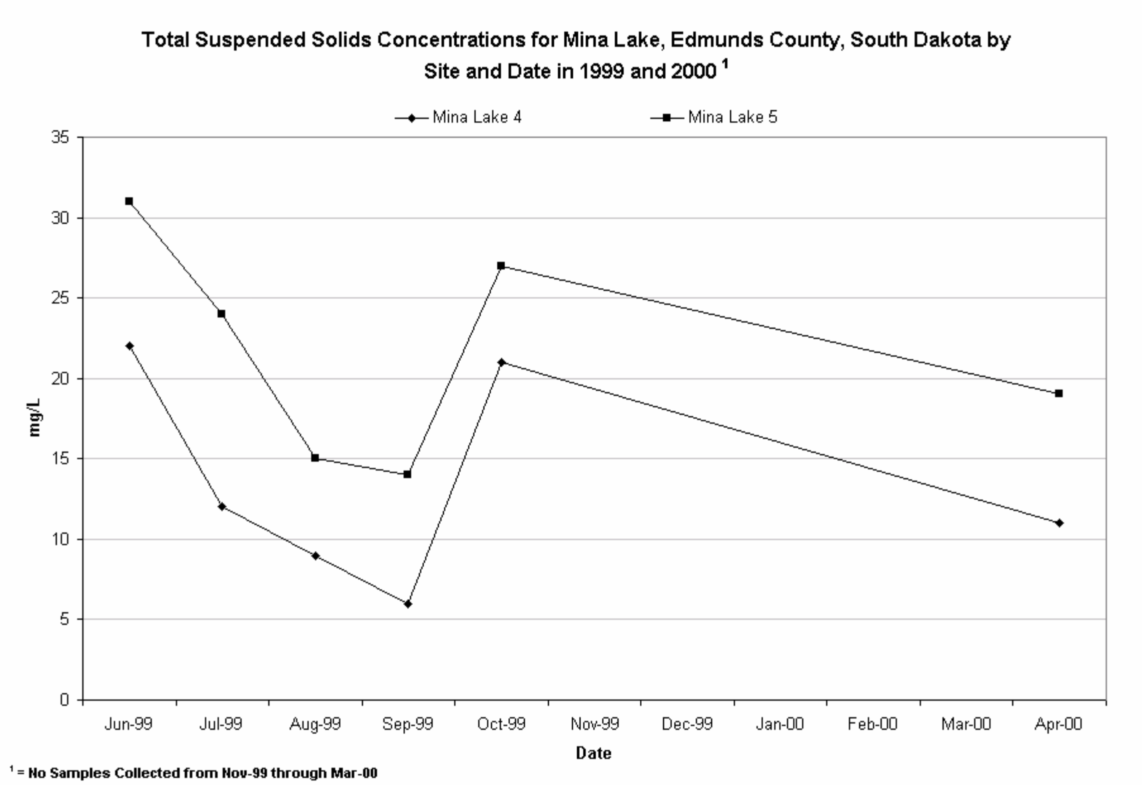


Figure 29. Monthly average total suspended solids concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

The total suspended solids concentrations in Mina Lake averaged 17.6 mg/L (median 17.0 mg/L) with a maximum of 31.0 mg/L and a minimum of 6.0 mg/L. Seasonal averages for total suspended solids concentrations were highest in the summer (Table 35). The surface sample with the highest total suspended solids concentration was collected in June 1999 (31 mg/L) at ML-5 (Appendix F). The East tributary (SC-2) transports the majority of total suspended solids load (57.6 percent) to Mina Lake and flows into ML-4. This suggests that ML-5 with higher concentrations of total suspended solids had a higher percentage of volatile solids (algae) than did ML-4. Total suspended solids data supports the trend observed in Secchi disk depth, with decreased Secchi depth in ML-5 (west arm). Total suspended solids concentrations between in-lake sampling sites were almost significant different (p=0.055) during this study (Figure 29).

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.

Volatile total suspended solids concentrations averaged 5.1 mg/L (median 4.50 mg/L) with a maximum of 14.0 mg/L and a minimum concentration of 2.0 mg/L. Seasonal average volatile total suspended solids concentrations were highest in the summer for ML-5 and in the fall for ML-4 (Table 35). The maximum surface water concentrations of volatile total suspended solids was collected in July 1999 (14 mg/L) at ML-5 (Figure 30). No significant differences were detected between in-lake sampling sites (p>0.05).

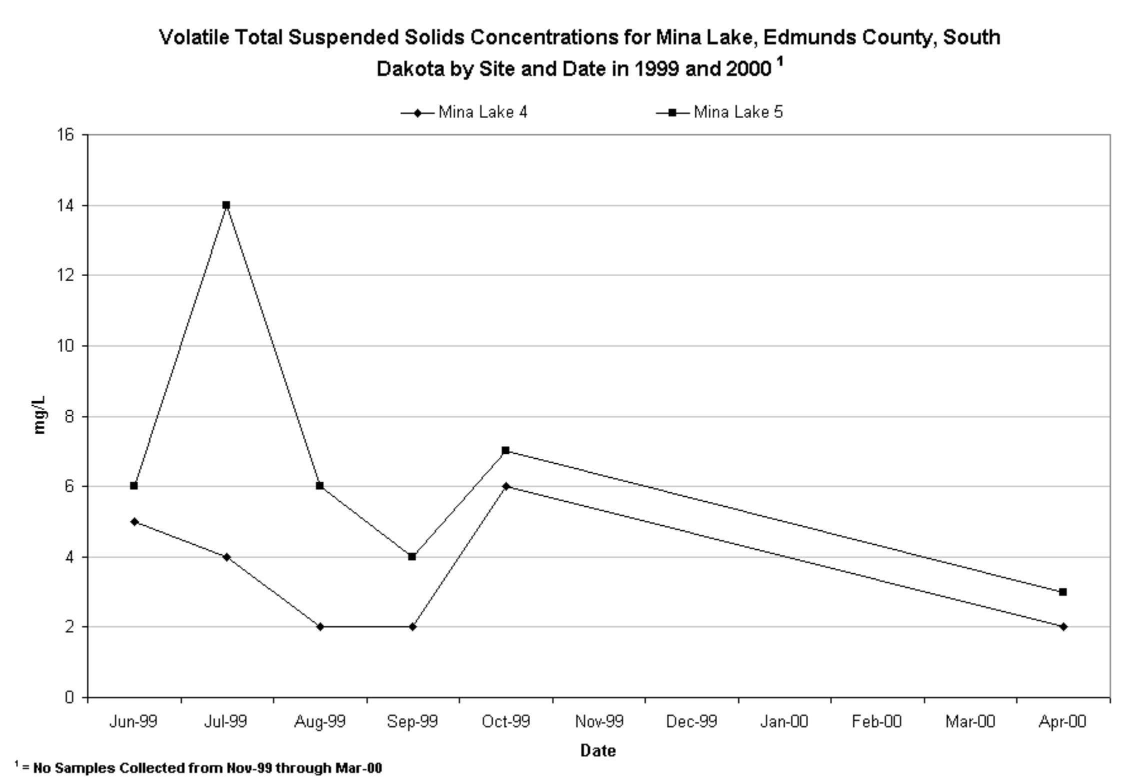


Figure 30. Monthly volatile total suspended solids concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

The percentage of volatile total suspended solids in total suspended solids by site ranged widely. ML-4 percent volatile suspended solids ranged from 18 percent to 33 percent and ML-5 ranged from 16 percent to 58 percent. The highest percentages of volatile solids occurred at ML-5 in July and August (58.3 percent and 40.0 percent, respectively). This supports the data showing both higher algal densities and algal biovolume at ML-5 during this time (Figure 65 and Figure 66, pages 114 and 115).

Total suspended solids and volatile total suspended solids affect Secchi transparency and chlorophyll-*a* concentrations, respectively. The parameter Mina Lake is listed for on the 303(d) list (impaired waterbody list) is increasing TSI trend (Trophic State Index) (SD DENR, 1998). A decrease in in-lake total suspended solids (both organic and inorganic) should improve (lower) all TSI values, and over time, improve in-lake 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 Mina Lake comes from Snake Creek loadings, runoff from ungauged areas of the watershed, livestock (cattle) with direct access to the lake, decaying organic matter and bacterial conversion of other nitrogen compounds.

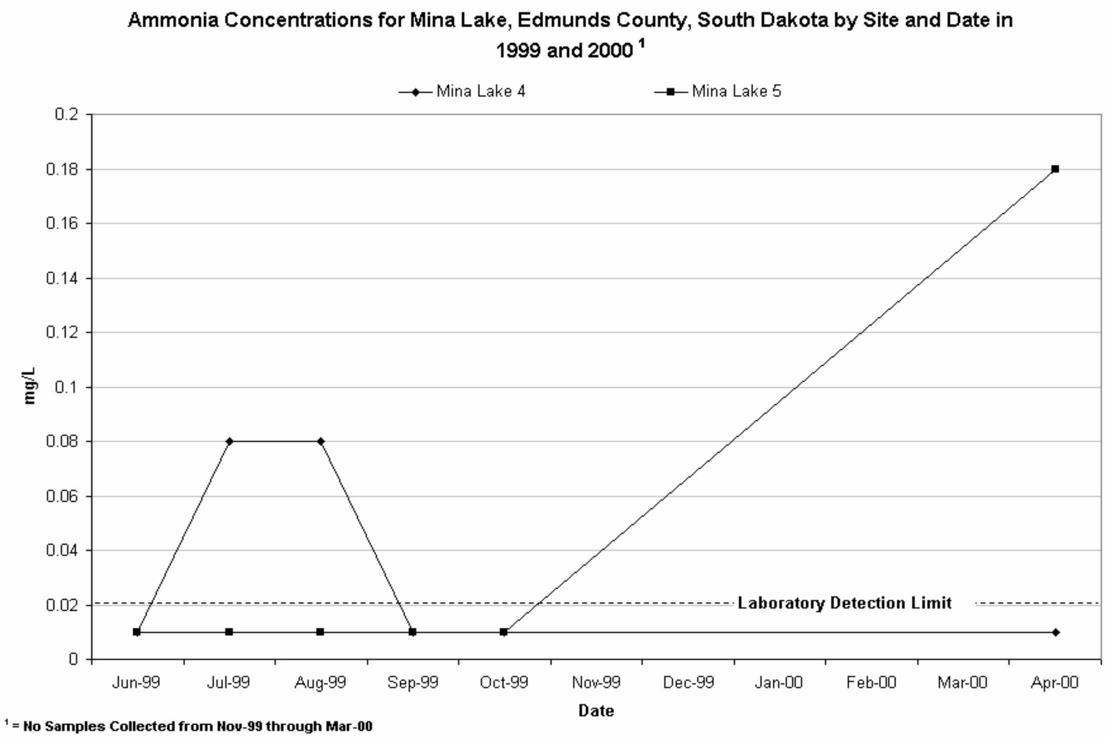


Figure 31. Monthly ammonia concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999.

The average concentration of ammonia in Mina Lake was 0.04 mg/L with a median of 0.01 mg/L. The standard deviation was 0.05 mg/L which indicates a slight variation in sample concentrations. On April 6, 2000, the ammonia concentration at ML-5 was 0.18 mg/L, 5.0 times higher than the average concentration for the entire study (0.0358 mg/L) (Figure 31). The ammonia concentration at ML-4 in April 2000 was below laboratory detection limits. Seventy-five percent of all surface samples collected at Mina Lake were below laboratory detection limits. Seasonal concentrations were highest in the summer for ML-4 (east arm) and in the spring for ML-5, the west arm (Table 35). No significant differences in ammonia concentrations were detected between ML-4 and ML-5 during this study ($p>0.05$).

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

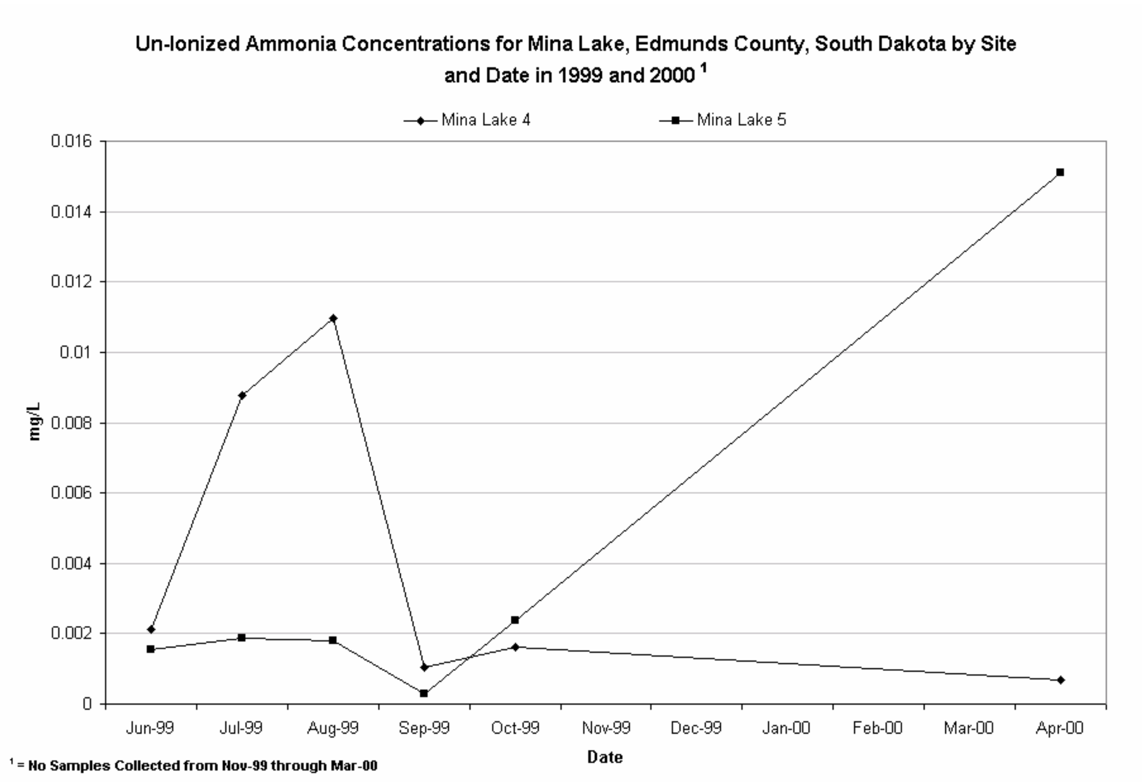


Figure 32. Monthly un-ionized ammonia concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

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 mean un-ionized ammonia concentration for Mina Lake was 0.004 mg/L (median 0.002 mg/L). The maximum concentration was 0.0151 mg/L and a minimum concentration of 0.0003 mg/L. Un-ionized ammonia concentrations (mg/L) peaked in the spring (Figure 32). This peak was the result of increased total ammonia concentrations at ML-5 in April. Since un-ionized ammonia is a calculated fraction of ammonia, the graphs for Figure 31 and Figure 32 are somewhat similar. The concentration un-ionized ammonia in the east and west arms of Mina Lake were statistically similar ($p>0.05$) in 1999 and 2000.

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.

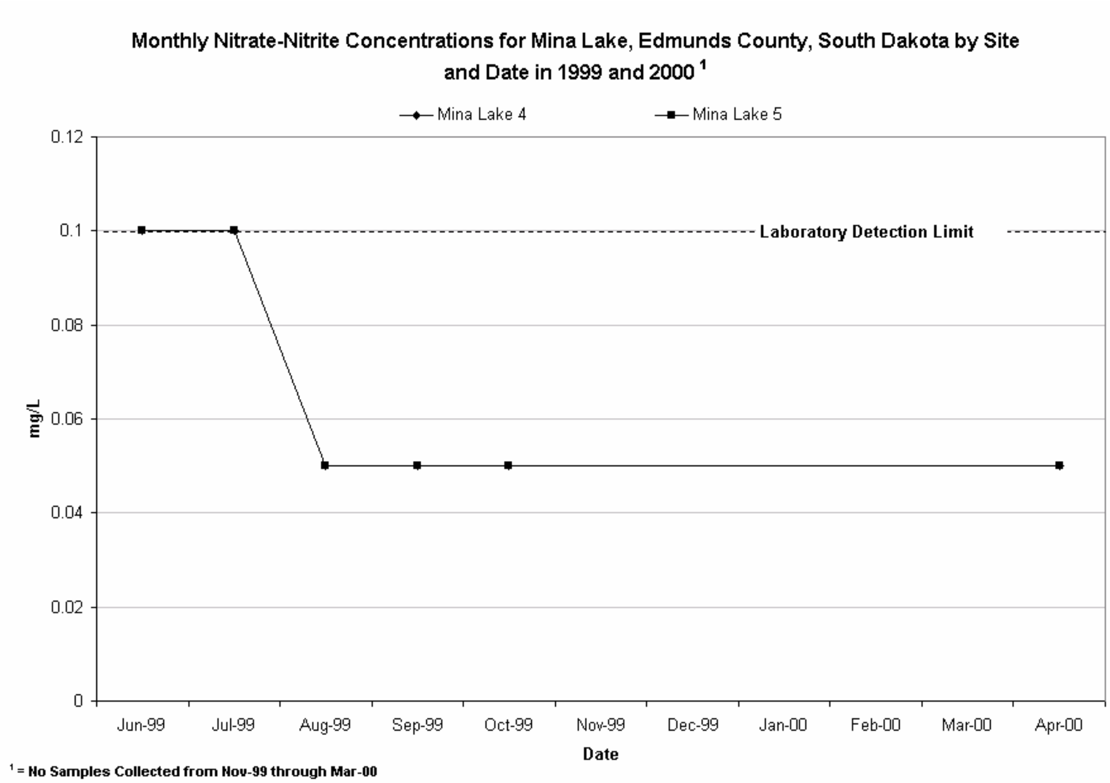


Figure 33. Monthly nitrate-nitrite concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999.

The average nitrate-nitrite concentration for Mina Lake was 0.07 mg/L (median 0.05 mg/L), with a maximum of 0.10 mg/L and a minimum concentration of 0.05 mg/L. Seasonal average nitrate–nitrite concentrations peaked in the summer and declined to less than detection limits by late summer, fall and spring samplings (Figure 33 and Table 35). 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, this situation was not observed in Mina Lake during this 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 ($p>0.05$).

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, lakeside septic systems, or agricultural waste. Organic nitrogen is broken down to more usable ammonia and other forms of inorganic nitrogen.

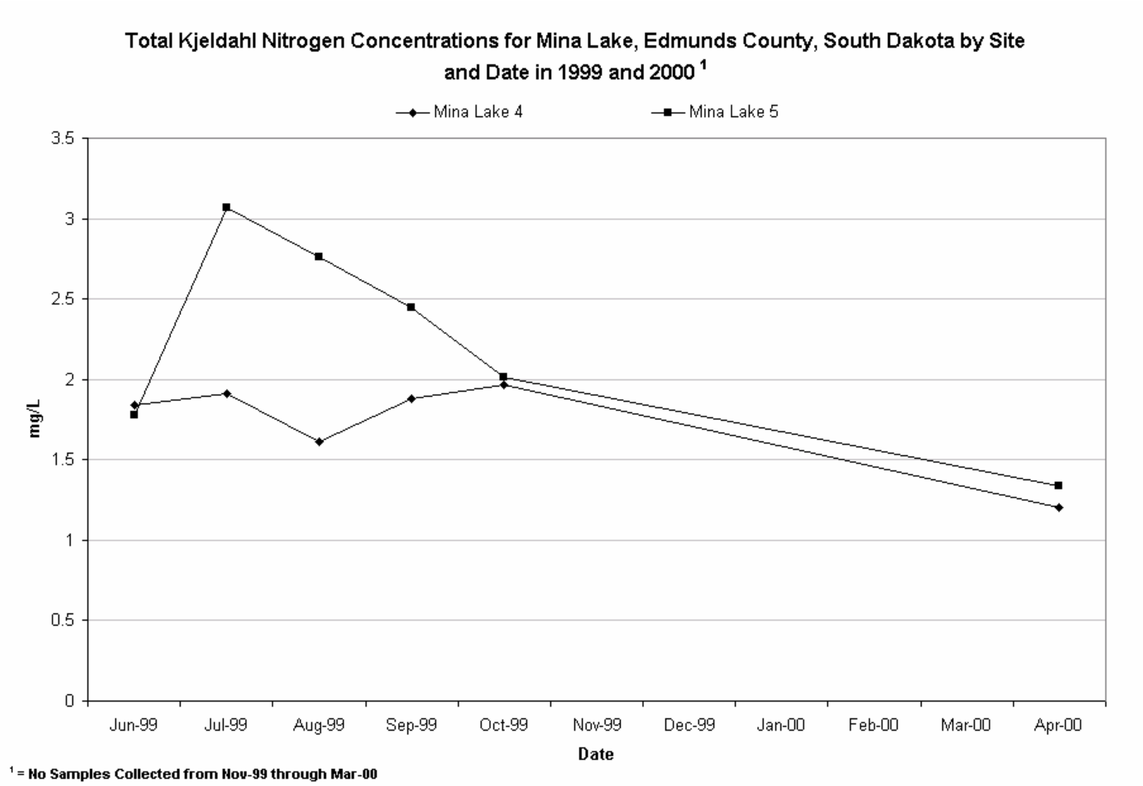


Figure 34. Monthly Total Kjeldahl Nitrogen (TKN) concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999.

The average and median TKN concentrations were 1.99 mg/L and 1.90 mg/L, respectively. There was a definite increase in the TKN concentrations at ML-5 in July 1999, after which concentrations gradually declined to levels similar to concentrations at ML-4 by October 1999 (Figure 34). Seasonally, average TKN concentrations were highest in the summer for ML-5 and in the fall for ML-4 (Figure 34 and Table 35). Monthly in-lake TKN concentrations were statistically similar between in-lake sampling sites ($p>0.05$).

Organic Nitrogen

The organic portion of TKN (TKN minus ammonia) is graphed on Figure 35. Organic nitrogen percentages (percent organic nitrogen in TKN) ranged from 86.6 percent to 99.7 percent and averaged 98.2 percent. The lowest organic percentage was in March 2000 at ML-5 (86.6 percent).

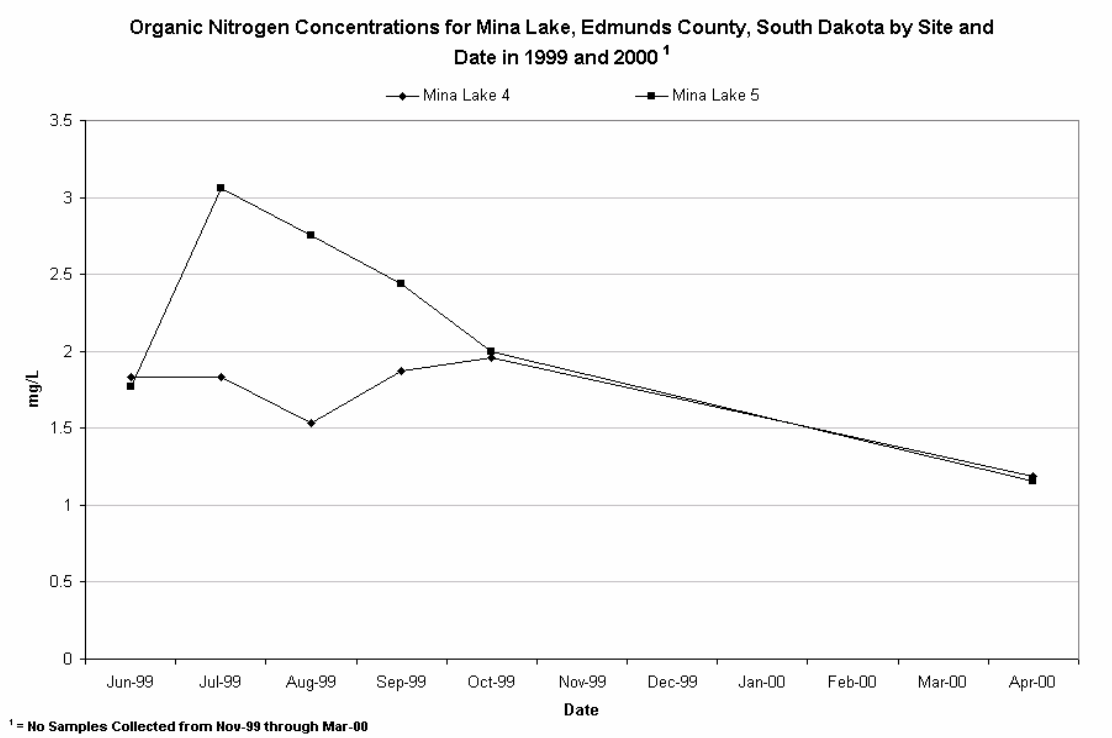


Figure 35. Monthly organic nitrogen concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

The average organic nitrogen concentration for Mina Lake was 1.95 mg/L (median 1.85 mg/L), with a maximum of 3.06 mg/L and a minimum concentration of 1.16 mg/L. Since organic nitrogen is a constituent of TKN, seasonal average organic nitrogen concentrations were similar (Figure 34, Figure 35 and Table 35). No significant differences in organic nitrogen concentrations were detected between in-lake sampling sites ($p>0.05$).

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 average total nitrogen concentration for Mina Lake was 2.05 mg/L (median 1.97 mg/L), with a maximum of 3.17 mg/L and a minimum concentration of 1.25 mg/L. Seasonally, average total nitrogen concentrations for Mina Lake were highest in the summer for ML-5 and in the fall for ML-4 (Table 35 and Figure 36).

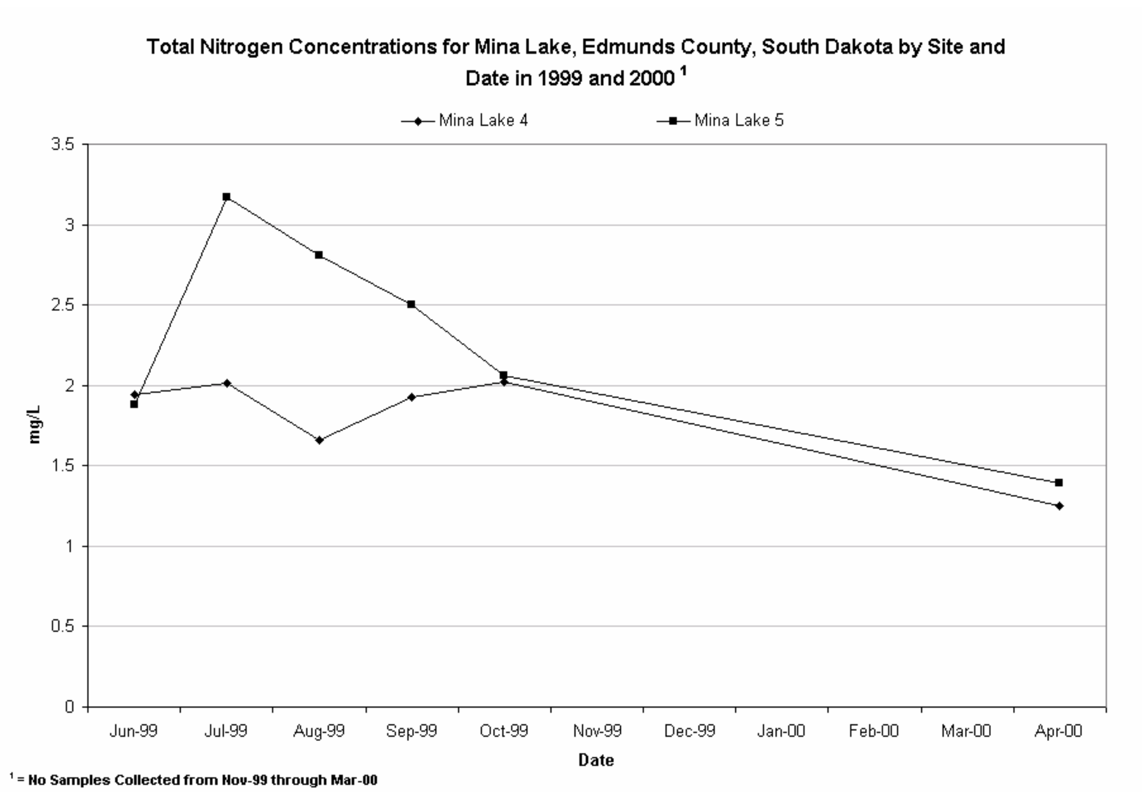


Figure 36. Monthly total nitrogen concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Total Phosphorus

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

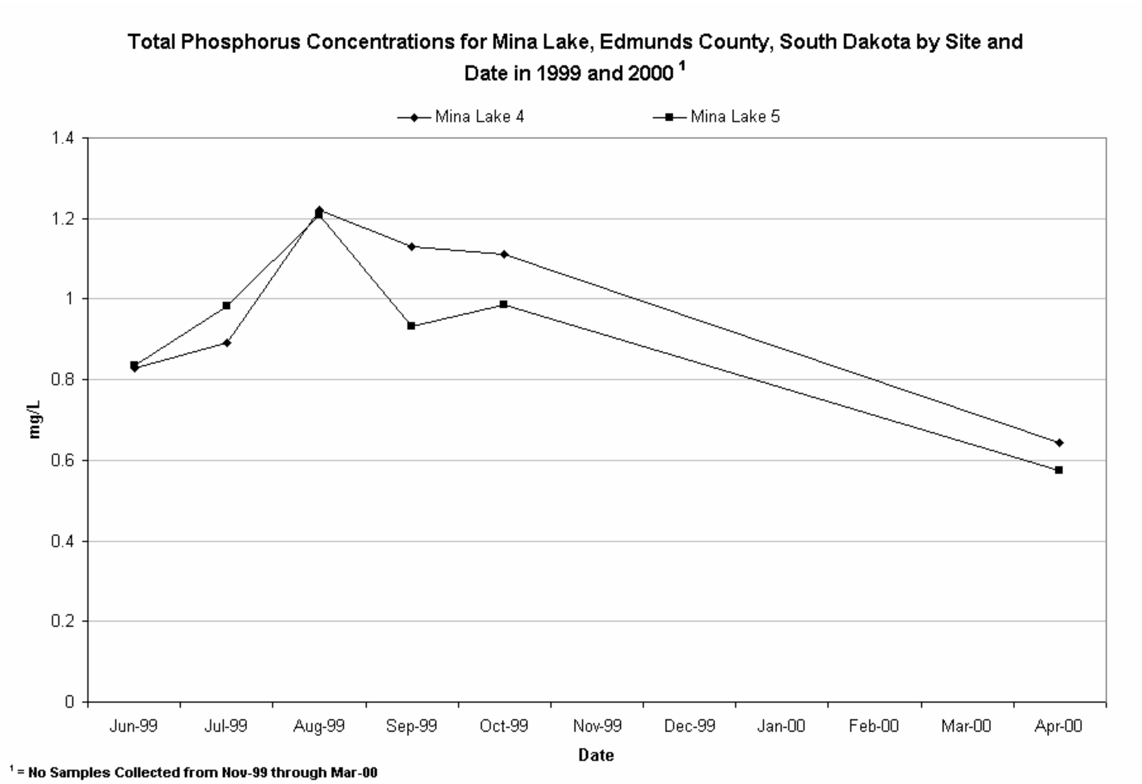


Figure 37. Monthly total phosphorus concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

The average concentration of total phosphorus throughout the study period was 0.945 mg/L (median 0.957 mg/L). The maximum sample concentration was collected at ML-4 in August (1.22 mg/L) (Figure 37). The minimum concentration of total phosphorus occurred at ML-5 in April 2000 (0.574 mg/L).

Seasonally, average total phosphorus concentrations were lower in the spring, highest in the summer for ML-5 and ML-4 (Figure 37). On average, Mina Lake had 47.2 times more total phosphorus than the amount needed to cause algal blooms (Wetzel, 1983). During this study, in-lake total phosphorus was in excess. The highest densities of algae occurred in the summer (August) with blue-green blooms of nuisance species at site ML-5 from mid-July through September. Algal blooms at ML-4 were considered moderate during the same period (Table 43, page 112). Based on this information, algae did not appear to utilize most of the available phosphorus, especially at ML-4. Since phosphorus can cause algal blooms, dramatically reducing phosphorus loads (tributary and internal loads) over time should promote better water quality.

Significant total phosphorus loading from Snake Creek occurred in July 1999 (Figure 16) and contributed to peak in-lake total phosphorus concentrations in August 1999. Increased in-lake concentrations were from both tributary and internal loading of total phosphorus in the lake. In-lake total phosphorus concentrations in August may have been much higher if it were not for peak submergent macrophyte and algal growth utilizing phosphorus during this time.

Data indicate that a considerable reduction in total phosphorus is needed in both the watershed and in Mina Lake to meet designated beneficial uses based on reference lake criteria for ecoregion 46. Due to such elevated in-lake phosphorus concentrations, Mina Lake appears not to fit ecoregion-based beneficial use criteria based on current ecoregional targets (pages 94 through 101). Economic and technical limitations preclude the realization of a 94.4 percent reduction in total phosphorus. Economically, such reductions would severely alter or eliminated most agriculture in the watershed. Technically, internal loading of in-lake total phosphorous resulting in elevated year round phosphorus concentrations impede reduction attainability even if extensive BMPs are implemented throughout the watershed. Every effort should be made to improve current management practices to reduce/control sediment and nutrient runoff in the Mina Lake 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 Mina Lake.

Figure 39 indicates a negative relationship between average chlorophyll-*a* and total dissolved phosphorus concentrations (negative slope (-0.90), R^2=0.50). This indicates that when availability of total dissolved phosphorus increases, chlorophyll-*a* concentrations decrease, suggesting, total dissolved phosphorus did not influence/control chlorophyll-*a* concentrations (algal populations) in Mina Lake.

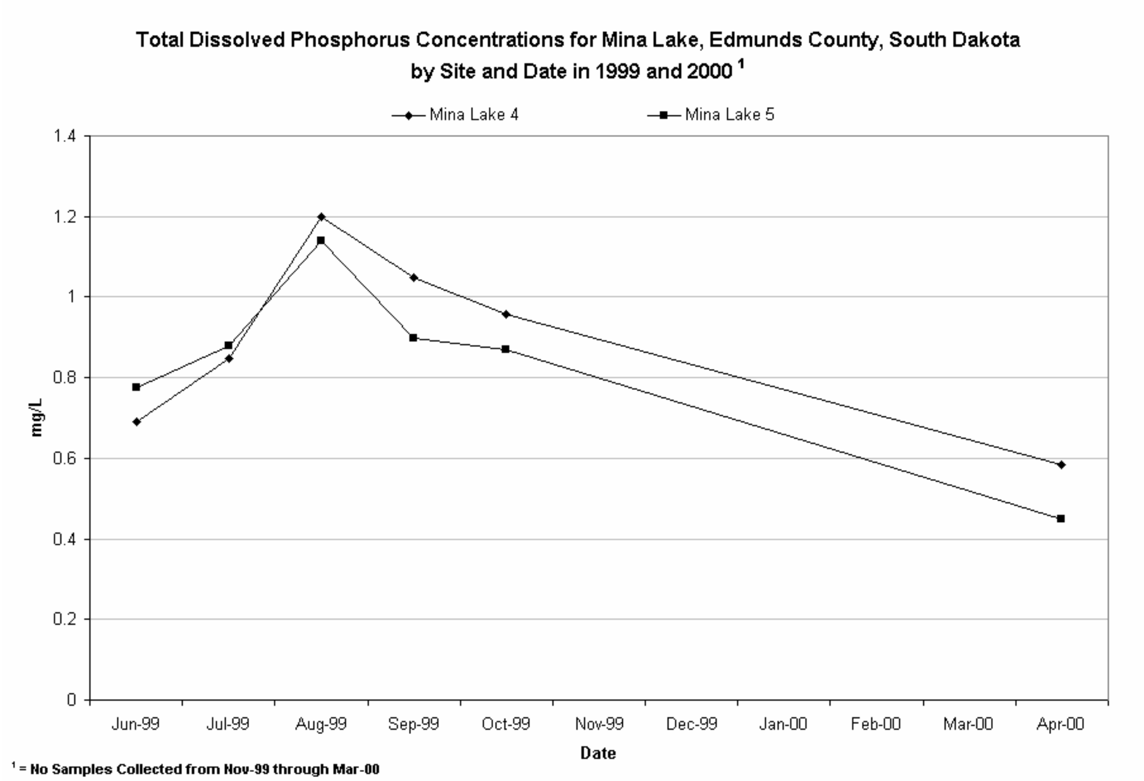


Figure 38. Monthly total dissolved phosphorus concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Generally, increased total suspended solids concentrations decrease concentrations of available total dissolved phosphorus; however, during this study total suspended solids showed a poor relationship to total dissolved phosphorus (R^2=0.01). The overall average percent phosphorus that was dissolved during the project was 91.1 percent. Percentages of total dissolved phosphorus ranged from 78.4 percent in the spring to 98.4 percent in the summer. The average dissolved phosphorus concentration in Mina Lake was 0.862 mg/L (median 0.874 mg/L). Since algae only need 0.02 mg/L of phosphorus to produce an algal bloom (Wetzel, 1983), Mina Lake averages 43.1 times the available phosphorus needed for algal blooms.

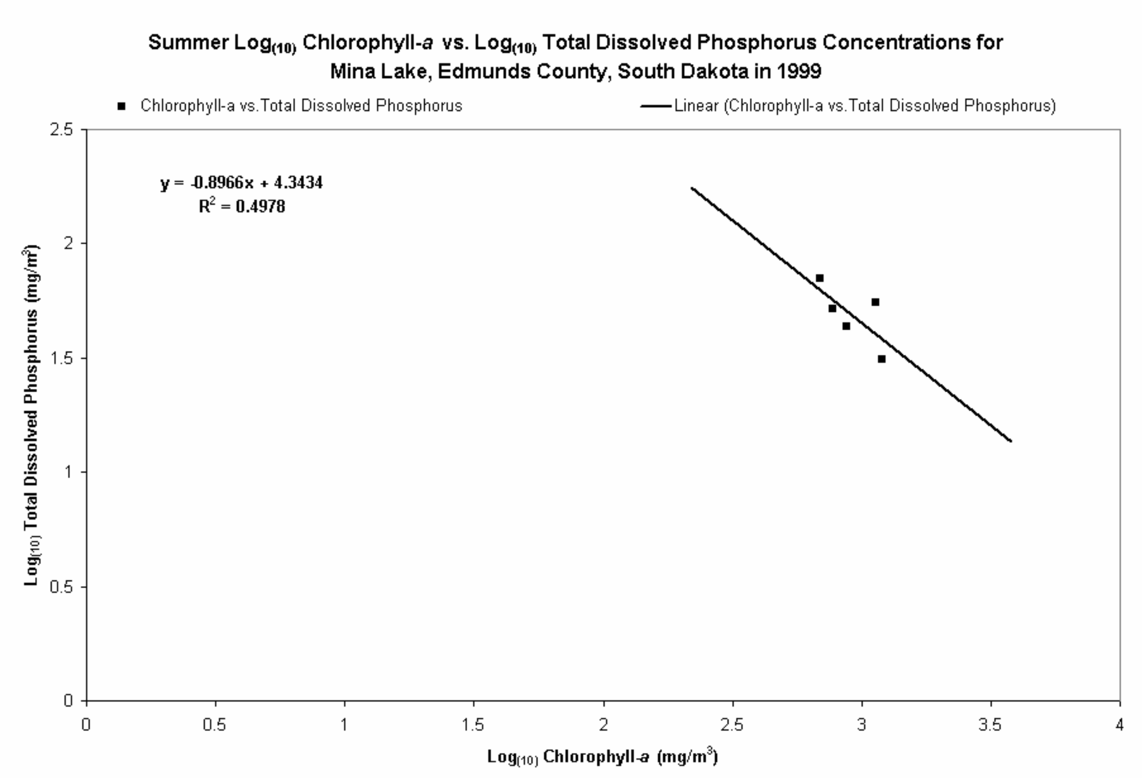


Figure 39. Summer log $_{(10)}$ chlorophyll-*a* concentrations vs. log $_{(10)}$ total dissolved phosphorus concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999.

Seasonal average total dissolved phosphorus concentrations were lower in the spring, increased to the highest concentrations in late summer at ML-5 (west arm) and in early fall for the east arm, ML-4 (Table 35). As stated in the total phosphorus section, total phosphorus, part of which is total dissolved phosphorus (on average 91.1 percent), was in excess during this project.

Average algae densities were highest in August and were still relatively high in September, theoretically, utilizing total dissolved phosphorus (available phosphorus) for growth. Total dissolved phosphorus concentrations did show a decline during this time (Figure 38). Data indicate that Mina Lake has a superabundance of phosphorus (total and dissolved) sufficient to cause objectionable algal blooms and surface scums. Since no nuisance algal blooms were reported by DENR personnel or the public during sampling, other conditions (other nutrients (nitrogen) or light transparency) suppressed excessive productivity. While, algal densities in Mina Lake were relatively high in summer 1999, those densities did not produce thick floating mats of objectionable algal masses in Mina Lake. Reducing 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.

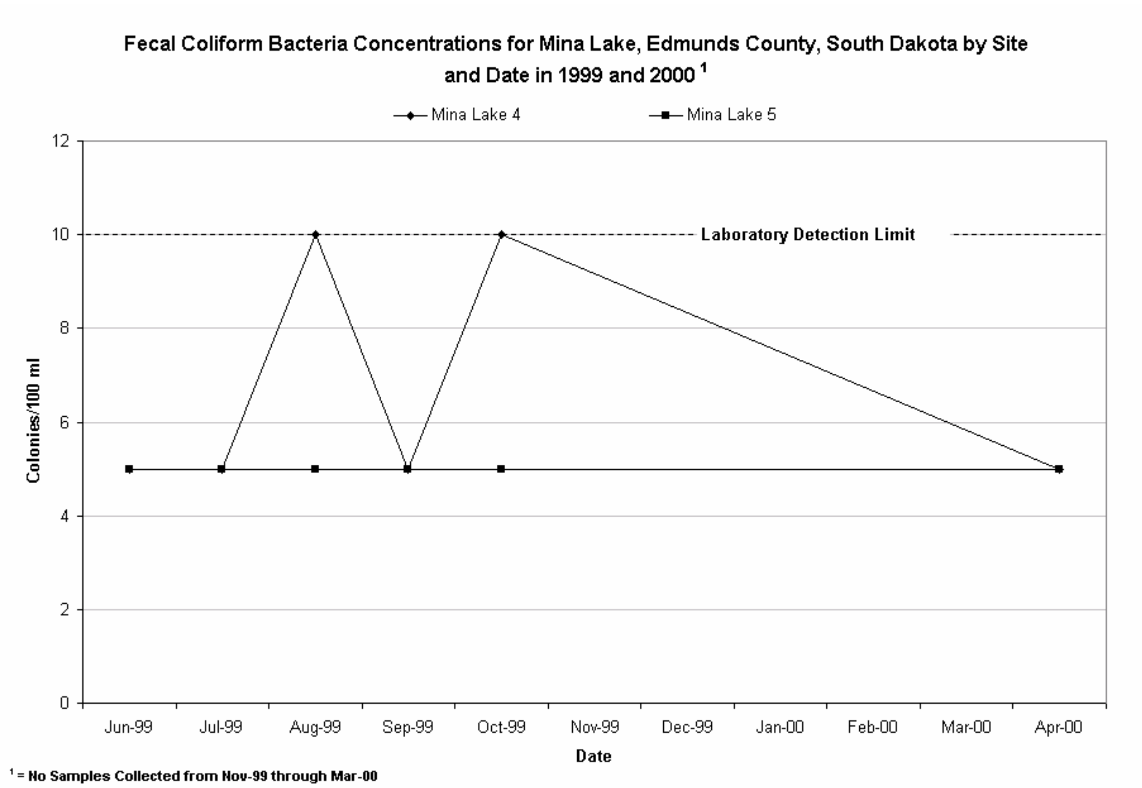


Figure 40. Fecal coliform bacteria colonies per 100 milliliters by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

In-lake fecal coliform concentrations are typically low because of exposure to sunlight and dilution of bacteria in a larger body of water. Of the 12 individual samples collected, 100 percent of fecal coliform concentrations were at or below detection limits (Figure 40). The maximum concentrations (10 colonies/100 ml) were collected on August 25, 1999 and October 12, 1999 at ML-4, all other fecal coliform counts were below laboratory detection limits. Using a value of 5 (½ the detection limit) for those samples below laboratory detection limits, the average fecal coliform bacteria count was approximately 5.8 colonies/100 ml. Figure 40 shows the in-lake fecal coliform concentrations by date.

Fecal coliform samples have been collected at the swimming beach by SD GF&P personnel from May 1992 to the present. Since May 1992, no fecal coliform swimming beach samples exceeded water quality standards for public beaches ($\leq$ 1,000 colonies/

100 ml for any one sample, ≤ 300 colonies/ 100 ml for two consecutive samples or ≤ 200 colonies/ 100 ml for three consecutive samples, Chapter 74:04:08:07). Swimming beach sample collection data from 1999 through 2001 is provided in Table 36.

The previous study (1992) recommended that 15 homes on the west side of Mina Lake be hooked up to the centralized sewer system and the drain fields be eliminated. Currently, all 15 homes except one temporary seasonal home are now hooked up to the centralized sewer system (personal communication – Janice Mohr, Mina Lake Sanitation District, 2002).

Fecal coliform samples collected from Snake Creek water quality sites upstream of Mina Lake had fecal coliform counts in excess of the 2,000 colonies/100 ml, the standard for Snake Creek (Table 7). Most high fecal coliform counts were collected during increasing flow conditions in the early summer of 1999. Fecal coliform exceedances in June and July in Snake Creek did not translate to exceedance in in-lake or swimming beach water quality standards (Table 36). This is due in part to increased exposure to sunlight and dilution in Mina Lake. Since high nutrient concentrations usually accompany elevated fecal bacteria counts, controlling animal waste would decrease both fecal colonies (concentrations) and nutrient concentrations alike. In-lake fecal coliform concentrations do not indicate animal waste is a problem.

Table 36. Swimming beach fecal coliform sample data for Mina Lake, Edmunds County, South Dakota, 1999 through 2001.

Season	Date	Fecal Coliform (col./100 mL)	Season	Date	Fecal Coliform (col./100 mL)	Season	Date	Fecal Coliform (col./100 mL)
Spring	05/24/99	10	Summer	06/06/00	120	Summer	06/11/01	50
Summer	06/01/99	20	Summer	06/12/00	60	Summer	06/18/01	20
Summer	06/07/99	<10	Summer	06/19/00	10	Summer	06/25/01	<10
Summer	06/14/99	<10	Summer	07/17/00	30	Summer	07/02/01	10
Summer	06/21/99	150	Summer	07/24/00	10	Summer	07/09/01	<10
Summer	06/28/99	10	Summer	07/31/00	<10	Summer	07/16/01	10
Summer	07/06/99	10	Summer	08/07/00	<10	Summer	07/23/01	<10
Summer	07/12/99	<10	Summer	08/14/00	<10	Summer	07/30/01	<10
Summer	07/19/99	<10	Summer	08/21/00	<10	Summer	08/06/01	<10
Summer	07/26/99	<10	Summer	08/28/00	<10	Summer	08/13/01	<10
Summer	08/02/99	<10				Summer	08/20/01	10
Summer	08/09/99	<10				Summer	08/27/01	<10
Summer	08/23/99	<10						
Summer	08/30/99	<10						

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 Mina Lake were relatively high (Figure 41).

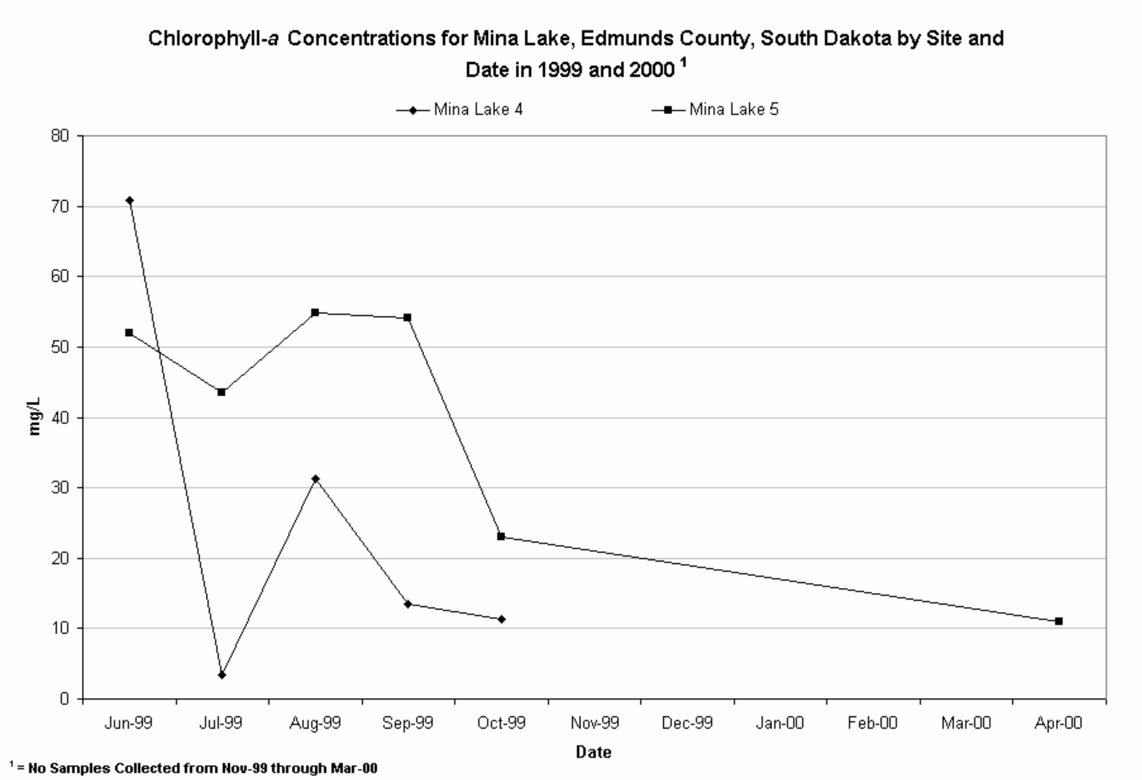


Figure 41. Monthly in-lake chlorophyll-*a* concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

The maximum in-lake chlorophyll-*a* concentration (70.8 mg/m^3) was collected on June 29, 1999 at ML-4 (Figure 41). Both samples in June (ML-4 and ML-5) and ML-5 (west arm) from June through September were much higher than the average chlorophyll-*a* concentration (33.5 mg/m^3) for the project. The median chlorophyll-*a* concentration for the project was 31.2 mg/m^3. The site separation in chlorophyll-*a* concentrations from June through October 1999 correspond to large differences in algal density and biovolume at each site (Figure 41, (Figure 65 and Figure 66, pages 114 and 115)).

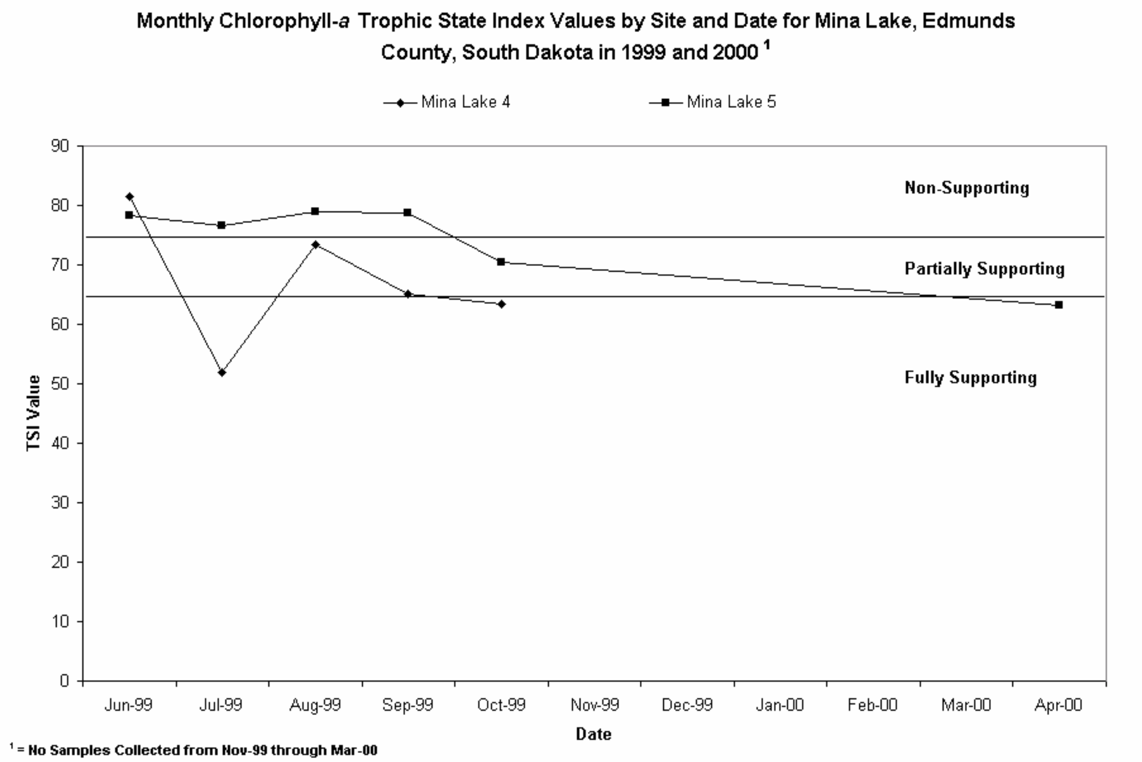


Figure 42. Monthly chlorophyll-*a* Trophic State Index (TSI) by beneficial use support categories, date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

If chlorophyll-*a* were the only parameter used to estimate the trophic status of lakes, Mina Lake would be rated hyper-eutrophic but partially-supporting or with an average TSI value of 71.03 (Figure 42 and Figure 43). Figure 42 indicates that five of the eleven samples analyzed during the project had TSI values were not supporting beneficial uses, and using Carlson's trophic categories, eight of the eleven TSI values that were in the hyper-eutrophic range > 65 (Figure 43). Chlorophyll-*a* TSI values deviated slightly from June to July 1999 at ML-4 but, overall, were not statistically significant ($p>0.05$).

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.

Chlorophyll-*a* samples for the two sites were averaged for each date so that they could be plotted against total phosphorus concentrations to determine their relationship in Mina Lake. 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 $R^2 = 1.0$. There were too few data points (4) to determine seasonal relationships (growing season) between chlorophyll-*a* and total phosphorus.

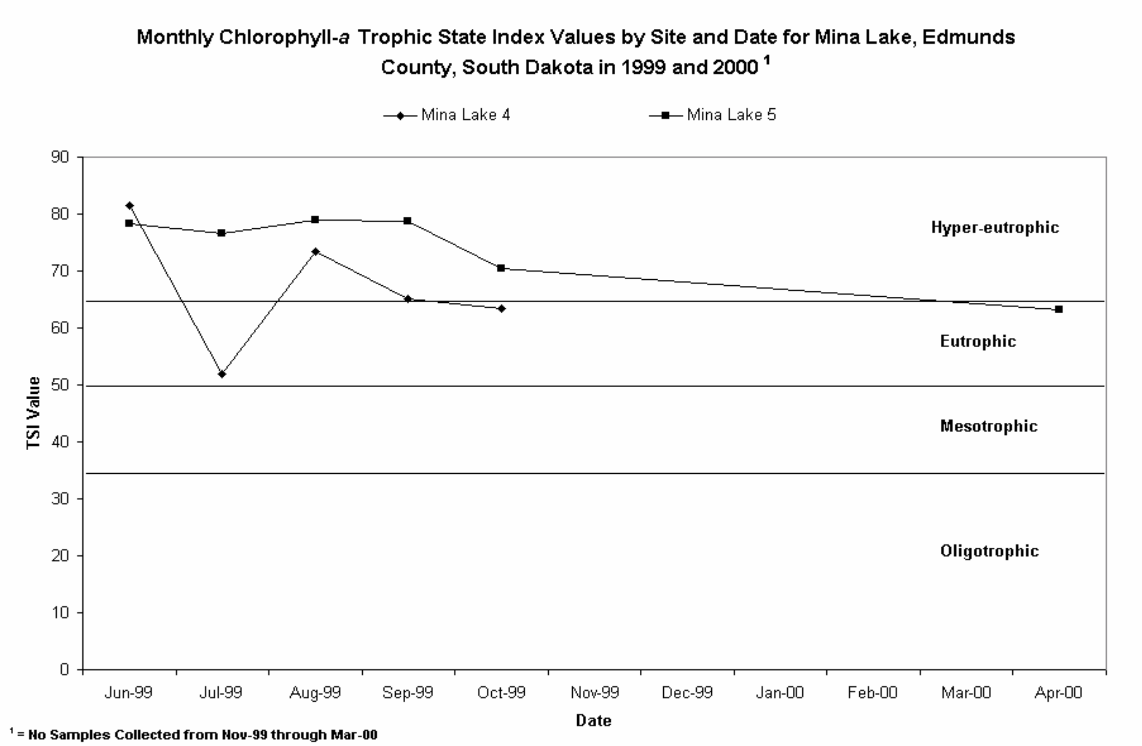


Figure 43. Monthly chlorophyll-*a* Trophic State Index (TSI) by Carlson trophic categories, date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Figure 44 indicates a negative relationship between average chlorophyll-*a* and total dissolved phosphorus concentrations (negative slope (-1.01), R^2=0.40). This indicates that when availability of total phosphorus increases, chlorophyll-*a* concentrations decrease. The negative slope indicates that total phosphorus is a poor predictor of chlorophyll-a concentrations (algal populations). Data suggests factors other than total phosphorus influence chlorophyll-*a* (algae) concentrations in Mina Lake.

Equation 3. Mina Lake total phosphorus-to-chlorophyll-*a* regression equation.

$$y = -1.0145(x) + 4.7319$$

y = $Log_{(10)}$ of predicted chlorophyll-a concentration
x = $Log_{(10)}$ of total phosphorus concentration in µg/L

The relationship between phosphorus and chlorophyll-*a* (regression equation) can be used to estimate a reduction in chlorophyll-*a* that can result by reducing in-lake phosphorus concentrations.

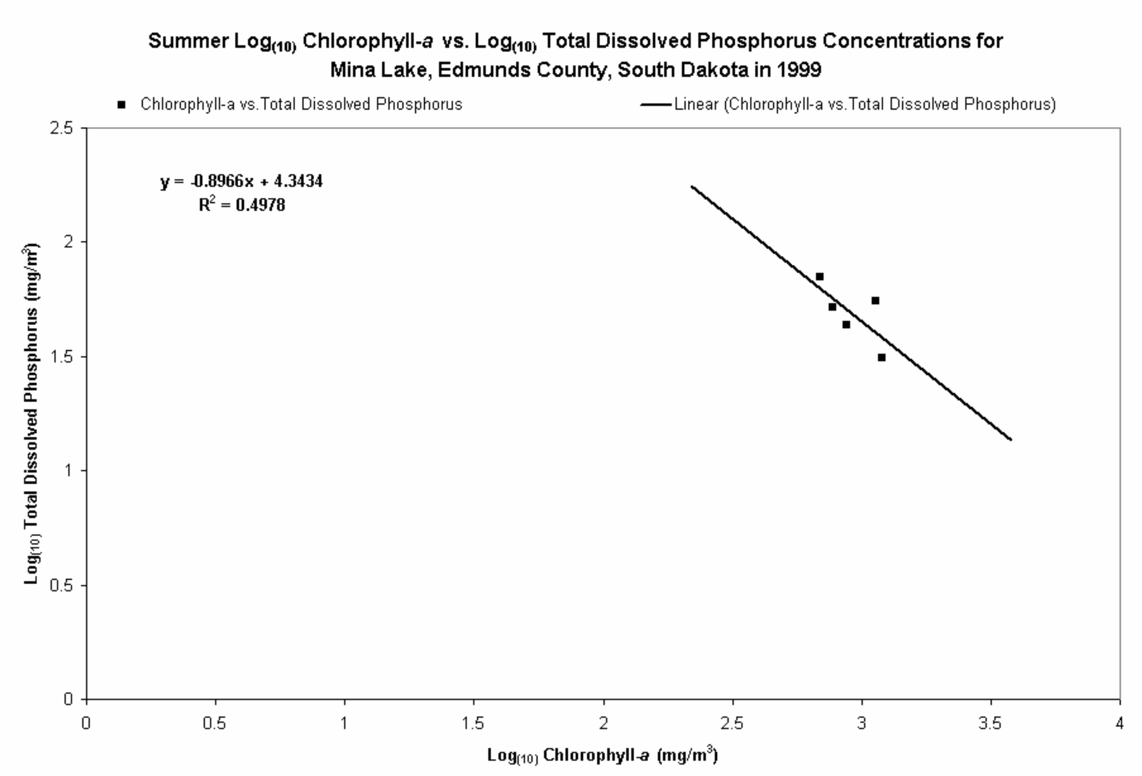


Figure 44. Log $_{(10)}$ chlorophyll-*a* concentrations vs. log $_{(10)}$ total phosphorus concentrations by date and sampling site for Mina Lake, Edmunds County, South Dakota in 1999.

This data can be used to model in-lake response based on Vollenweider and Kerekes 1980. The better the relationship the more confident lake managers can be in the expected results. For this study, reduction response modeling for chlorophyll-*a* concentrations was done using 'BATHTUB' (Walker, 1999).

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.

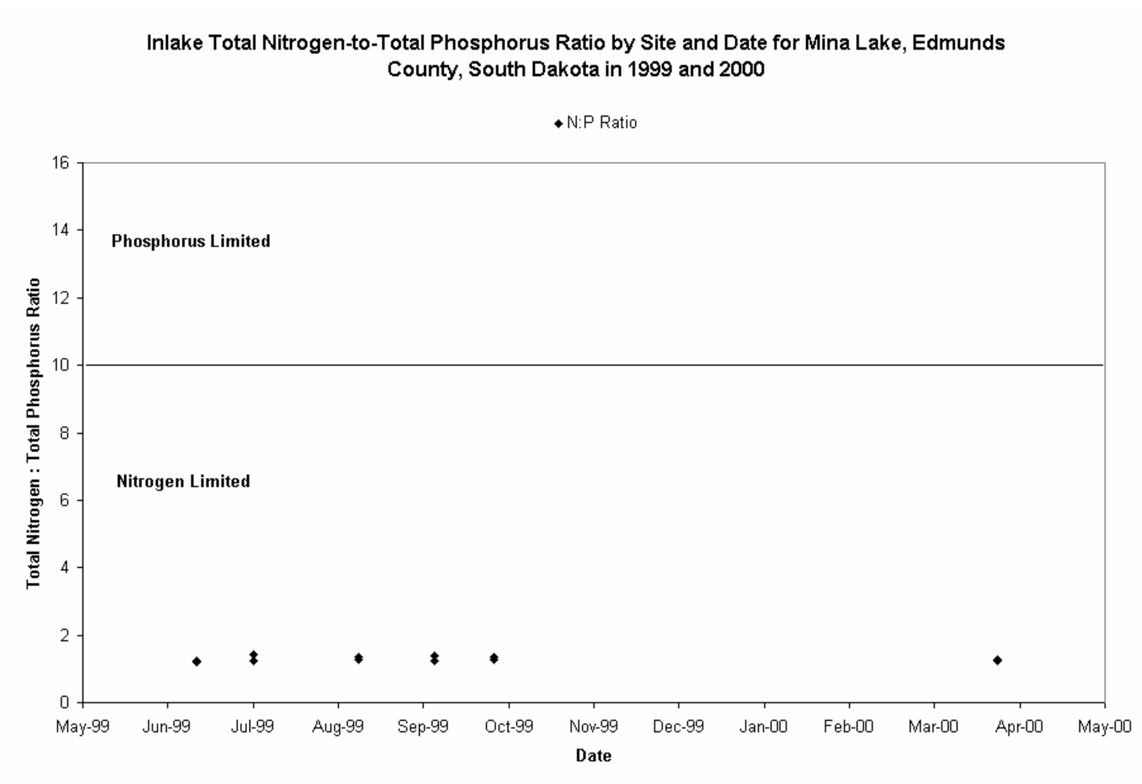


Figure 45. Surface total nitrogen-to-total phosphorus ratios by date and sampling site for Mina Lake, Edmunds County, South Dakota for 1999 and 2000.

During the project, Mina Lake was nitrogen-limited (Figure 45). The average total nitrogen-to-total phosphorus ratio in Figure 45 was 2.2:1 (nitrogen-limited below 10) with a standard deviation of 0.48, indicating both sampling sites had similar ratios. Mina Lake was nitrogen-limited on all six sampling dates and both sampling sites (ML-4 and ML-5) were statistically similar ($p>0.05$).

As stated earlier, limiting factors can be anything physical or chemical that limits the growth or production of organisms. Although nitrogen limitation was observed over the entire project, algal densities (cells/ml) increased from June to August and gradually decreased by October for both arms (ML-4 and ML-5) of Mina Lake (Table 43, page 112, (Figure 65 and Figure 66, pages 114 and 115)). However, ML-5 had significantly higher algal densities ($p<0.05$) than ML-4 during the project (Figure 65 and Figure 66, pages 114 and 115). Algal production fluctuated (increased and decreased) at the same time total nitrogen-to-total phosphorus ratios varied only slightly (always nitrogen-limited), indicating nutrients may not be as limiting as other factors in determining algae population densities.

Hydrologic, Sediment and Nutrient Budgets for Mina Lake

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 the 1999 through 2000 tributary sampling data. During 1999, rainfall was 136.9 percent of normal (1999-648.7 mm (25.54 inches), normal 473.7 mm (23.86 inches)) and the average temperature was 119.4 percent of normal (1999-7.56 °C (45.6 °F), normal 6.33 °C (43.4 °F)). Sampling and gauging began in the summer and continued until ice up and began again when ice left the stream and continuous discharge measurements could be collected.

Hydrologic inputs to Mina Lake included precipitation, tributary runoff, both gauged and ungauged areas of the watershed (Figure 46). Hydrologic output from Mina Lake included the water leaving the lake over the spillway from the end of June to early November 1999 and evaporation. Precipitation data was acquired from the state climatologist in Brookings, South Dakota. Monthly precipitation data was obtained from the Ipswich, South Dakota field station. Tributary sites were gauged when possible, and, as stated in the previous section, ungauged discharge was estimated using the AGNPS model and the data modified (adjusted) using gauged 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. During the study period, water was below the level of the spillway 182 days out of 311 days of monitoring (58.5 percent).

Table 37. Hydrologic budget for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Tributary	Input (acre-feet)	Tributary	Output (acre-feet)
Snake Creek SC-1	4,045	**Outlet Discharge**	9,744
Snake Creek SC-2	3,819		
Ungauged Watershed	1,880		
Total	**9,744**		**9,744**

The hydrologic budget for Mina Lake is provided in Table 37. Table 37 incorporates precipitation and evaporation in both the input and output calculations/estimations. The hydrologic budget was determined using output data from the FLUX model (Walker, 1996). One factor never directly measured in Mina Lake was the total volume of ground water that passed through the lake. Ground water is usually of good quality and 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 sources of hydrologic input to Mina Lake were Snake Creek at 80.7 percent of the total hydrologic load, followed by the ungauged portion of the watershed contributing 19.3 percent (Figure 46). The hydraulic residence is the time between when water enters a reactor (lake) and the same water leaves the reactor. The hydraulic residence time for Mina Lake calculated using BATHTUB (Walker, 1996) was 0.9784 years or 357 days.

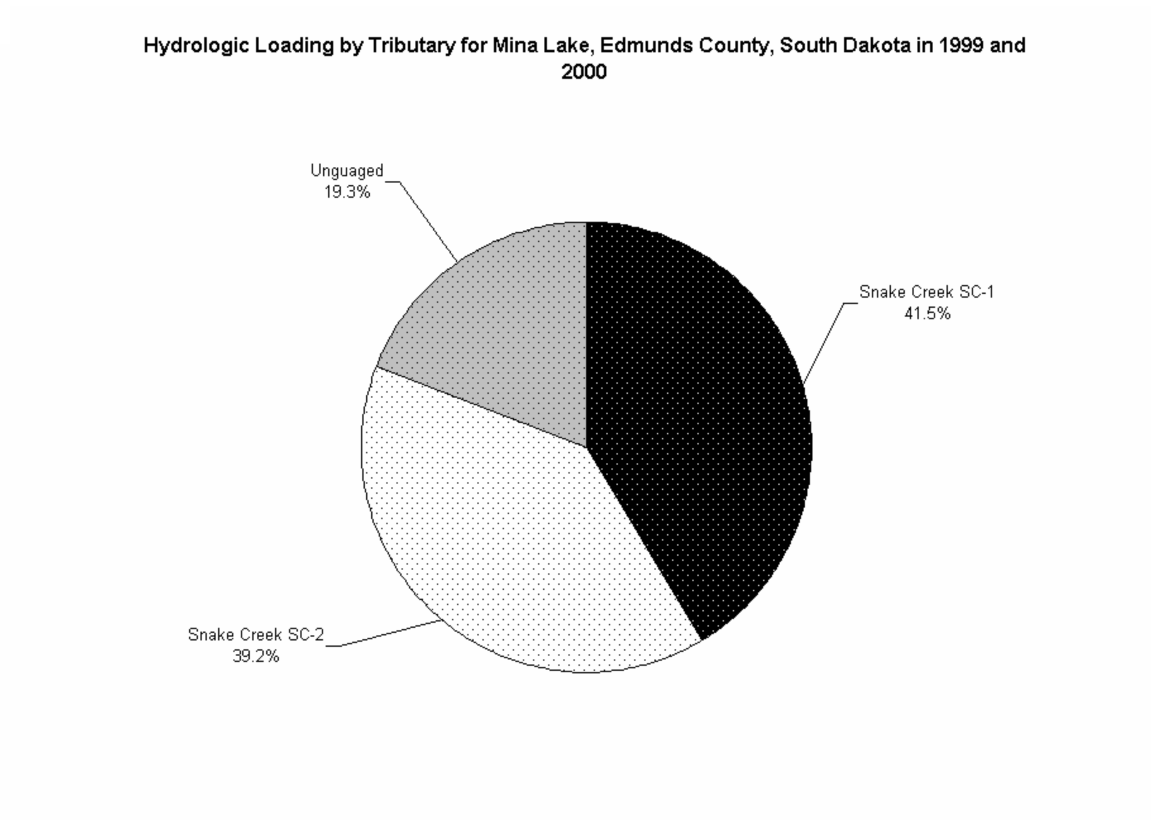


Figure 46. Hydrologic loading by parameter for Mina Lake, Edmunds County, South Dakota by source in 1999 and 2000.

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 Snake Creek and the estimated amount from the ungauged portion of the watershed, Mina Lake received approximately 556.6 m^3 (0.45 acre-feet) of sediment, during this study. This translates to an overall increase of 17.0 mm of sediment depth over the entire lake. The volume of sediment was calculated by dividing the annual kilograms of sediment (1,203,581 kg) by 2,162.5 kg/m^3 (Stueven and Bren, 1999).

Figure 47 shows the estimated percentage of total suspended solids loading from Snake Creek tributaries derived from water quality sampling. Measured loadings from Snake Creek were by far the greatest at 84.3 percent. The ungauged portion of the watershed contributed an estimated 15.7 percent of the total suspended solids load to Mina Lake based on modified export coefficients. A percentage of this load was from erosion from the lack of vegetative cover, cutbank erosion and bank sloughing near the shoreline. Most of these areas are near the confluence of Snake Creek (SC-1 and SC-2) and on the shoreline of Mina Lake and are caused in part by allowing livestock (mainly cattle) access to these areas. Livestock tend to consume and trample down vegetative cover causing increased erosion and bank stabilization problems.

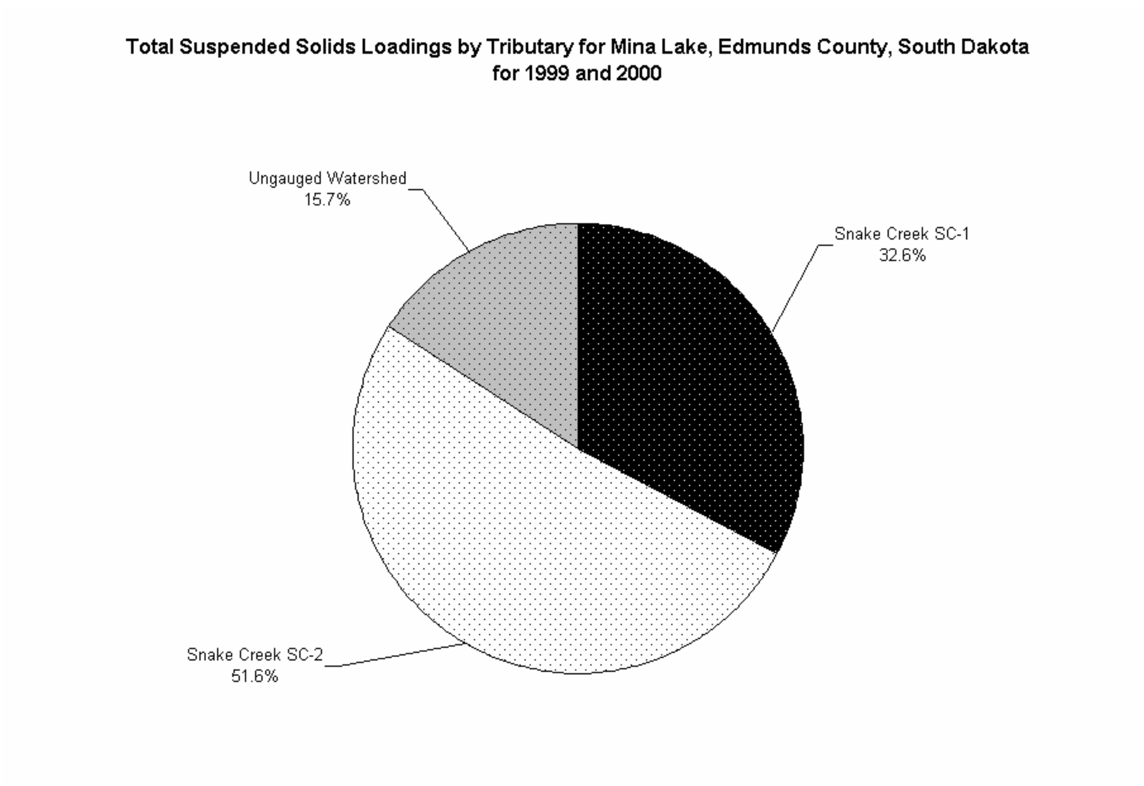


Figure 47. Percent total suspended solids loading to Mina Lake, Edmunds County, South Dakota by source in 1999 and 2000.

The calculation of total suspended solids at the outlet (SC-3) found approximately 99,675 kg or 46.1 m^3 (0.04 acre-feet) of sediment leaving Mina Lake. The amount of suspended solids retained in Mina Lake during this study was approximately 1,103,905 kg, which is 510.5 m^3 (41.4 acre-feet) or 91.7 percent of the total of suspended solids loading to the lake.

To estimate the average organic portion of total suspended solids leaving Mina Lake, the total kilograms per year of volatile total suspended solids were divided by the total suspended solids to predict the percentage of organic suspended solids (VTSS). The organic percentage of suspended solids measured at SC-3 (outlet) was 52.1 percent. In comparison, the overall average in-lake percentage of volatile total suspended solids at ML-4 (east arm) was 25.9 percent while the percentage of volatile total suspended solids at ML-5 (west arm) was 30.7 percent. An increase in organic composition of total suspended solids from tributary to in-lake percentages (ML-5 (west), 25.05 percent and ML-4 (east), 19.68 percent) was observed in Mina Lake. A large portion of this increase may be attributed to in-lake algal populations. The estimated volatile total suspended solids that was discharged from Mina Lake using FLUX modeling data was approximately 51,957 kg or 24.0 m^3 (0.02 acre-feet) using the outlet overall average load. The west arm of Mina Lake received significantly more volatile total suspended solids than the east arm ($p<0.05$). Reducing suspended solids concentrations to Mina Lake should be beneficial in reducing trophic state indices and the non-supporting (hyper-eutrophic) condition of the lake.

Nitrogen Budget

Inputs for the nitrogen budget for Mina Lake were from tributaries (gauged and ungauged) and ground water. Tributary loadings were taken from the water quality data collected. Ground water loading was not considered in the overall input budget because there was no way to measure the input or fate of ground water nitrate from the time it enters the lake until it leaves.

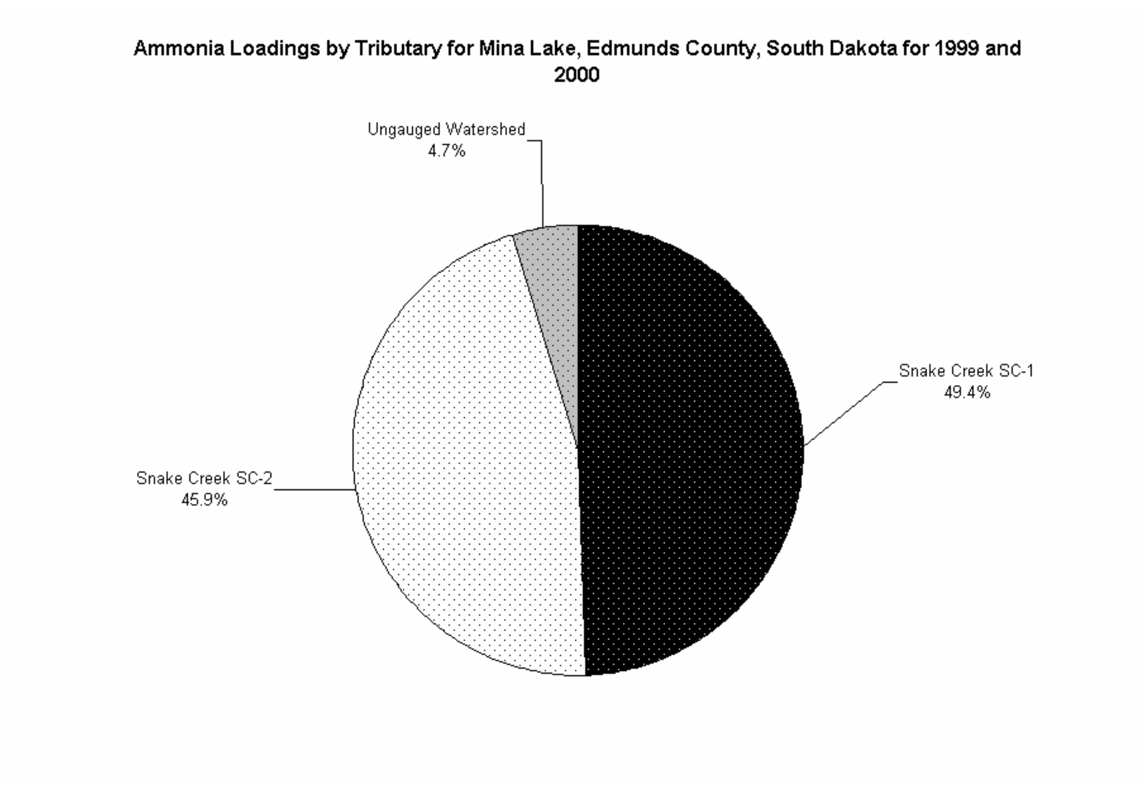


Figure 48. Percent ammonia loading to Mina Lake, Edmunds County, South Dakota by source in 1999 and 2000.

Atmospheric nitrogen can enter a waterbody in many forms: as nitrogen, nitric acid, ammonia, nitrite, and as organic compounds either dissolved or particulate (Wetzel, 1983). It was not possible to know what ratio of inorganic to organic nitrogen entered the lake from the atmosphere. Blue-green algae are able to fix atmospheric nitrogen; however, the rate and amount at which atmospheric nitrogen was incorporated could not be determined given the scope of this project. Because no water quality data from precipitation was collected, the inputs will be estimated as minimal and not considered in this report. The estimated ungauged tributary inputs for nitrogen parameters were estimated/calculated based on modified export coefficients. The following charts show the percent of nitrogen loadings from different sources in the Mina Lake watershed (Figure 48 through Figure 51).

The ammonia (NH_3) budget for Mina Lake showed an increase in in-lake ammonia of 173.1 kg (381.6 pounds) or 41.9 percent of the total loading to the lake. As can be seen from Figure 48, the largest input was from SC-1 (49.4 percent). Approximately 58.1 percent (240.4 kg) of the total ammonia load to Mina Lake was lost to algae or converted to other forms of nitrogen because ammonia is inorganic and is readily used by algae for uptake and growth.

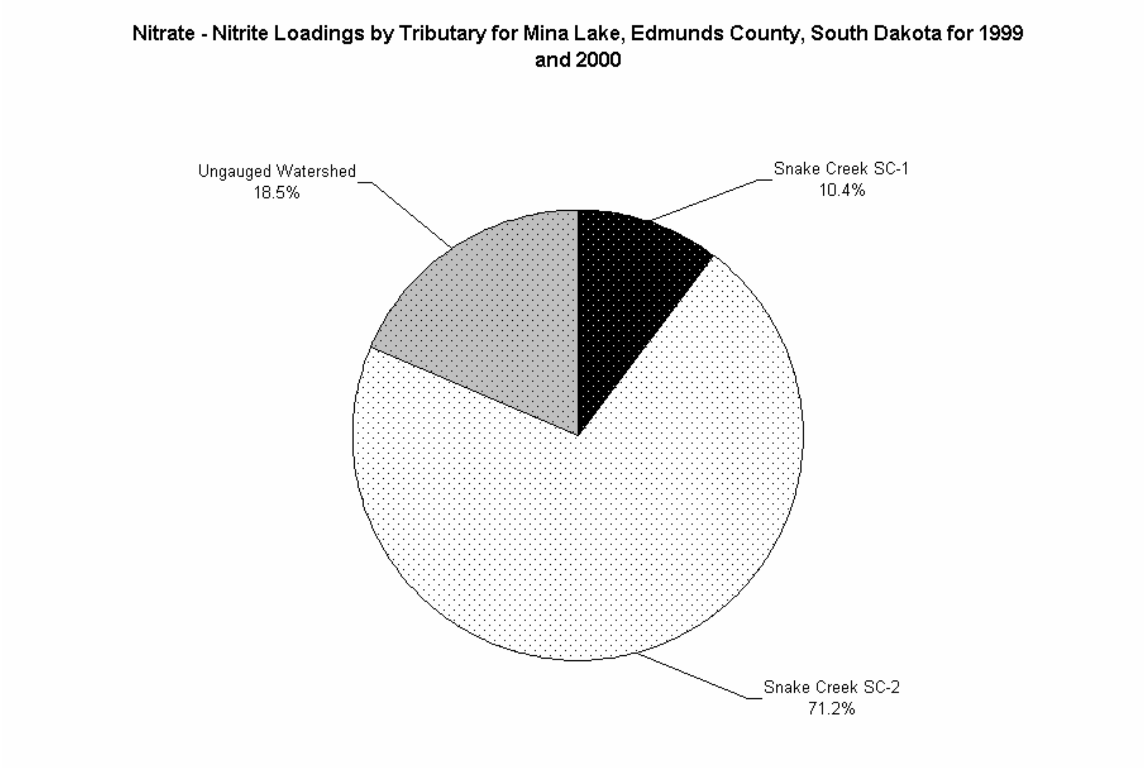


Figure 49. Percent nitrate-nitrite loading to Mina Lake, Edmunds County, South Dakota by source in 1999.

Another inorganic parameter sampled was nitrate-nitrite (NO_3^- and NO_2^-). The nitrate-nitrite budget indicated an increase of nitrate in Mina Lake. An estimated 7,955 kg (8.77 tons) or 86.9 percent of the nitrate-nitrite load to Mina Lake was utilized by in-lake algae, aquatic macrophytes and/or sorbed on to the sediments. Algae can take up nitrate-nitrite nitrogen if available and convert it to ammonia for use through a nitrate reduction process. Approximately 1,202 kg (1.3 tons) of nitrate-nitrite was discharged from Mina Lake in 1999. SC-2 had the largest input of nitrate-nitrite (68.1 percent) partially because it comprises (drains) 59.7 percent of the watershed (Figure 49).

Organic nitrogen can come in the form of animal waste, vegetation from the watershed or algae. If organic nitrogen is not dissolved, it can drop out of the water column once it reaches the lake. In the bottom sediments, organic nitrogen can be broken down into usable forms of nitrogen. Algae can then use the converted nitrogen for growth and leave the lake through the outlet. Figure 50 indicates SC-1 contributed the largest input 7,037.5 kg or 48.5 percent of the total organic nitrogen load to Mina Lake. Approximately 2,311.7 kg (2.6 tons) or 9.0 percent of the organic nitrogen load was retained in Mina Lake, increasing in-lake available nitrogen during the project.

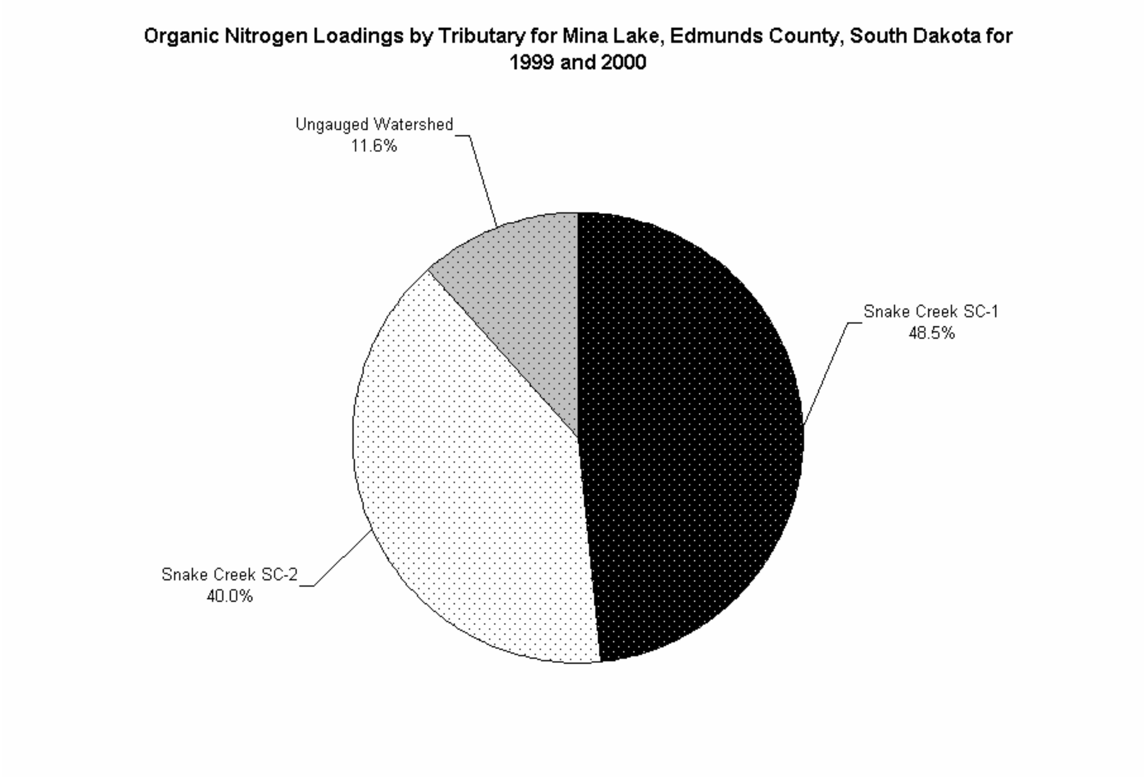


Figure 50. Percent organic nitrogen loading to Mina Lake, Edmunds County, South Dakota by source in 1999 and 2000.

Total nitrogen concentrations are derived from adding TKN concentrations to nitrate–nitrite concentrations. Approximately 11,911 kg (13.1 tons) or 32.5 percent of the total nitrogen load was retained in Mina Lake during 1999. Figure 51 identifies SC-2 as contributing the largest input 16,914 kg or 46.2 percent of the total nitrogen loading. 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. In-lake and tributary total nitrogen-to-total phosphorus ratios indicated a nitrogen-limited system during 1999 and 2000 (Figure 19 and Figure 45). All forms of nitrogen can eventually be broken down and reused for algal growth. Reducing the influx of nitrogen will be beneficial for reducing the hyper-eutrophic (non-supporting) condition found in Mina Lake.

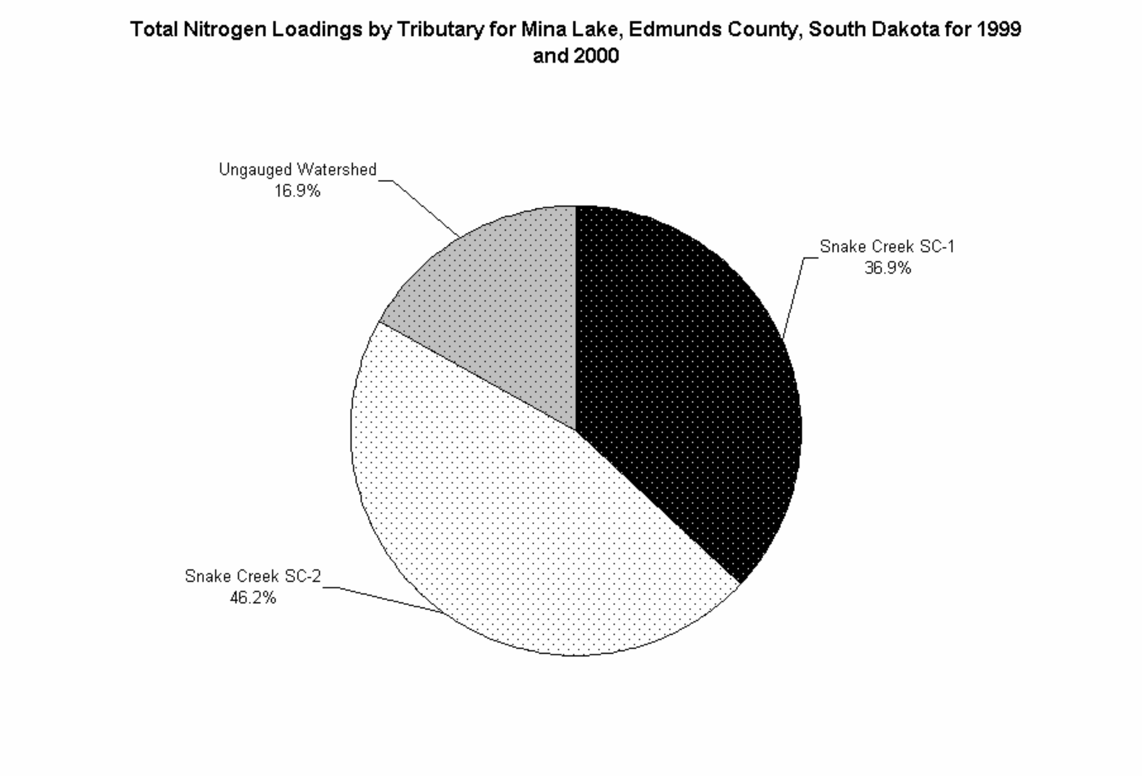


Figure 51. Percent total nitrogen loading to Mina Lake, Edmunds County, South Dakota by source in 1999.

Phosphorus Budget

Total phosphorus inputs to Mina Lake during the 1999 – 2000 sampling season totaled approximately 15,304 kg (16.9 tons). Inputs to Mina Lake included gauged tributaries, an estimate for ungauged tributaries, and precipitation (Figure 52). The ground water load of phosphorus 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. The precipitation load was multiplied by 0.03 mg/L, an average often found in unpopulated areas (Wetzel, 1983), and was 97.8 kg (215.6 pounds) or 0.6 percent of the total phosphorus load. The ungauged tributary load was estimated by using adjusted export coefficients derived from water quality loading data. The ungauged portion of the watershed contributed an estimated 2,190 kg (2.4 tons) of total phosphorus to Mina Lake. Phosphorus residence time for Mina Lake was calculated using BATHTUB (Walker, 1999) and was estimated to be 0.7046 years or 257 days.

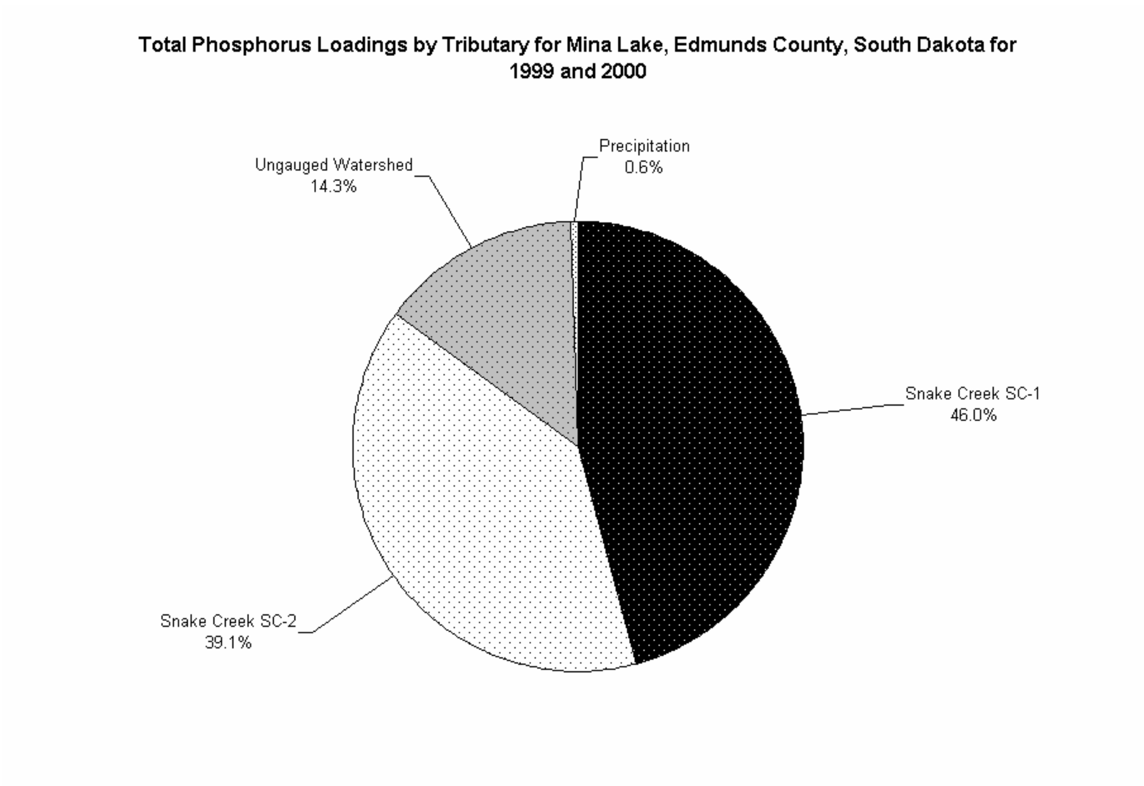


Figure 52. Percent total phosphorus loading to Mina Lake, Edmunds County, South Dakota by source in 1999 and 2000.

The total load out of Mina Lake was approximately 10,917 kg (12.0 tons). In the 1999 sampling season, there was an estimated 4,389 kg (4.8 tons), or 28.7 percent more phosphorus entering the lake than left the lake. This does not include the phosphorus attached to the sediment that fell in or eroded from the shoreline. Because sediment is an excellent source of phosphorus, any erosional areas near the shoreline of the lake contributed (delivered) an unmeasured source of phosphorus to the lake. The phosphorus from shoreline erosion would most likely be found as total phosphorus instead of dissolved phosphorus. Again, Snake Creek contributed the largest load (13,016 kg, 14.3 tons) or 85.1 percent of the total phosphorus load to Mina Lake. Increased in-lake concentrations of total phosphorus were observed throughout this study. Elevated total phosphorus concentrations in conjunction with steady or decreasing total nitrogen concentrations contributed to the nutrient limitations (nitrogen) observed in 1999 and 2000.

Algal densities (cells/mL) and biovolume was high for most of the growing season indicating algae were assimilating total and total dissolved phosphorus and to some extent total nitrogen during this period (Table 43 and Table 44, pages 112 and 113). This suggests elevated total phosphorus concentrations were not controlling or limiting algal production in Mina Lake in 1999. Other factors or combination of factors such as nitrogen, total suspended solids or water transparency may have controlled the algal population during this time.

Increases 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 ($p>0.05$). Reducing the influx of total phosphorus will improve the overall trophic state of the lake and increase the beneficial use status of Mina Lake.

Significant total phosphorus loading from Snake Creek occurred in July 1999 (Figure 16) and contributed to peak in-lake total phosphorus concentrations in August 1999. The estimated 4,389 kg (4.8 tons) of total phosphorus remaining in the lake from tributary sources and the in-lake internal loading of total phosphorus in the lake sustain and increase, over time, in-lake total phosphorus concentrations in Mina Lake. Due to excessive in-lake total phosphorus concentrations resulting in increased phosphorus TSI values, Mina Lake will not meet, and does not fit, ecoregional beneficial use criteria. Significant reductions (94.4 percent) in total phosphorus loads to Mina Lake are unrealistic both economically and technically and preclude attainment based on current ecoregional beneficial use criteria. Economically, such reductions would severely alter or eliminated most agriculture in the watershed. Technically, internal loading of in-lake total phosphorous resulting in elevated year round phosphorus concentrations impede reduction attainability even if extensive BMPs are implemented throughout the watershed. Realistic criteria/goals for Mina Lake should be based on watershed specific attainability.

Total Dissolved Phosphorus

The inputs (loads) of total dissolved phosphorus (Figure 53) to Mina Lake were estimated at 12,702 kg (14.0 tons). Mina Lake retained approximately 14.1 percent (1,785 kg) of the total dissolved phosphorus load. Tributary loading percentage of dissolved phosphorus in total phosphorus was 83.0 percent while the outlet percentage of total dissolved phosphorus increased to 93.9 percent. The 10.9 percent difference may imply in-lake internal processing (loading) of total dissolved phosphorus or may represent a higher percentage of dissolved organic phosphorus compounds, which are utilized at a slower rate than inorganic forms (Wetzel, 2001). Reducing the influx of total dissolved phosphorus will improve the overall trophic state of Mina Lake.

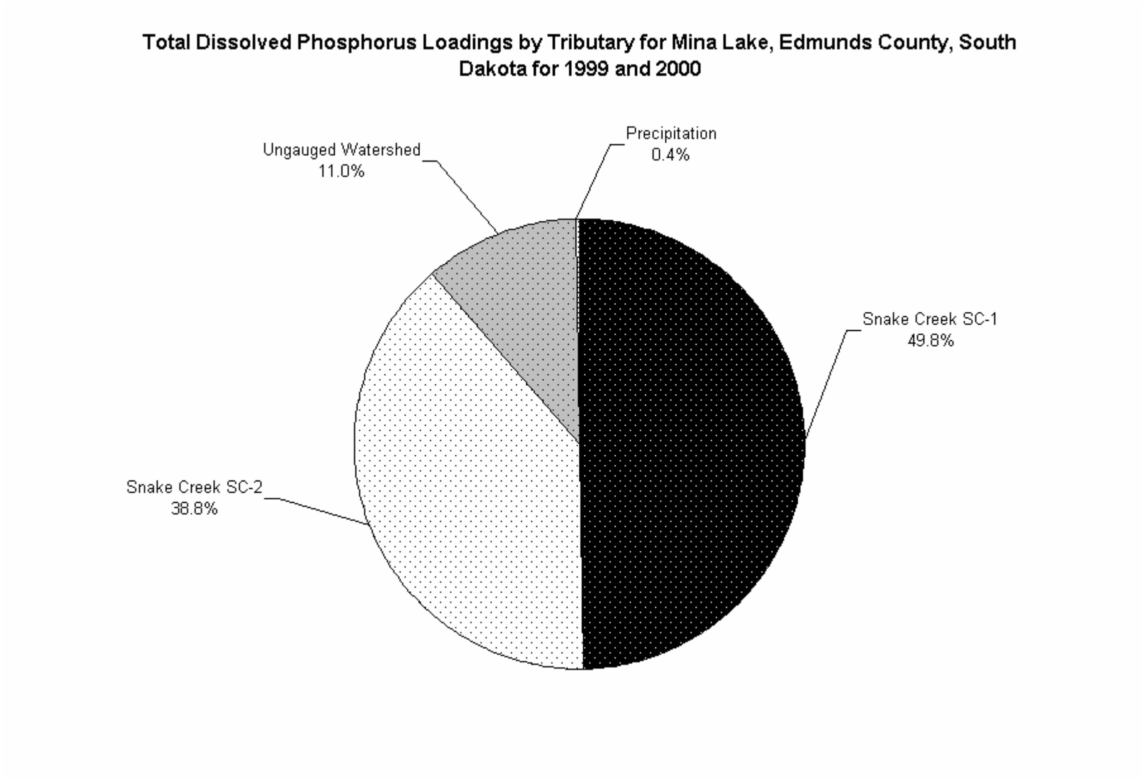


Figure 53. Percent total dissolved phosphorus loading to Mina Lake, Edmunds County, South Dakota by source in 1999 and 2000.

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 38 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 Mina Lake are shown in Table 38 and a graph showing the TSI parameters for 1999 and 2000 is plotted on Carlson's trophic levels as shown in Figure 54.

Table 38. 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. By October 2000, EPA had 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. Mina Lake is in Ecoregion 46R and is categorized as non-supporting based on the SD DENR (2000a) document above. There are three beneficial use categories: non-supporting, partially supporting and fully supporting. Numeric ranges for beneficial use categories are shown in Table 39.

Table 39. Ecoregion 46 R beneficial use category and Carlson TSI numeric ranges by category.

Ecoregion (46 R) Beneficial Use Category	TSI Numeric Range
Non-Supporting	76 – 100
Partially Supporting	66 – 75
Fully Supporting	0 – 65

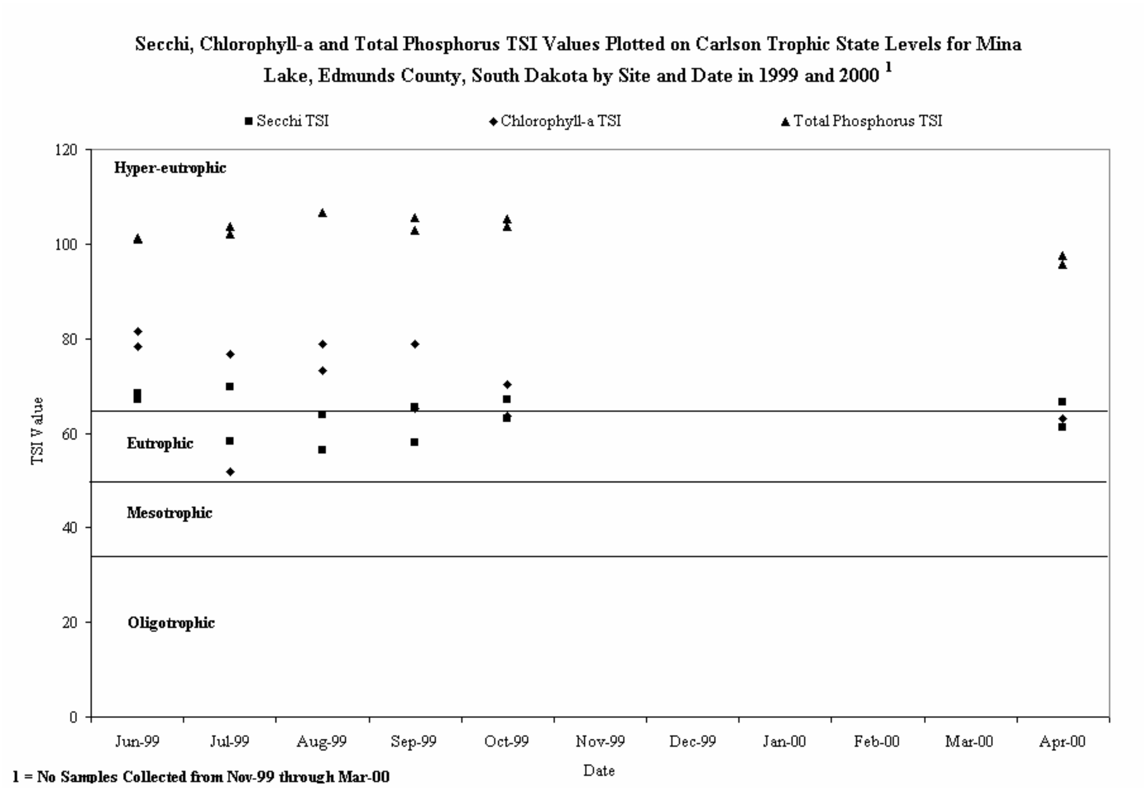


Figure 54. TSI values for phosphorus, chlorophyll-*a* and Secchi TSI plotted by Carlson trophic level from Mina Lake, Edmunds County, South Dakota by date in 1999 and 2000.

Trophic State Index values are plotted using beneficial use categories in Figure 55. Generally, most of the TSI values (especially total phosphorus and chlorophyll-*a* TSI values) were in the non-supporting category. Mina Lake is categorized as non-supporting using ecoregion targeting (SD DENR 2000a). The mean and median for chlorophyll-*a* and total phosphorus TSI were non-supporting (hyper-eutrophic), with the mean and median Secchi TSI just into the partially supporting (eutrophic) category (Table 40). The average TSI rating over the entire project based on observed data was 79.39.

Excessive total phosphorus resulting in elevated TSI values are the result of elevated in-lake total phosphorus concentrations (Figure 54 and Figure 55). Based on current data Mina Lake will not meet ecoregional beneficial use criteria. Unrealistic reductions in total phosphorus loads (94.4 percent) are needed to achieve ecoregional criteria. Realistic criteria/goals for Mina Lake should be based BMP reductions within the Mina Lake watershed resulting in watershed specific attainability. Attainability based on estimated BMP reductions in total phosphorus will lower total phosphorus and possibly chlorophyll-*a* TSI values, improving water quality in Mina Lake and its' watershed.

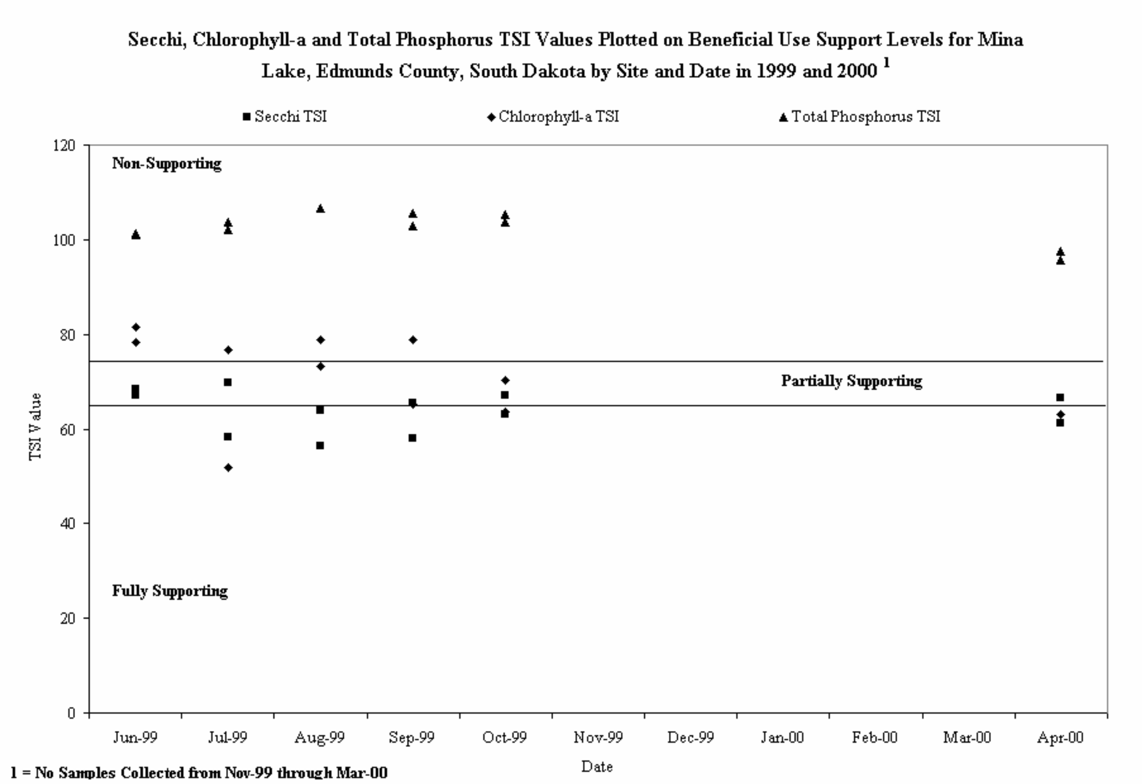


Figure 55. TSI values for phosphorus, chlorophyll-*a* and Secchi TSI plotted by Ecoregion 46 R beneficial use categories for Mina Lake, Edmunds County, South Dakota by date in 1999 and 2000.

Table 40. Descriptive statistics for observed Trophic State Index values collected in Mina Lake, Edmunds County, South Dakota in 1999.

Parameter	Chlorophyll-*a*	Total Phosphorus	Secchi Depth	Parameters Combined
Mean TSI	71.03	102.65	63.78	79.39
Median TSI	73.35	103.18	64.68	79.87
Standard Deviation	9.17	3.40	4.42	3.94

Long -Term Trends

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 in Mina Lake over time. Since the samples taken in 1979, 1989, 1991, 1993, 1994 and 1998 were collected in the summer, generally summer samples (June, July, August) collected during this project were used in long-term trend analysis. Long-term TSI values were plotted on both Carlson's trophic levels and ecoregion beneficial use categories for comparison (Figure 56 and Figure 57).

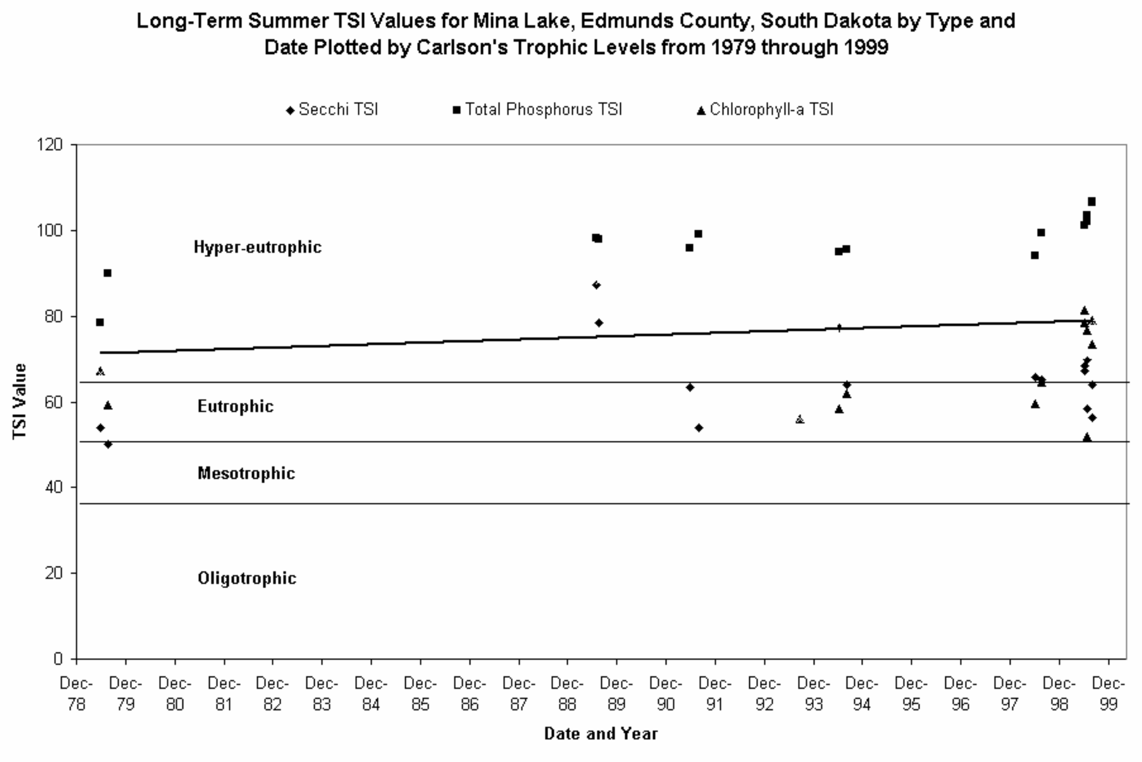


Figure 56. Long-term summer TSI trend for phosphorus, chlorophyll-*a* concentrations and Secchi depth plotted by Carlson trophic levels in Mina Lake, Edmunds County, South Dakota by year and date.

The general trend for all TSI values (Secchi, chlorophyll-*a* and total phosphorus) showed a slight increase from 1979 through 1999. No samples were collected from 1980 through 1988 in Mina Lake.

All TSI values, except for nine Secchi and seven chlorophyll-*a* values were in the non-supporting and partially supporting (eutrophic/hyper-eutrophic) categories (Figure 56 and Figure 57). The long-term trend for all TSI values indicates an increasing trend from the partially supporting category and increasing to the non-supporting category (Figure 57). Mitigation projects in the Mina Lake watershed should, over time, reduce nutrient TSI values, reversing the overall trend observed from 1979 to 1999.

Again, attainability based on estimated BMP reductions in total phosphorus will lower total phosphorus and possibly chlorophyll-*a* TSI values, reducing the long-term trend observed in Mina Lake.

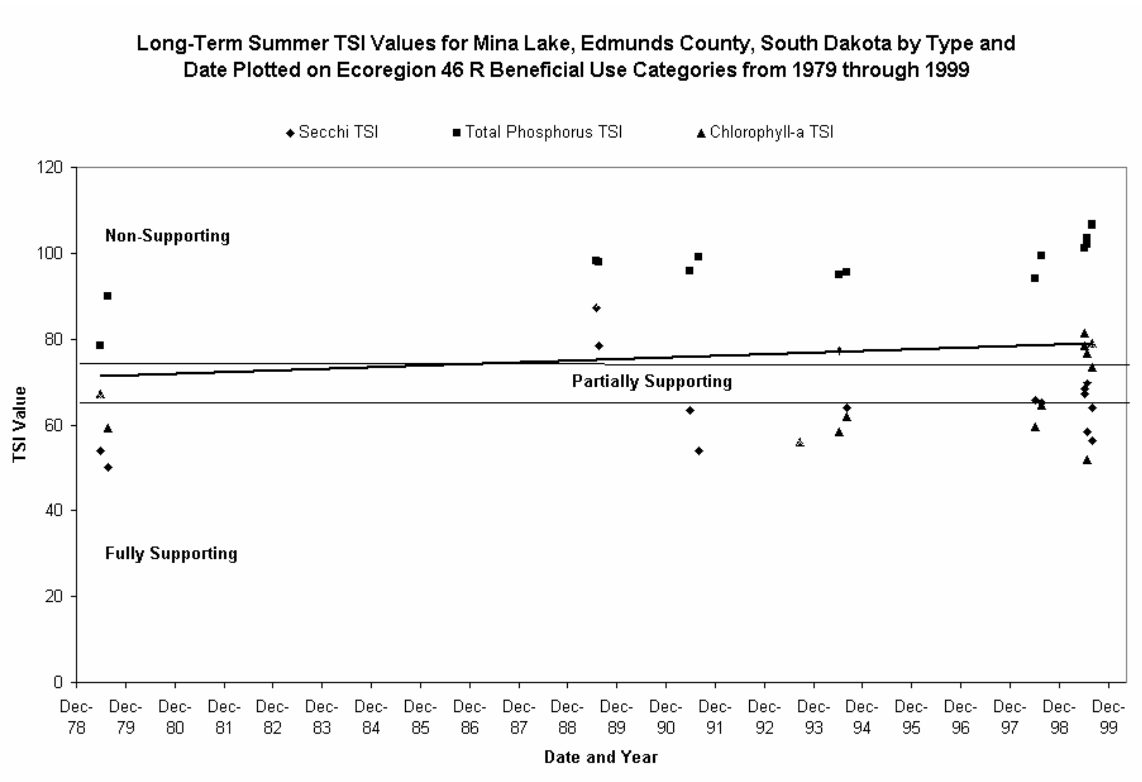


Figure 57. Long-term summer TSI trend for phosphorus, chlorophyll-*a* concentrations and Secchi depth plotted by Ecoregion 46 R beneficial use categories in Mina Lake, Edmunds County, South Dakota by year and date.

Long-term TSI data was also graphed to determine causes in deviation from biomass-based TSI trends. Data points below zero in the X-axis indicate nutrients other than phosphorus (nitrogen etc.) limitation and points above the X-axis relates to phosphorus limitation. Points left of zero on the Y-axis suggests non-algal turbidity (lower transparency than predicted by TSI) and data points to the right of zero on the Y-axis indicate transparency is greater than predicted by biomass based TSI (Wetzel, 2001).

Mina Lake data from 1979 through 1999 (20-years) indicate nutrients other than phosphorus were limited and oscillated around the Y-axis from lower transparency (non-algal turbidity, sediment or dissolved organic matter) to increased transparency (large cyanobacteria and zooplankton grazing). TSI data from 1999 based on this scenario related well with high concentrations of in-lake total phosphorus and high densities of cyanobacteria (Figure 58). Oscillations from predicted transparencies may be related to yearly or seasonal variations in hydrologic, nutrient and internal loading.

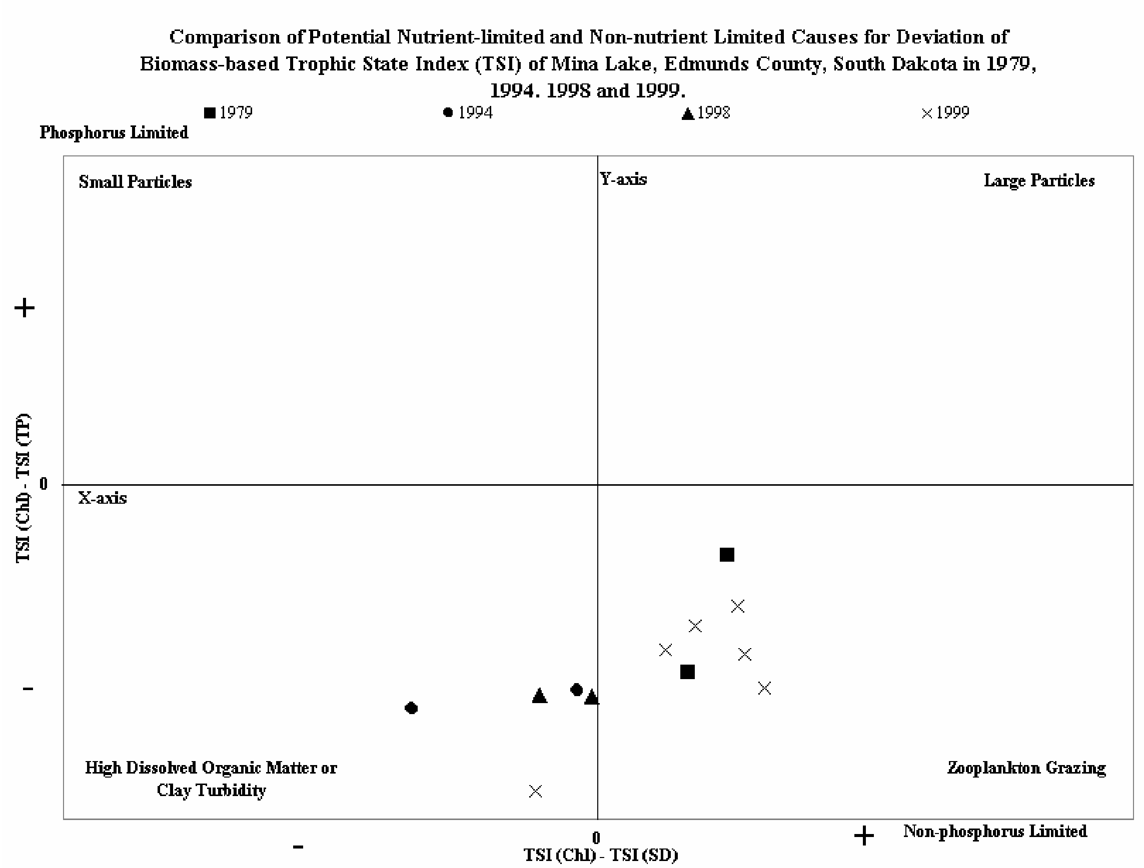


Figure 58. Potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) for Mina Lake, South Dakota in 1979, 1994, 1998 and 1999

Richmond Lake is within 16.1 km (10 miles) of Mina Lake and has similar surface area (Mina 326.2 ha (806 acres) and Richmond 335.5 ha (829 acres)) and shape. Long-term TSI data (1987, 1988, 1992, 1993 and 1999) from Richmond Lake was graphed along side of Mina Lake long-term data for comparison (Figure 59).

Similar to Mina Lake, Richmond Lake data oscillated around the Y-axis from lower transparency (non-algal turbidity, sediment or dissolved organic matter) to increased transparency (large cyanobacteria and zooplankton grazing). However, unlike Mina Lake, most of the 1991 (June and July) and all 1992 data hovered around the zero on the X-axis which indicated that nutrients, phosphorus and nitrogen, were not as limited in the system at that time. Data from 1993 indicated that Richmond Lake was limited by nutrients other than phosphorus, similar to Mina Lake (Figure 59).

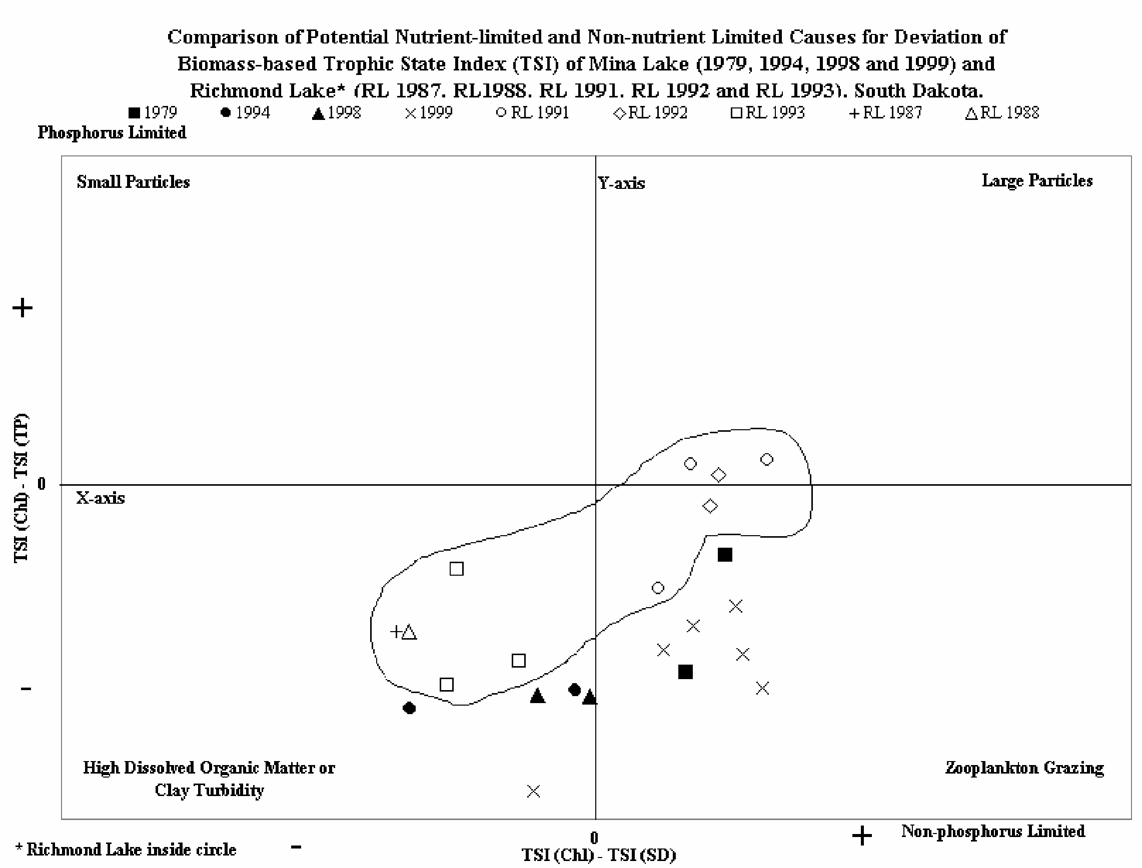


Figure 59. A comparison of potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) between Mina Lake (1979, 1994, 1998 and 1999), and Richmond Lake (RL 1987, RL 1988, RL 1991, RL 1992 and RL 1993) in Edmunds and Brown Counties, South Dakota.

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 Mina Lake watershed for 1999 and 2000 (Table 41).

Table 41. Existing and predicted tributary reductions in nitrogen and phosphorus concentrations and predicted in-lake mean TSI values using the BATHTUB model.

	Percent Nutrient Reduction											
Parameter	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**95%**	**99%**
Total Phosphorus (mg/m^3)	1069.41	963.27	857.13	750.98	644.84	538.7	432.56	326.41	220.27	114.12	61.05	18.59
Total Nitrogen (mg/m^3)	2052	2052	2052	2052	2052	2052	2052	2052	2052	2052	2052	2052
Composite Nutrient (mg/m^3) [1]	156.79	156.4	155.86	155.08	153.92	152.05	148.82	142.58	128.65	92.61	56.97	18.47
Chlorophyll-*a* (mg/m^3)	57.99	57.92	57.83	57.7	57.49	57.16	56.58	55.39	52.5	42.87	29.15	8.33
Secchi (Meters)	0.54	0.54	0.54	0.54	0.54	0.55	0.55	0.56	0.58	0.68	0.88	1.63
Organic Nitrogen (mg/m^3)	1509.58	1508.05	1505.94	1502.88	1498.24	1490.72	1477.36	1450.41	1384.31	1164.77	852.09	377.34
Total Phosphorus-Total Dissolved Phosphorus (mg/m^3)	108.7	108.58	108.41	108.17	107.81	107.22	106.18	104.08	98.92	81.78	57.37	20.3
Antilog PC-1 (Principle Components) [2]	3349.87	3340.22	3326.88	3307.72	3278.83	3232.51	3151.88	2994.97	2640.29	1704.67	817.88	118.14
Antilog PC-2 (Principle Components) [3]	12.55	12.55	12.56	12.56	12.57	12.58	12.59	12.62	12.68	12.7	12.23	8.63
(Total Nitrogen - 150) / Total Phosphorus	1.78	1.97	2.22	2.53	2.95	3.53	4.4	5.83	8.63	16.67	31.15	102.29
Inorganic Nitrogen / Phosphorus	0.56	0.64	0.73	0.85	1.03	1.3	1.76	2.71	5.5	27.43	325.53	1674.66
Turbidity 1/M (1/Secchi – 0.025* Chlorophyll-*a*)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Mixed layer Depth * Turbidity	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Mixed layer Depth / Secchi	5.01	5.00	4.99	4.99	4.97	4.95	4.91	4.83	4.63	3.98	3.06	1.65
Chlorophyll-*a* * Secchi	31.28	31.27	31.26	31.25	31.22	31.18	31.11	30.97	30.58	29.05	25.73	13.6
Mean Chlorophyll-*a* / Total Phosphorus	0.05	0.06	0.07	0.08	0.09	0.11	0.13	0.17	0.24	0.38	0.48	0.45
Frequency (Chlorophyll-*a* >10) %	99.42	99.42	99.41	99.41	99.4	99.38	99.35	99.29	99.1	97.92	92.16	27.26
Frequency (Chlorophyll-*a* >20) %	92.03	92	91.96	91.91	91.82	91.68	91.42	90.88	89.37	82.11	61.71	4.25
Frequency (Chlorophyll-*a* >30) %	77.43	77.37	77.3	77.18	77.01	76.73	76.22	75.15	72.33	60.48	36.08	0.87
Frequency (Chlorophyll-*a* >40) %	61.38	61.31	61.21	61.06	60.84	60.49	59.85	58.52	55.12	42.13	20.6	0.23
Frequency (Chlorophyll-*a* >50) %	47.16	47.09	46.99	46.84	46.61	46.24	45.58	44.24	40.84	28.83	11.89	0.07
Frequency (Chlorophyll-*a* >60) %	35.75	35.68	35.59	35.45	35.23	34.89	34.28	33.04	29.96	19.7	7.02	0.02
Carlson TSI-(Phosphorus)	104.73	103.22	101.54	99.63	97.43	94.84	91.68	87.62	81.94	72.46	63.44	46.3
Carlson TSI-(Chlorophyll-*a*)	70.43	70.42	70.4	70.38	70.35	70.29	70.19	69.98	69.45	67.47	63.68	51.4
Carlson TSI-(Secchi)	68.89	68.88	68.86	68.84	68.8	68.73	68.62	68.38	67.78	65.61	61.8	52.93
Mean TSI	81.35	80.84	80.27	79.62	78.86	77.95	76.83	75.33	73.06	68.51	62.97	50.21

Existing tributary phosphorus concentrations were reduced by 10 percent successively (10 percent increments) and modeled to create an in-lake reduction curve. Reductions in each TSI category (Secchi, total phosphorus and chlorophyll-*a*) are plotted by Ecoregion 46 R beneficial use categories separately in Figure 60.

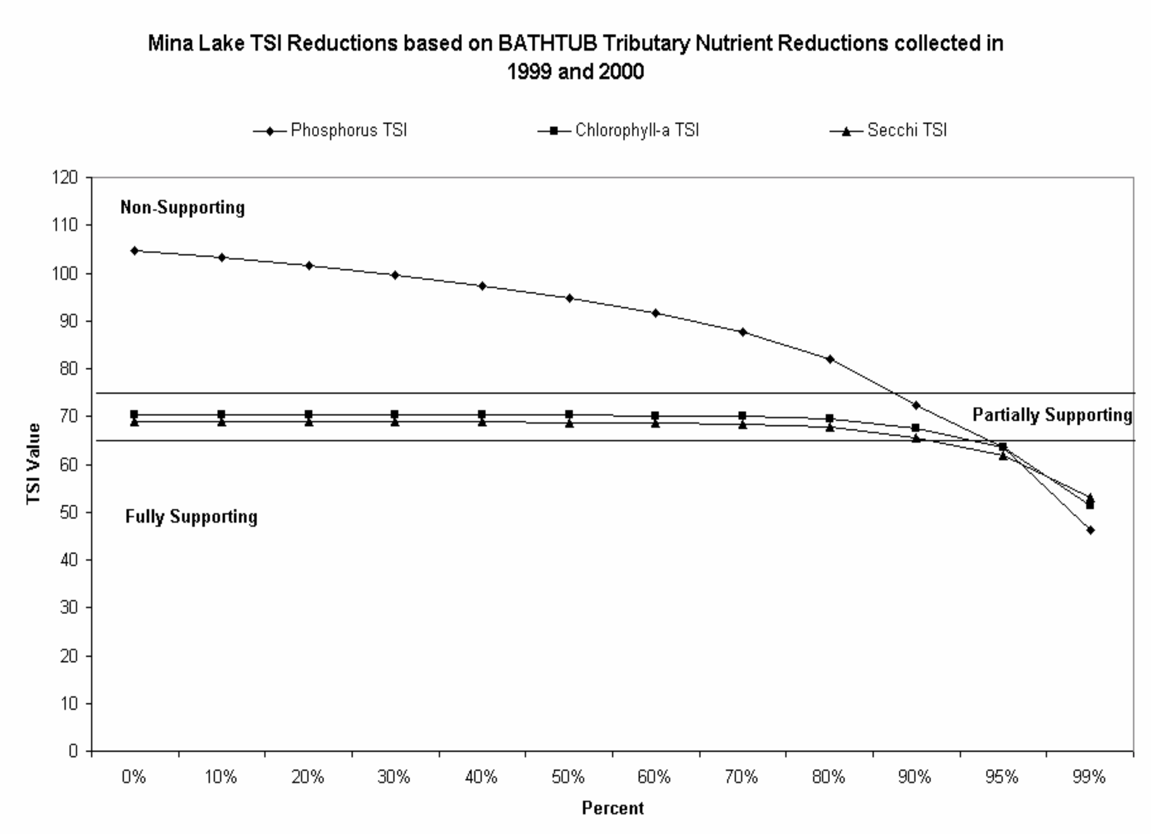


Figure 60. Predicted Trophic State Index (TSI) reductions using the BATHTUB reduction model ranked by Ecoregion 46 R beneficial use categories for Mina Lake, Edmunds County, South Dakota using 1999 data.

Initial Secchi and chlorophyll-*a* Trophic State Index reduction values all begin in the partially supporting category, while total phosphorus TSI values began in the non-supporting category. Phosphorus TSI reduction values decline at a steady rate within the non-supporting category. The Secchi and chlorophyll-*a* predicted reduction lines within the partially supporting category were basically level and began to trend downward only after an 80 percent load reduction (Figure 60). This suggests that total phosphorus in-lake concentrations must be reduced 80 percent before they affect changes in chlorophyll-*a* and Secchi TSI values, suggesting a nitrogen-limited system (Figure 19 and Figure 45). Predicted (modeled) in-lake concentrations of phosphorus need to be reduced by approximately 94.4 percent, chlorophyll-*a* concentrations by approximately 93 percent and Secchi TSI values by approximately 89 percent for Mina Lake to fall within the fully supporting beneficial use category.

The current phosphorus load to Mina Lake based on 1999 through 2000 data is 15,304 kg/yr (total phosphorus budget, pages 91 trough 93). Current phosphorus loading would have to be reduced by 14,447 kg/yr to fully support beneficial uses based on phosphorus TSI values. Reduction in in-lake phosphorus may also be realized by reducing internal loading in Mina Lake. To fully support beneficial uses based on phosphorus TSI the TMDL would be 857 kg/yr.

However, excessive tributary total phosphorus loading and elevated in-lake total phosphorus concentrations resulted in increased phosphorus TSI values (Figure 60). Based on current data, Mina Lake will not meet ecoregional based beneficial use criteria. A 94.4 percent reduction in total phosphorus loads to Mina Lake is needed to meet current criteria but this is unrealistic and unachievable. Realistic criteria/goals for Mina Lake should be based BMP reductions within the Mina Lake watershed resulting in watershed specific criteria. BMP based reduction criteria for Mina Lake was estimated based on a 38.8 percent reduction in total phosphorus loads resulting in a mean TSI of 79.18 and a TMDL of 9,366 kg/yr.

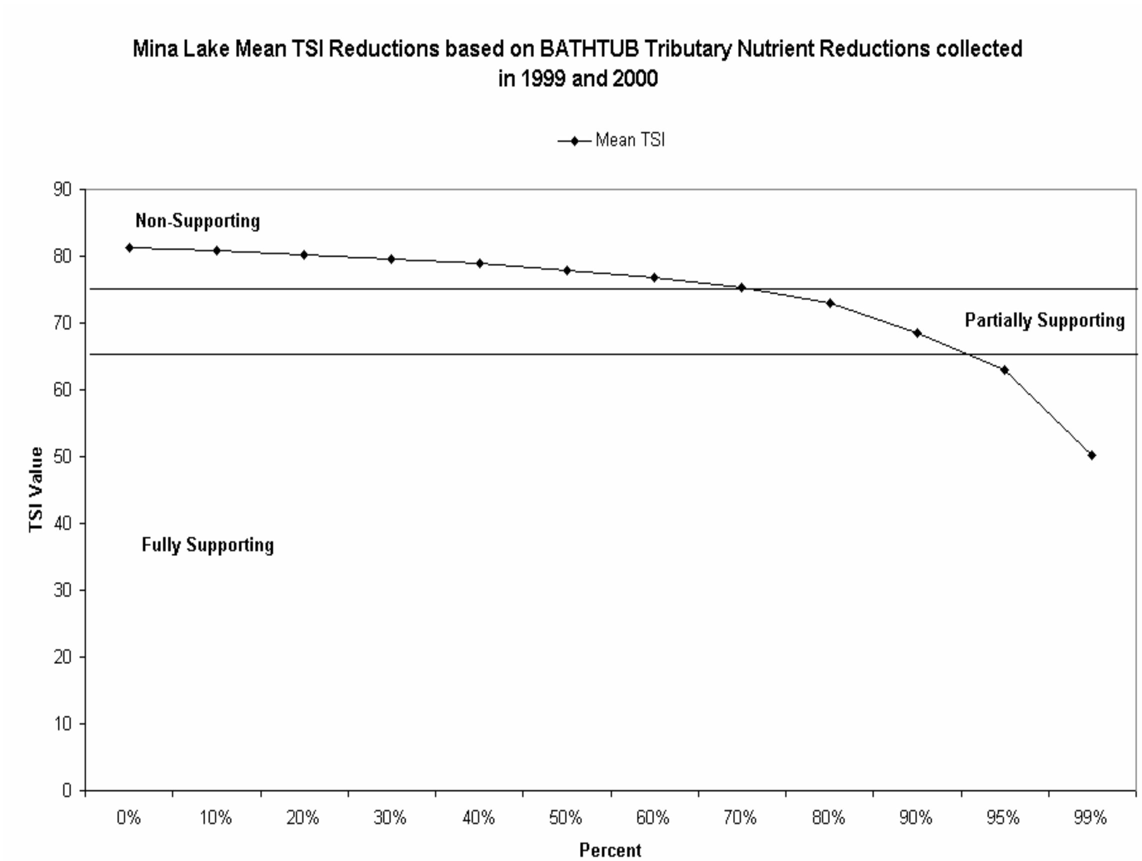


Figure 61. Predicted mean Trophic State Index (TSI) reductions using the BATHTUB reduction model ranked by Ecoregion 46 R beneficial use categories for Mina Lake, Edmunds County, South Dakota using 1999 loading data.

Mean TSI values were calculated for each reduction and plotted by beneficial use categories (Figure 61). Current mean TSI values for 1999 were calculated using "BATHTUB" and found to be non-supporting although Mina Lake is ranked as partially supporting (SD DENR 2000a). Using predicted TSI reductions based on 1999 through 2000 tributary water quality data, a 74 percent reduction in mean TSI values (approximate) will bring the lake into partially supporting status, a 94 percent reduction (approximate) will bring Mina Lake to fully supporting its beneficial uses, (Figure 61).

Based on mean TSI values, current phosphorus loading to Mina Lake would have to be reduced by 14,386 kg/yr to fully support beneficial uses. To fully support beneficial uses based on mean TSI, the total phosphorus yearly load needs to be 918 kg/yr based on 1999 and 2000 data.

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

3.2 Groundwater Monitoring

Groundwater was not monitored during the Mina Lake Watershed Assessment project.

3.3 Biological Monitoring (In-lake)

Mina Lake Phytoplankton

Planktonic algae were collected monthly, using surface grab samples, from June to October 1999 and April 2000 at two in-lake sites in Mina Lake (Figure 62) and consisted of 71 taxa (Table 42). Diatoms (Bacillariophyceae) and green algae (Chlorophyta) were the most diverse groups with 25 and 24 taxa, respectively, followed distantly by blue-green algae (Cyanophyta) with six taxa. The remaining 14 identified taxa were distributed among four phyla of motile (flagellated) algae. Of those, cryptomonads (Cryptophyta) and yellow-brown flagellates (Chrysophyta) constituted the most diverse groups with five and six taxa each. Dinoflagellates (Pyrrhophyta) and euglenoids (Euglenophyta) were represented by only two taxa and one taxon, respectively.

Table 42. Algae species collected from Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Species	Algae Type
Amphora ovalis	Diatom
Anabaena circinalis	Blue-Green Algae
Anabaena flos-aquae	Blue-Green Algae
Anabaena sp.	Blue-Green Algae
Ankistrodesmus falcatus	Green Algae
Ankistrodesmus sp.	Green Algae
Aphanizomenon flos-aquae	Blue-Green Algae
Asterionella formosa	Diatom
Botryococcus braunii	Green Algae
Ceratium hirundinella	Flagellated Algae (Dinoflagellate)
Chlamydomonas sp.	Flagellated Algae (Green Algae)
Chlorella sp.	Green Algae
Chlorogonium sp.	Flagellated Algae (Green Algae)
Chromulina sp.	Flagellated Algae (Yellow-Brown Algae)
Chroomonas sp.	Flagellated Algae (cryptophyte)
Chrysochromulina parva	Flagellated Algae (Yellow-Brown Algae)
Closteriopsis longissima	Green Algae
Closterium aciculare	Green Algae (desmid)
Cryptomonas erosa	Flagellated Algae (cryptophyte)
Cryptomonas ovata	Flagellated Algae (cryptophyte)
Cryptomonas sp.	Flagellated Algae (cryptophyte)
Cyclotella meneghiniana	Diatom
Cyclotella stelligera	Diatom
Cymatopleura solea	Diatom
Cymbella muelleri	Diatom
Cymbella triangulum	Diatom
Dictyosphaerium pulchellum	Green Algae
Dinobryon sertularia	Flagellated Algae (Yellow-Brown Algae)
Eudorina elegans	Flagellated Algae (Green Algae)
Eudorina sp.	Flagellated Algae (Green Algae)
Euglena sp.	Flagellated Algae (euglenoid)
Fragilaria capucina	Diatom
Fragilaria crotonensis	Diatom
Fragilaria sp.	Diatom
Glenodinium sp.	Flagellated Algae (Dinoflagellate)
Gloeocystis gigas	Green Algae
Mallomonas akrokomos	Flagellated Algae (Yellow-Brown Algae)
Mallomonas tonsurata	Flagellated Algae (Yellow-Brown Algae)
Melosira ambigua	Diatom
Melosira granulata	Diatom
Melosira granulata v. angustissima	Diatom
Micractinium pusillum	Green Algae
Microcystis aeruginosa	Blue-Green Algae

Table 42 (continued). Algae species collected from Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Species	Algae Type
Nitzschia acicularis	Diatom
Nitzschia palea	Diatom
Nitzschia sp.	Diatom
Nitzschia vermicularis	Diatom
Oocystis lacustris	Green Algae
Oocystis pusilla	Green Algae
Oocystis sp.	Green Algae
Oscillatoria sp.	Blue-Green Algae
Pandorina morum	Flagellated Algae (Green Algae)
Pediastrum duplex	Green Algae
Platymonas elliptica	Flagellated Algae (Green Algae)
Rhodomonas minuta	Flagellated Algae (cryptophyte)
Rhoicosphenia curvata	Diatom
Scenedesmus quadricauda	Green Algae
Selenastrum gracile	Green Algae
Selenastrum minutum	Green Algae
Spermatozoopsis sp.	Flagellated Algae (Green Algae)
Sphaerocystis schroeteri	Green Algae
Stephanodiscus astraea	Diatom
Stephanodiscus astraea minutula	Diatom
Stephanodiscus hantzschii	Diatom
Stephanodiscus niagarae	Diatom
Synedra acus	Diatom
Synedra ulna	Diatom
Synura uvella	Flagellated Algae (Yellow-Brown Algae)
Unidentified algae	Algae
Unidentified flagellates	Flagellated Algae
Unidentified pennate diatoms	Diatom
Total Species	**71**

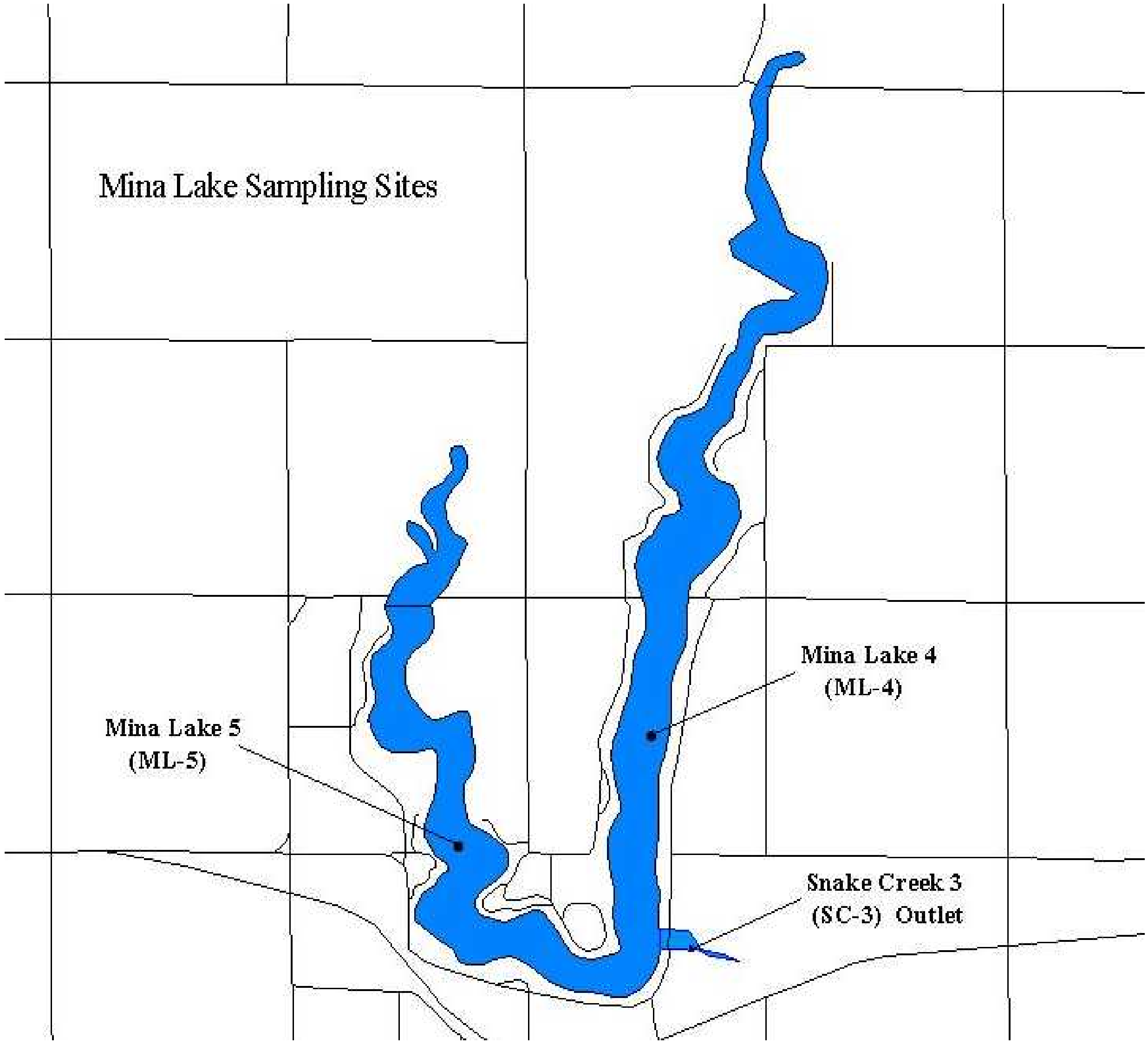


Figure 62. In-lake algal monitoring sites for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

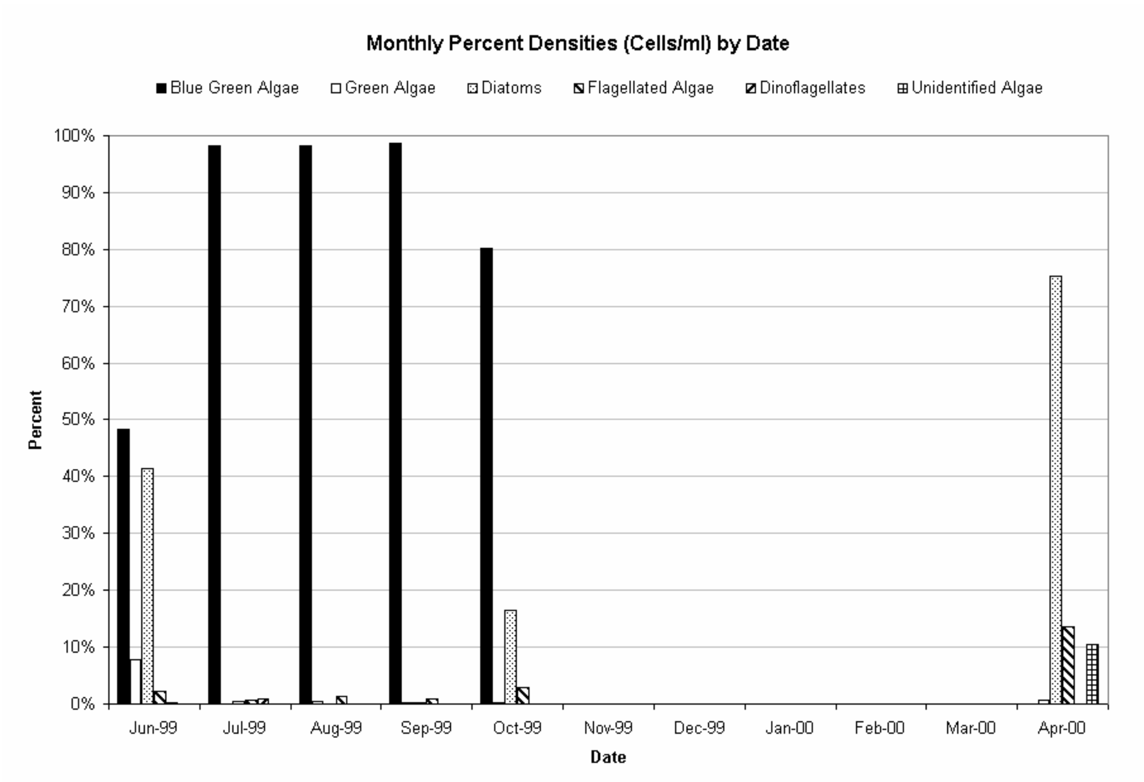


Figure 63. Monthly percent densities (cells/ml) of major algae groups by date for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Filamentous blue-green algae numerically dominated the reservoir plankton for four of the six sampling dates, mainly *Aphanizomenon flos-aquae* in July and August, and *Anabaena flos-aquae* in September and October (Figure 63). For half of the sampling dates (July to September) bluegreens were dominant in terms of biovolume (Figure 64). In June and October 1999 and April 2000, diatoms, primarily *Melosira granulata, Fragilaria crotonensis, Stephanodiscus astraea*, and *Asterionella formosa*, exceeded blue-greens in biovolume and/or density (Figure 63 and Figure 64). In July 1999, summer populations of a large-sized dinoflagellate, *Ceratium hirundinella* (particularly at ML-5) comprised 40 percent of the mean lakewide biovolume (Figure 64).

Total phytoplankton mean density and biovolume ranged from 101,026 cells/ml and 13.00 µl/L (= 13,000,000 μm^3 /ml x 10^{-6}) in August to 14,379 cells/ml and 4.78 µl/L in June 1999 and April 2000, respectively (Table 43 and Table 44). The latter disparity in the timing of density and biovolume minima was due primarily to the abundance of *Melosira granulata* (cell volume: 550 μm^3) in June which had more than twice the volume of *Asterionella formosa* that was most abundant in April 2000. Mean algal density of the two sites was 47,110 cells/ml and biovolume averaged 8.22 µl/L for the project. Site ML-5 contributed 82 percent of this density and 72 percent of the total algal biovolume (Figure 65 and Figure 66).

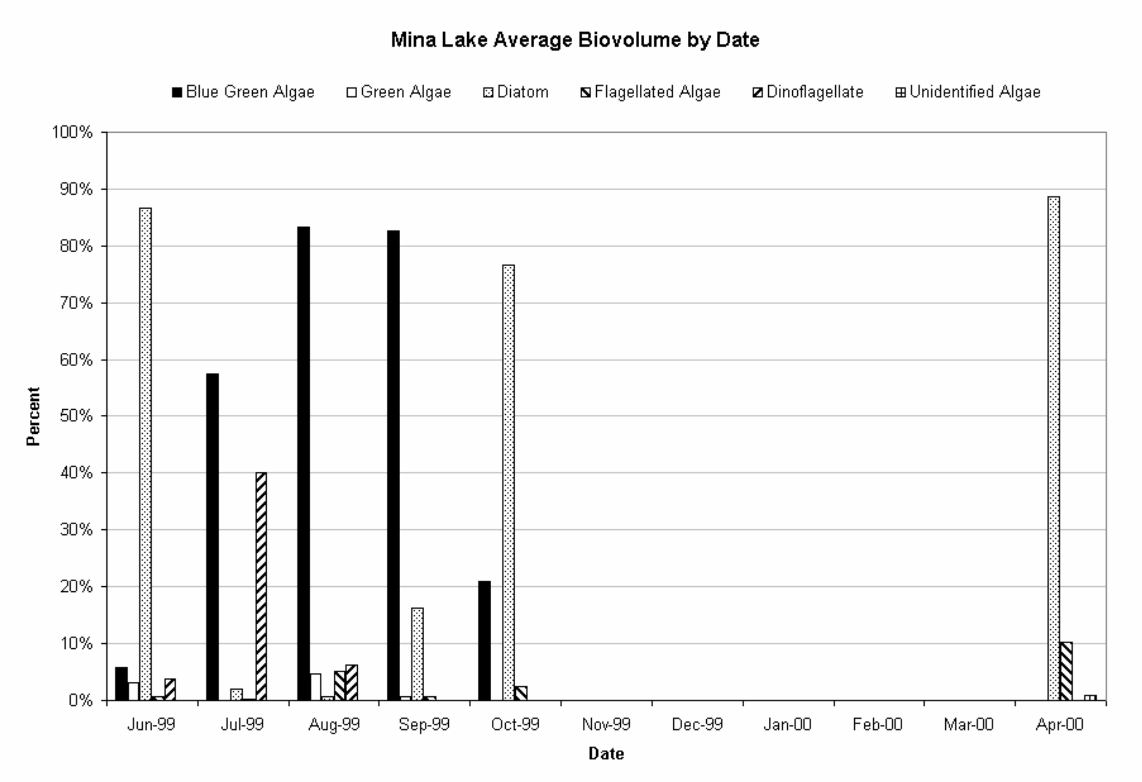


Figure 64. Monthly algal biovolume (µm^3/ml) percentages by algal type and date for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

The initial algae samples for this short survey were collected in early summer on June 29,1999. Analysis of samples from both sites indicated a mean population of 14,379 algal cells/ml, the smallest density obtained during this study. Population densities were similar for both sites in late June, each being within 10 percent of the above mean (Table 43 and Figure 65). The biovolumes for the two sites were somewhat more divergent with a 16 percent difference (Table 44 and Figure 66). For the only time in this survey, there was a greater algal volume recorded at site ML-4 than at site ML-5 (Figure 66), due to greater abundance of the filamentous diatom *Melosira granulata* at site ML-4 in June (Table 43 and Appendix E). Other diatoms common at one or both sites included *Fragilaria crotonensis* and *Asterionella formosa*. All diatoms comprised nearly 64 percent of total algal density and 87 percent of total biovolume. Algal groups of lesser importance in late June were several taxa of green algae, blue-greens and flagellated algae. Dinoflagellates represented the least common group recorded for the month (Table 43).

Table 43. Mina Lake algal density (cells/ml) for 1999 and 2000.

Date	Algae Type	ML-4	ML-5	Total	Average	Percent
29-Jun-99	**Blue Green Algae**	684	7,398	8,082	4,041	28.1%
	Diatom	11,971	6,326	18,297	9,149	63.6%
	Dinoflagellate	19	35	54	27	0.2%
	Flagellated Algae	250	331	581	291	2.0%
	Green Algae	536	1208	1744	872	6.1%
29-Jun-99 Total		13,460	15,298	28,758	14,379	
19-Jul-99	**Blue Green Algae**	1,088	118,660	119,748	59,874	97.7%
	Diatom	273	430	703	352	0.6%
	Dinoflagellate	35	966	1001	501	0.8%
	Flagellated Algae	203	698	901	451	0.7%
	Green Algae	209	54	263	132	0.2%
19-Jul-99 Total		1,808	120,808	122,616	61,308	
25-Aug-99	**Blue Green Algae**	25,761	167,734	193,495	96,748	95.8%
	Diatom	363		363	182	0.2%
	Dinoflagellate	91	72	163	82	0.1%
	Flagellated Algae	1,880	2,434	4,314	2,157	2.1%
	Green Algae	3,000	716	3,716	1,858	1.8%
25-Aug-99 Total		31,095	170,956	202,051	101,026	
21-Sep-99	**Blue Green Algae**	20,988	98,907	119,895	59,948	96.7%
	Diatom	2,276	331	2,607	1,304	2.1%
	Flagellated Algae	204	826	1030	515	0.8%
	Green Algae	243	166	409	205	0.3%
21-Sep-99 Total		23,711	100,230	123,941	61,971	
12-Oct-99	**Blue Green Algae**	8,331	21,935	30,266	15,133	72.6%
	Diatom	5,512	4,509	10,021	5,011	24.0%
	Flagellated Algae	452	820	1,272	636	3.1%
	Green Algae	48	88	136	68	0.3%
12-Oct-99 Total		14,343	27,352	41,695	20,848	
06-Apr-00	**Blue Green Algae**	55	15	70	35	0.2%
	Diatom	13,527	21,167	34,694	17,347	75.0%
	Dinoflagellate	1	1	2	1	0.0%
	Flagellated Algae	2,715	3,855	6,570	3,285	14.2%
	Green Algae	13	173	186	93	0.4%
	Unidentified Algae	1,800	2,940	4,740	2,370	10.2%
06-Apr-00 Total		18,111	28,151	46,262	23,131	
Grand Total		102,528	462,795	565,323	282,662	

The next samples collected on July 19,1999, indicated a fourfold increase in mean algal density to 61,308 cells/ml due to the presence of a dense bloom of *Aphanizomenon flos-aquae* at site ML-5 estimated at 118,660 cells/ml. Total biovolume at site ML-5 also increased fourfold from June levels to 23.6 µl/L. By contrast, no substantial bloom of any kind was evident at site ML-4 where algae density and biovolume had fallen to the smallest values recorded for the study (Table 43 and Table 44). *Aphanizomenon* was present at a moderate density of 1,088 cells/ml. The cause of that wide disparity may be due to differences in nutrient loads to the two arms of the reservoir from two respective sub-watersheds (Figure 12 and Figure 17). Large differences in algal populations between in-lake sites can be expected in waterbodies of irregular morphology such as Mina Lake with different sampling sites influenced by different tributaries and sub-watersheds. For example, similar sharp and localized differences in the size of algal biomass (chlorophyll-*a* concentration) were noted in Richmond Lake, another reservoir with a comparably shaped basin (SD DENR, 1990).

Table 44. Mina Lake algal biovolume (µm^3/ml) for 1999 and 2000

Date	Type	ML-4	ML-5	Total	Average	Percent
29-Jun-99	Blue Green Algae	54,720	750,348	805,068	402,534	5.8%
	Diatom	7,617,817	4,339,512	11,957,329	5,978,665	86.6%
	Dinoflagellate	186,200	343,000	529,200	264,600	3.8%
	Flagellated Algae	42,114	59,440	101,554	50,777	0.7%
	Green Algae	131,516	284,679	416,195	208,098	3.0%
29-Jun-99 Total		8,032,367	5,776,979	13,809,346	6,904,673	
19-Jul-99	Blue Green Algae	127,296	13,883,220	14,010,516	7,005,258	57.4%
	Diatom	264,543	236,500	501,043	250,522	2.1%
	Dinoflagellate	343,000	9,466,800	9,809,800	4,904,900	40.2%
	Flagellated Algae	18,506	39,988	58,494	29,247	0.2%
	Green Algae	28,004	1,350	29,354	14,677	0.1%
19-Jul-99 Total		781,349	23,627,858	24,409,207	12,204,604	
25-Aug-99	Blue Green Algae	2,981,430	18,674,595	21,656,025	10,828,013	83.3%
	Diatom	200,490	0	200,490	100,245	0.8%
	Dinoflagellate	891,800	705,600	1,597,400	798,700	6.1%
	Flagellated Algae	256,910	1,078,198	1,335,108	667,554	5.1%
	Green Algae	1,065,777	157,139	1,222,916	611,458	4.7%
25-Aug-99 Total		5,396,407	20,615,532	26,011,939	13,005,970	
21-Sep-99	Blue Green Algae	1,769,454	8,336,757	10,106,211	5,053,106	82.6%
	Diatom	1,793,987	185,277	1,979,264	989,632	16.2%
	Flagellated Algae	40,992	36,282	77,274	38,637	0.6%
	Green Algae	41,823	31,623	73,446	36,723	0.6%
21-Sep-99 Total		3,646,256	8,589,939	12,236,195	6,118,098	
12-Oct-99	Blue Green Algae	770,265	1,883,745	2,654,010	1,327,005	21.0%
	Diatom	5,315,875	4,356,910	9,672,785	4,836,393	76.6%
	Flagellated Algae	78,930	217,790	296,720	148,360	2.3%
	Green Algae	1,200	2,200	3,400	1,700	0.0%
12-Oct-99 Total		6,166,270	6,460,645	12,626,915	6,313,458	
06-Apr-00	Blue Green Algae	1,450	1,200	2,650	1,325	0.0%
	Diatom	3,156,410	5,315,325	8,471,735	4,235,868	88.7%
	Dinoflagellate	700	700	1,400	700	0.0%
	Flagellated Algae	398,727	577,337	976,064	488,032	10.2%
	Green Algae	700	5,614	6,314	3,157	0.1%
	Unidentified Algae	36,000	58,800	94,800	47,400	1.0%
06-Apr-00 Total		3,593,987	5,958,976	9,552,963	4,776,482	
Grand Total		27,616,636	71,029,929	98,646,565		

By late August, the blue-green bloom at site ML-5 had grown larger after *Aphanizomenon* density increased to 142,392 cells/ml and two species of *Anabaena* appeared in the late summer plankton as 21,763 cells/ml. In addition, *Microcystis aeruginosa* was collected at site ML-5 as 3,579 cells/ml. The total cell count for these taxa of 167,734 cells/ml represented the annual blue-green maximum recorded for 1999 in Mina Lake (Figure 65). *Aphanizomenon* density also increased at site ML-4 to form a moderate bloom of 23,086 cells/ml. *Anabaena* spp. amounted to 2,675 cells/ml at this site. While the lakewide algae population and that of site ML-5 had increased to an annual peak in August, the biovolume for site ML-5 indicated a moderate decrease from the July value (Figure 65 and Figure 66) caused by a steep decline in the local population of *Ceratium hirundinella*. This is one of the largest-sized dinoflagellates common to in-lake plankton with a cell volume estimated at 9,890 μm^3.

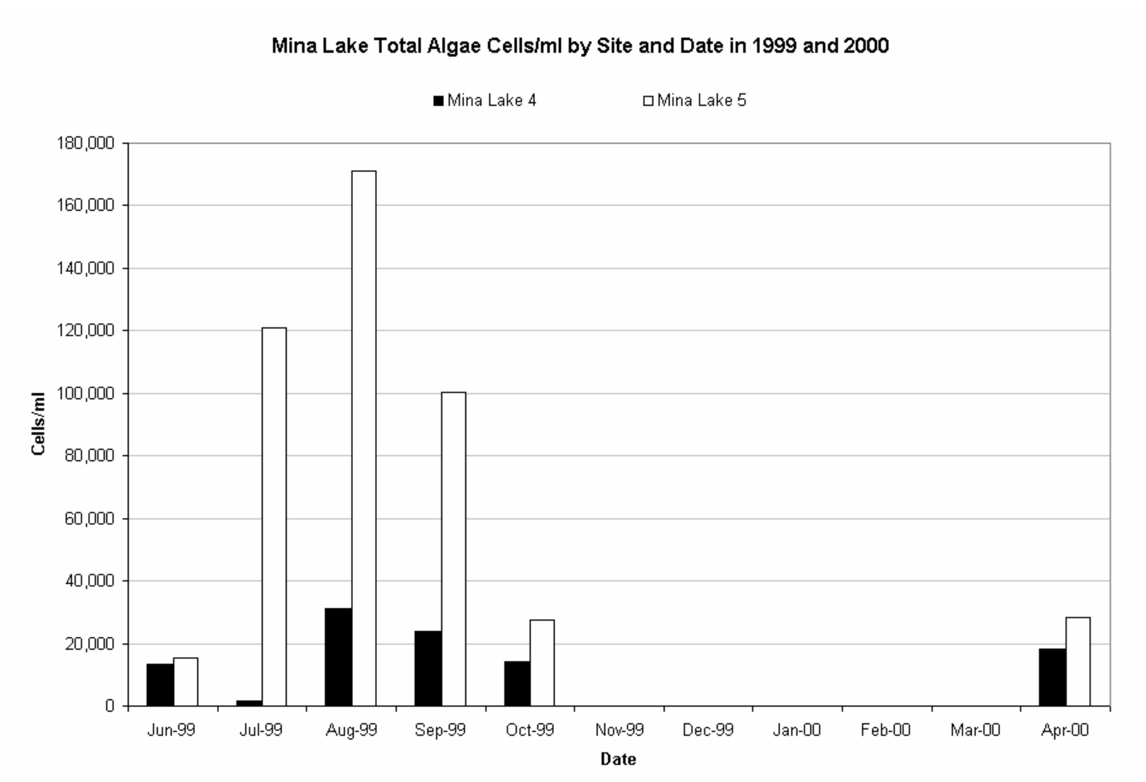


Figure 65. Total algal cells per milliliter by site and date for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

September mean algae density declined by 38.7 percent from 101,026 cells/ml in August to 61,971 cells/ml, primarily as a result of a significant decrease in the large August *Aphanizomenon* population (Table 43). A comparable decline in biovolume was also noted between those months. In September, *Aphanizomenon* was replaced by *Anabaena flos-aquae* and *Microcystis aeruginosa* as the most abundant algae in the plankton community. Decreases in flagellated algae were also noted, mainly in the cryptomonads *Rhodomonas minuta* and *Cryptomonas erosa*, and green algae. Diatoms, mainly

Fragilaria crotonensis, was the only algal group that showed an increase in September (Table 45). Diatoms are frequently present in larger numbers during spring and autumn in temperate latitudes (Hutchinson 1967).

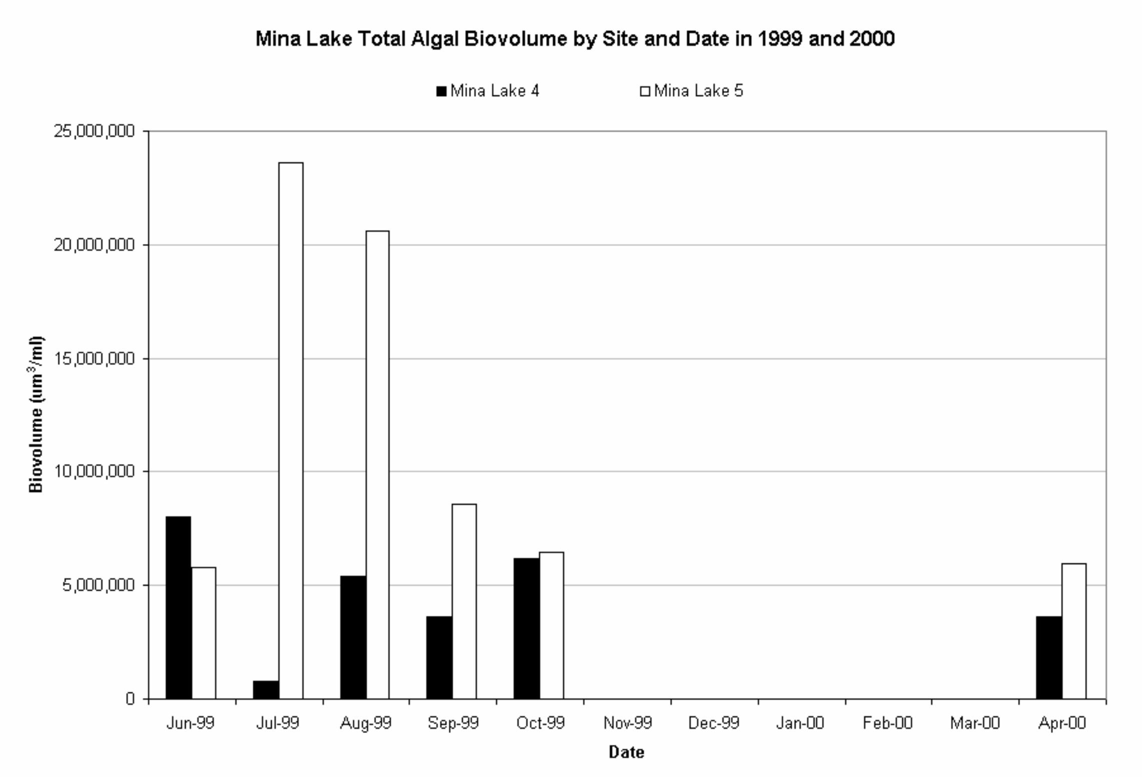


Figure 66. Total algal biovolume (µm^3/ml) by site and date for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Despite a moderate diatom bloom that developed in mid October, total algal densities fell to 20,848 cells/ml. Blue-green algae, mainly *Anabaena flos-aquae,* remained numerically dominant, comprising nearly 73 percent of the algal density in October. However, diatoms, primarily *Fragilaria crotonensis*, *Melosira ambigua,* and *Stephanodiscus astraea* (probably *S. niagarae*) made up 24 percent of total density and nearly 77 percent of the biovolume (Table 43, Table 44 and Appendix E). The October and June algae communities were comparable in total algal abundance, biovolume, abundance of diatoms, and general similarity between the in-lake sites (Figure 65 and Figure 66, pages 114 and 115).

The final samples of this survey were collected the following year on April 6, 2000. Sample analysis indicated an early spring bloom of *Asterionella formosa* which was present at a mean density of 12,960 cells/ml and composed 56 percent of April plankton numbers and nearly 60 percent of total biovolume. *Asterionella* is a common planktonic diatom that often produces large spring populations and small autumnal ones (Round 1965). Although *Asterionella* was not collected in Mina Lake during autumn, the remnants of a fall bloom of this diatom were collected in Lake Louise, a narrow reservoir in east central South Dakota. Diatoms comprised 75 percent of April plankton numbers in Mina Lake and 89 percent of the biovolume. Besides *Asterionella*, the only other diatom considered abundant in April was a small centric species, *Stephanodiscus hantzschii*. As on most other sampling dates, larger algae populations were collected at site ML-5. Other than flagellated algae, other algal groups such as blue-greens and green algae occurred in trace densities in early April at both sites. The most common flagellated algae included *Chrysochromulina sp.* and *Chroomonas* sp. Butcher 1967 (= *Rhodomonas minuta*).

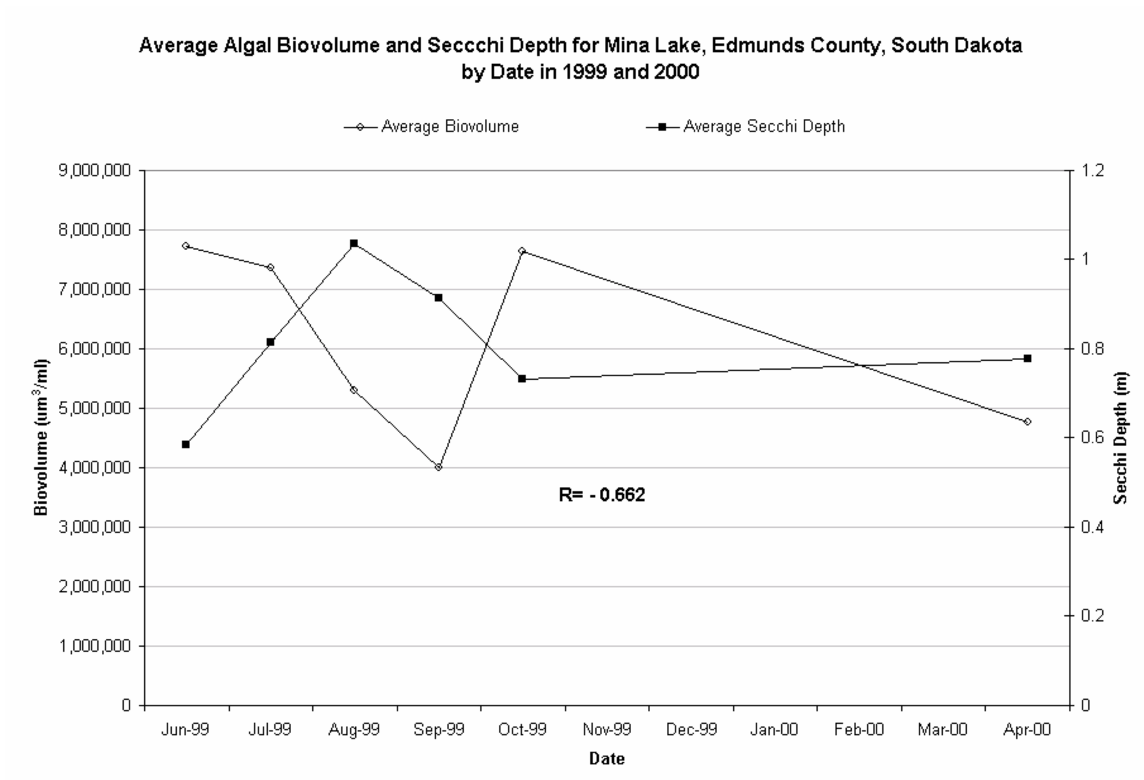


Figure 67. Average algal biovolume (µm^3/ml) and Secchi depth by date for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Because past sampling of Mina Lake algae populations has been somewhat limited, few reliable conclusions can be drawn regarding historical changes and trends in the algae communities of this highly eutrophic (hyper-eutrophic) reservoir. Lake assessment samples collected in June and August of 1979 indicated a low to moderate summer algal population dominated by *Anabaena flos-aquae* with small numbers of *Aphanizomenon* sp. and *Melosira* sp. (Koth 1981). Total algae densities amounted to 4,890 cells/ml in June and only 399 cells/ml in August 1979. However, chlorophyll-*a* averaged 30 mg/m^3 for the two months. Secchi visibility was fair to good for a eutrophic lake, averaging 1.75 meters (5.7 feet), with summer stratification occurring in August 1999 (Appendix

G). Phosphorus and chlorophyll-*a* levels indicated Mina Lake was highly eutrophic in 1979.

The next algae samples were collected 10 years later on July 19, 1989 in turbid water conditions (Secchi visibility: 0.22 m). Algae density was a low 63 units/ml (Stueven and Stewart, 1996). The following algae samples were again collected after nearly a decade in June and August 1998. These indicated moderately high algae densities of 54,770 cells/ml and 48,416 cells/ml, respectively. A moderate bloom of *Aphanizomenon flos-aquae* (25,210 cells/ml) was detected on June 29 but only trace numbers of this taxon (925 cells/ml) were present in August 1998.

Twice-yearly assessment sampling for the years 1979, 1989, 1991, and 1994 (Koth, 1981 and Stueven and Stewart, 1996), suggested that chlorophyll-*a* (algae density in 1989) and Secchi visibility values were directly correlated whereas in 1998 and, particularly, in the more extensive present survey, average algae biovolume and mean Secchi visibility values showed a inverse correlation of $R = -0.662$ (Figure 67). This would indicate suspended sediment (silt and clay) had more of an influence on Secchi disk visibility than algae populations prior to 1998, whereas the opposite was true in 1998 and 1999. While these data are sparse and circumstantial, they seem to suggest a recent and substantial decrease in sediment turbidity of Mina Lake waters particularly during 1998 and 1999. This may partially account for the large summer algae populations present in those two years compared to the previous years listed in the first sentence of this paragraph.

No summer stratification was detected in Mina Lake from 1979 to 1994. Algae cells would therefore have been circulated into the deeper layers of the water column by summer winds and have had limited exposure to adequate illumination in the upper water layers, especially under conditions of high sediment turbidity. Under those light-limiting conditions, algae populations would be expected to be small. Stratification in summer would reduce the depth of algal circulation to the depth of the epilimnion, thus substantially increasing the cells’ exposure to adequate light even under conditions of considerable sediment turbidity. Some stratification temporarily developed in summer of August 1999 in the deeper areas of the reservoir since algal populations on July 19 were 7 and 90 times larger near the water surface than near the bottom, 20 feet and 12 feet down, at sites ML-4 and ML-5, respectively. Possibly, there may have been no enduring thermal stratification, but the mixing of the reservoir water by wind-induced wave action and tributary inflow may have been limited to 9 or 10 feet from the surface, thus creating a still zone in the deeper layers where most plankton arriving from the upper water strata could not remain suspended in the water column but would quickly sink to the bottom substrate. This would not apply to a few actively buoyant blue-green species such as *Aphanizomenon* and some *Anabaena* species.

Aquatic Macrophyte Survey

An aquatic macrophyte survey of Mina Lake was conducted on August 26 and August 30, 1999. The survey consisted of surveying the entire shoreline and identifying emergent and terrestrial plant species followed by 32 in-lake transects to quantify the submergent plant community (Figure 68). Each transect had from one to three survey points to evaluate the macrophyte community (approximately ten and thirty meters from shore). Sampling at each survey point consisted of casting a plant grapple approximately six meters in four separate directions (north, south, east and west), slowly retrieving the grapple and identifying plant species retained on the grapple.

Table 45. Terrestrial and emergent plant species identified during the shoreline survey of Mina Lake, Edmunds County, South Dakota in 1999.

Number		Scientific Name
	Emergent and Terrestrial Shoreline Species	
1	Arrowhead	*Sagittaria latifolia var. obtusa*
2	Green Ash	*Fraxinus pennsylvanica*
3	Common Reed	*Phragmites australis*
4	Cottonwood	*Poplar* sp.
5	Curly Dock	*Rumex crispus*
6	Dull-Leaf Indigo	*Amorpha fruticosa*
7	Elm	*Ulmus* sp.
8	Maple	*Acer* sp.
9	Narrow-leaf Cattail	*Typha angustifolia*
10	Prairie Cordgrass	*Spartina pectinata*
11	Reed Canary Grass	*Phalaris arundinacea*
12	River Bulrush	*Scirpus fluviatilis*
13	Russian Olive	*Elaeagnus angustifolia*
14	Sandbar Willow	*Salix longifolia*
15	Silver Maple	*Acer saccharinum*
16	Slender Flatsedge	*Cyperus odoratus*
17	Soft-stem Bulrush	*Scirpus validus*
18	Spearmint	*Mentha arvensis*
19	Sumac	*Rhus glabra*
20	Swamp Smartweed	*Polygonum coccineum*
21	Weeping Willow	*Salix babylonica*
22	White Sweet Clover	*Melliotus alba*
23	Willow	*Salix* sp.

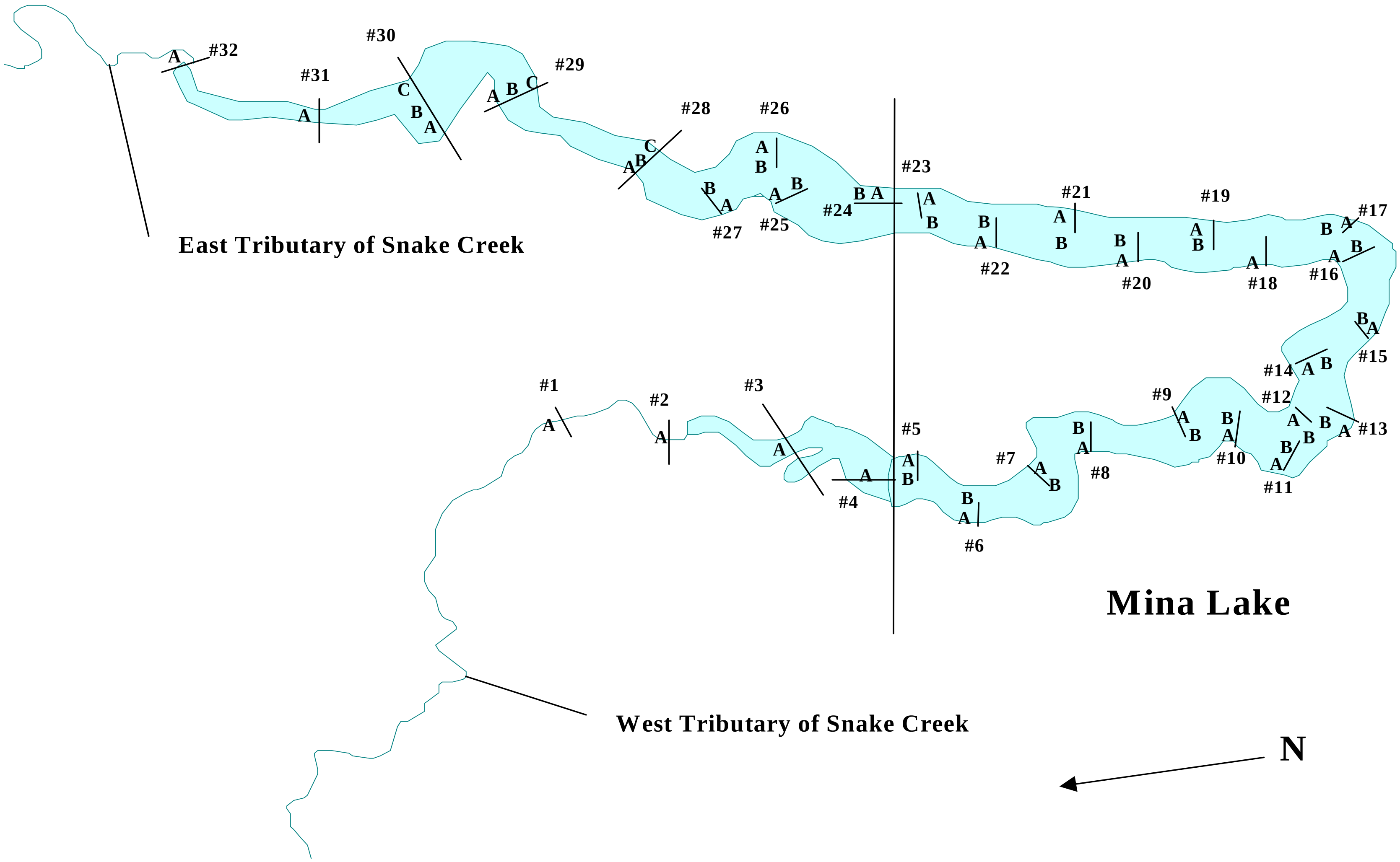


Figure 68. Submergent macrophyte transect locations at Mina Lake, Edmunds County, South Dakota in 1999.

The shoreline survey identified a number of common riparian emergent and wetland (lakeshore) plant species similar to other lakes in this ecoregion (Ecoregion 46R, SD DENR 2000a). Aquatic plant species were identified using Fassett (1957) and are listed in Table 45. Narrow-leaf cattail (*Typha angustifolia*) was the most abundant shoreline species in the upper reaches of both the east and the west arms of Mina Lake in 1999.

Table 46. Submergent plant species identified in Mina Lake, Edmunds County, South Dakota in 1999.

Number		Scientific Name
	Shoreline Submerged Species	
1	Coontail	*Ceratophyllum demersum*
2	Lesser Duckweed	*Lemna minor*
3	Sago Pondweed	*Stuckenia pectinata*
4	Clasping Leaf Pondweed	*Potamogeton Richardsonii*
	Transect Submerged Species	
1	Coontail	*Ceratophyllum demersum*
2	Sago Pondweed	*Stuckenia pectinata*
3	Clasping Leaf Pondweed	*Potamogeton Richardsonii*

Submergent macrophyte species were sampled using 32 transects (Figure 68) with 61 survey points throughout the lake. Four separate shoreline species were identified during the survey and are listed on Table 46. Three of the four shoreline species, sago pondweed (*Stuckenia pectinata*), clasping leaf pondweed (*Potamogeton Richardsonii*) and coontail (*Ceratophyllum demersum*) were identified at transect sampling locations. Only eight sampling locations (survey points) yielded submerged vegetation (Table 47 and Table 48).

There were significantly more shoreline submergent species (the number of submergent species sampled at the shoreline of each transect) than transect submergent species (the number of species sampled at each sampling location) ($p<0.05$). However, no significant difference in shoreline submergent species was detected between the east and west arms of Mina Lake ($p>0.05$).

Depth of sampling sites (A) were significantly shallower than sampling sites (B) which correlates with significantly more submerged macrophyte species collected at sampling sites A ($p<0.05$). No significant difference in submerged transect species was detected between the two arms of Mina Lake ($p>0.05$).

Table 47. Shoreline and transect submergent plant species sampled from the west arm of Mina Lake, Edmunds County, South Dakota in 1999.

Transect and Station	Total Depth (m)	Secchi Depth (m)	Shoreline Submergent Species	Transect Species	Transect Density
1A	1.34	0.30	*Lemna minor* (2 Shores)	*Stuckenia pectinata*	2
				Ceratophyllum demersum	1
2A	2.04	0.55	*Lemna minor* (2 Shores)	None	0
			Stuckenia pectinata (2 Shores)		
			Ceratophyllum demersum (2 Shores)		
3A	1.49	0.46	*Lemna minor* (2 Shores)	*Ceratophyllum demersum*	1
			Stuckenia pectinata (2 Shores)		
			Ceratophyllum demersum (2 Shores)		
4A	2.35	0.58	*Stuckenia pectinata* (1 Shore)	None	0
5A	1.07	0.34	*Stuckenia pectinata*	None	0
			Potamogeton Richardsonii		
5B	1.52	0.30	None	None	0
6A	3.26	0.34	None	None	0
6B	3.54	0.34	-	None	0
7A	1.89	0.46	None	None	0
7B	3.35	0.46	-	None	0
8A	2.10	0.40	None	None	0
8B	2.96	0.46	-	None	0
9A	1.34	0.49	None	None	0
9B	2.50	0.52	-	None	0
10A	0.88	0.49	None	*Stuckenia pectinata*	1
10B	1.55	0.46	-	None	0
11A	1.58	0.64	*Stuckenia pectinata*	None	0
11B	1.92	0.73	-	None	0
12A	1.22	0.67	*Potamogeton Richardsonii*	None	0
12B	2.65	0.61	-	None	0
13A	0.91	0.88	*Potamogeton Richardsonii*	*Stuckenia pectinata*	3
				Potamogeton Richardsonii	1
13B	4.27	0.94	-	None	0
14A	1.52	0.91	*Stuckenia pectinata*	*Stuckenia pectinata*	3
14B	2.35	0.88	-	None	0
15A	1.65	0.76	None	None	0
15B	2.44	0.76	-	None	0
16A	2.19	1.07	*Stuckenia pectinata*	*Stuckenia pectinata*	1
16B	3.51	1.01	-	None	0

Table 48. Shoreline and transect submergent plant species sampled from the east arm of Mina Lake, Edmunds County, South Dakota in 1999.

Transect and Station	Point Depth (m)	Secchi Depth (m)	Shoreline Submergent Species	Transect Species	Transect Density
17A	2.04	0.91	None	None	0
17B	4.51	0.91	-	None	0
18A	2.07	0.91	*Stuckenia pectinata*	None	0
18B	2.87	1.07	-	None	0
19A	2.41	1.07	*Potamogeton Richardsonii*	None	0
19B	4.11	1.07	-	None	0
20A	2.32	1.22	None	None	0
20B	3.05	1.19	-	None	0
21A	2.19	1.10	*Stuckenia pectinata*	None	0
21B	2.93	1.13	-	None	0
22A	2.07	1.07	*Stuckenia pectinata*	None	0
22B	2.77	0.91	-	None	0
23A	1.89	0.94	None	None	0
23B	2.44	0.98	-	None	0
24A	4.60	0.55	None	None	0
24B	4.63	0.52	-	None	0
25A	1.01	0.58	None	None	0
25B	1.71	0.55	-	None	0
26A	1.98	0.52	None	None	0
26B	2.99	0.55	-	None	0
27A	1.31	0.40	*Stuckenia pectinata*	None	0
27B	2.23	0.37	-	None	0
28A	1.55	0.34	None	None	0
28B	2.99	0.37	-	None	0
28C	1.89	0.34	-	None	0
29A	1.55	0.30	None	None	0
29B	2.29	0.30	-	None	0
29C	2.71	0.34	-	None	0
30A	1.98	0.30	None	None	0
30B	1.68	0.30	-	None	0
30C	1.52	0.27	*Lemna minor* (East Shore)	None	0
31A	1.22	0.24	*Stuckenia pectinata* (2 Shores) *Ceratophyllum demersum* (2 Shores)	*Stuckenia pectinata*	2
32A	1.01	0.46	*Lemna minor* (2 Shores) *Ceratophyllum demersum* (2 Shores)	Ceratophyllum demersum	5

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 the east arm of 0.70 meter (2.30 feet) was slightly less than that of the west arm-0.75 meter (2.46 feet). Calculations were based upon the average measured Secchi depth in meters during the aquatic macrophyte survey (Table 47 and Table 48). The average MDC for Mina Lake was 0.72 meter (2.37 feet). MDC values agree with sample collection data which indicated that both the shoreline and shallower transect sites (A) had significantly more submerged macrophytes than did transect sites (B).

The lack of submerged vegetation in Mina Lake appears to be a result of decreased light penetration due to organic and inorganic turbidity. 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 Mina Lake conducive to colonization, which will increase the uptake of nutrients and increase habitat for fish and macroinvertebrates.

3.4 Other Monitoring

Fisheries Data

The most recent fisheries survey data was collected by South Dakota Game, Fish and Parks from August 5 through August 7, 1997. That report is summarized below and is presented in Appendix H. Mina Lake is being managed using the latest management plan (F-21-R-28) 1994. The lake is classified as a warm-water permanent fishery and supports fifteen species of fish.

Fish collection consisted of setting six monofilament gill nets and seventeen overnight double framed trap nets for three nights. Frame nets were constructed with steel frames and 1.9 cm (0.75 inch) bar mesh netting. All nets were checked, emptied and moved to a new location every 24 hours. Fish captured in each net were measured (total length in millimeters), weighed (grams) and identified to species. Captured walleye/saugeye had scale samples taken to back-calculate length by year class (age). Other sampling techniques (shoreline seining – late August 1997 and a creel survey May through August 1997) were also used during this survey.

South Dakota Game, Fish and Parks (SD GF&P) recommendations for Mina Lake were 1.) Manage primarily for saugeye and black crappie and continue large fingerling stocking at 2.0 pounds/acre, 2.) Electrofish to determine status of bass populations, 3.) Determine feasibility of establishing a low-density trophy muskellunge fishery or stocking northern pike to increase density and 4.) To maximize predatory effects on black crappie, to extend the length of time these fish contribute to the fishery and to increase the size of fish in angler creels, a 432 mm (17-inch) minimum length limit should be considered for the Mina Lake fishery.

Endangered Species

The South Dakota Natural Heritage Database identified one species, the whooping crane, as being endangered. This database contains documented identifications of rare, threatened or endangered species across the state and is listed in Appendix I. The whooping crane (*Grus americana*), a federally-listed endangered species, has been recorded in the Snake Creek/ Mina Lake watershed. It was last observed in the watershed on April 24, 1977. The State of South Dakota lists the whooping crane as SZ, no definable occurrences for conservation purposes, a category usually assigned to migrants. There are no other threatened or endangered species documented in the Snake Creek watershed; however, three species are identified as being rare. Species identified as rare in the Mina Lake watershed were two bird species, Cooper's hawk (*Accipiter cooperii*) and Henslow's sparrow (*Ammodramus henslowii*) and one fox species, kit or swift fox (*Vulpes velox*). 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 was encountered during this study; however, care should be taken when conducting mitigation projects in the Mina Lake/Snake Creek watershed.

3.5 Quality Assurance Reporting

Eleven quality assurance and quality control (QA/QC) samples were collected throughout the summer and fall 1999 and spring 2000 sampling periods for both the tributary and in-lake sampling sites. Standard chemical analysis was performed on all blank and duplicate samples collected. Analysis followed both the tributary and in-lake standard routine chemical parameters for analysis and are listed in Table 2 for tributary samples and Table 30 for in-lake samples. Un-ionized ammonia was not calculated for tributary and in-lake QA/QC samples because all ammonia values were at or below laboratory detection limits (0.02 mg/L).

Duplicate 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.

Table 49. Tributary quality assurance quality/control samples collected in Snake Creek, Edmunds and McPherson Counties, South Dakota in 1999 and 2000.

Site	Time	Date	Air Temp (° C)	Field pH (su)	DO (mg/L)	Water Temp. (° C)	Fecal Coliform (#/100 ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Organic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Volatile Total Suspended Solids (mg/L)
SC2	1230	07/27/99	-	-	-	-	10	7	5	4	1	0.14	0.02	0.1	0.12	0.24	0.002	0.012	1
SC12	1130	10/21/99	-	-	-	-	10	7	7	6	1	0.14	0.02	0.1	0.12	0.24	0.007	0.002	1
SC13	1015	03/27/00	-	-	-	-	10	6	7	6	1	0.21	0.02	0.1	0.19	0.31	0.002	0.002	1
Mean							10.0	6.7	6.3	5.3	1.0	0.16	0.02	0.1	0.14	0.26	0.004	0.005	1.0
Standard Deviation							0.00	0.58	1.15	1.15	0.00	0.04	0.00	0.00	0.04	0.04	0.003	**0.006**	0.00
SC7	930	03/27/00	12	8.17	9.4	6	10	176	1585	1568	17	2.58	0.02	0.7	2.56	3.28	0.658	0.494	2
SC7	930	03/27/00	12	8.17	9.4	6	10	176	1585	1568	17	2.47	0.02	0.7	2.45	3.17	0.650	0.524	3
Industrial Statistic (%I)			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.18%	0.00%	0.00%	2.20%	1.71%	0.61%	2.95%	**20.00%**
SC1	1045	07/07/99	31	7.83	5.4	25	840	400	1277	1255	22	2.75	0.02	0.1	2.73	2.85	1.930	1.78	6
SC1	1045	07/07/99	31	7.83	5.4	25	610	407	1277	1257	20	2.83	0.02	0.1	2.81	2.93	1.940	1.78	3
Industrial Statistic (%I)			0.00%	0.00%	0.00%	0.00%	**15.86%**	0.87%	0.00%	0.08%	4.76%	1.43%	0.00%	0.00%	1.44%	1.38%	0.26%	0.00%	**33.33%**
SC7	930	07/27/99	23	7.3	1	24	200	166	681	675	6	2.47	0.02	0.1	2.45	2.57	1.980	1.79	1
SC7	930	07/27/99	23	7.3	1	24	120	165	681	674	7	2.40	0.02	0.1	2.38	2.50	1.890	1.82	1
Industrial Statistic (%I)			0.00%	0.00%	0.00%	0.00%	**25.00%**	0.30%	0.00%	0.07%	7.69%	1.44%	0.00%	0.00%	1.45%	1.38%	2.33%	0.83%	0.00%
SC8	1020	07/13/99	23	7.55	2.8	24.9	70	146	569	564	5	1.74	0.02	0.1	1.72	1.84	0.685	0.575	4
SC8	1020	07/13/99	23	7.55	2.8	24.9	30	144	569	562	7	1.96	0.02	0.1	1.94	2.06	0.696	0.583	3
Industrial Statistic (%I)			0.00%	0.00%	0.00%	0.00%	**40.00%**	0.69%	0.00%	0.18%	**16.67%**	5.95%	0.00%	0.00%	6.01%	5.64%	0.80%	0.69%	**14.29%**

Table 50. In-lake quality assurance/quality control samples collected in Mina Lake, Edmunds County, South Dakota in 1999.

Site	Sample Type	Date	Air Temp (° C)	Field pH (su)	DO (mg/L)	Sample Depth	Water Temp (° C)	Fecal Coliform (#/100 ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Organic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Volatile Total Suspended Solids (mg/L)
PL1	Blank	09/21/99	-	-	-	Surface	17.4	10	7.0	7	6	1	0.17	0.02	0.1	0.15	0.27	0.002	0.002	1
PL4	Blank	09/21/99	-	-	-	Surface	17.4	10	3.5	7	6	1	0.17	0.02	0.1	0.15	0.27	0.002	0.002	1
Mean							17.4	10.00	5.25	7.00	6.00	1.00	0.17	0.02	0.10	0.15	0.27	0.002	0.002	1.00
Standard Deviation							0.00	0.00	2.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.00
ML4	Routine	09/21/99	14.0	8.57	8.8	Surface	16.6	10	200	719	713	6	1.88	0.02	0.1	1.86	1.98	1.13	1.05	2
ML4	Duplicate	09/21/99	14.0	8.57	8.8	Surface	16.9	10	201	719	712	7	1.90	0.02	0.1	1.88	2.00	1.13	1.04	2
Industrial Statistic (%I)			0.00%	0.00%	0.00%		0.90%	0.00%	0.25%	0.00%	0.07%	7.69%	0.53%	0.00%	0.00%	0.53%	0.50%	0.00%	0.48%	0.00%
ML5	Routine	10/12/99	11.6	9.14	9.8	Surface	12.5	10	190	737	710	27	2.01	0.02	0.1	1.99	2.11	0.986	0.87	7
ML5	Duplicate	10/12/99	11.6	8.93	9.2	Surface	12.7	10	195	717	696	25	1.97	0.02	0.1	1.95	2.11	1.11	0.957	6
Industrial Statistic (%I)			0.00%	1.16%	3.16%		0.79%	0.00%	1.30%	1.38%	1.00%	3.85%	1.01%	0.00%	0.00%	1.02%	0.00%	5.92%	4.76%	7.69%

Three tributary duplicate sample parameters (fecal coliform bacteria, total suspended solids and volatile total suspended solids) had a industrial statistic (%I) greater than 10 percent (absolute percent). All duplicate samples (three of the four dates) varied more than 10 percent from the original samples for fecal coliform bacteria counts (# colonies/ 100 ml). Fecal coliform counts can vary considerably because of sample collection, incubation temperature and media variability. One duplicate total suspended solids sample and three volatile total suspended solids samples varied more than 10 percent during this study. Variations in field sampling techniques and preparation may be some reasons for differences. Over all, 89.7 percent of all tributary industrial statistics values were less than 10 percent different (Table 49).

One tributary blank sample parameter's standard deviation was greater than the mean for total dissolved phosphorus (Table 49). This occurrence was probably caused by failure to rinse the filtering device properly prior to filtering the blank sample. Overall, 92.3 percent of all tributary blank standard deviation values were less than their respective mean value.

All in-lake duplicate and blank sample parameters met their respective quality control/quality assurance criteria (for duplicates - industrial statistic (%I) less than 10 percent (absolute percent), for blanks - the standard deviation is less than the mean (Table 50)).

3.6 Monitoring Summary and Recommendations

Monitoring Summary

Tributary

Snake Creek was monitored for tributary loading to Mina Lake from June 1999 through early April 2000. Approximately 7,864 acre-feet of water flowed into Mina Lake from the gauged portion of the watershed (145,080 acres) in 1999 and 2000. The export coefficient (water delivered per acre) for this area of the watershed was 0.20 acre-foot. The remaining 12,880 acres or 8.15 percent of the watershed was ungauged. During this study an estimated 1,880 acre-feet of water was delivered to Mina Lake from the ungauged watershed. Peak hydrologic load for most sub-watersheds occurred in the summer. Approximately three-fourths of the total hydrologic load delivered to Mina Lake was delivered in the summer of 1999.

Snake Creek was monitored using seventeen water quality parameters, a large percent of which (41.2 percent) had the highest average concentrations and values for both tributaries in the summer. Six water quality parameters (35.3 percent) had the highest average concentrations and values for the east and west tributaries in the spring. Four parameters (23.5 percent), alkalinity, total suspended solids, volatile total suspended solids and nitrate-nitrite had the highest average values in different seasons for each tributary. Twenty-nine samples exceeded water quality standards during the project period.

Three water quality parameters; dissolved oxygen, fecal coliform and total suspended solids exceeded tributary water quality standards in Snake Creek during the project. All Snake Creek water quality monitoring sites above Mina Lake (SC-1, SC-2, SC-6, SC-7 and SC-8) had at least one violation of water quality standards. Twenty dissolved oxygen standard violations were detected over the entire range of the hydrologic curve (increasing, peak and decreasing flows). Many exceedances coincided with increased fecal coliform, ammonia, organic nitrogen and volatile total suspended solids concentrations. Most fecal coliform bacteria standard violations (four of the five violations) were detected during increasing hydrologic flows which suggests runoff from land-applied manure, animal feeding areas, cattle pastured in the riparian area of Snake Creek or poor manure management may be responsible for the high fecal concentrations. Total suspended solids standards were exceeded on four sampling occasions, two samples in July were sampled during increasing flows and the September and October samples were collected under base or decreasing flows. Both samples collected in July during increasing flows indicated event-based loading to Snake Creek. The September and October samples collected at low or base flows may suggest sampling-specific irregularities.

Mina Lake was included in the impaired waterbodies list for an increasing TSI trend. The watershed assessment and AGNPS modeling identified priority areas and critical cells within the watershed for mitigation (treatment). Priority areas and critical cells were selected/chosen based on both water quality and AGNPS export coefficients for nutrients (nitrogen and phosphorus) and sediment (erosion/total suspended solids) and were listed throughout this report and in Appendix C. All watershed nutrient parameters eventually affect in-lake concentrations and TSI values in Mina Lake. Reductions in any or all of these parameters may lower in-lake TSI values.

Total phosphorus loading to Mina Lake is 15,304 kg/yr; all recommended Best Management Practices (BMPs) should be implemented in the watershed to reduce the nutrient loading to Mina Lake. A significant reduction in nutrient loads is needed, especially in total phosphorus (94.4 percent reduction based on total phosphorus TSI and 94 percent based on mean TSI values), for Mina Lake to fully support beneficial uses. Mina Lake appears not to fit ecoregion-based beneficial use criteria based on the large reduction in total phosphorus needed to meet current ecoregional targets. Technical limitations preclude the realization of a 94.4 percent reduction in total phosphorus. Such reductions are not attainable even if extensive BMPs are implemented throughout the watershed. The recommended achievable reduction based on current data is a 38.8 percent reduction in total phosphorus which would meet the TMDL goal of 9,366 kg/yr or a mean in-lake TSI of 79.18.

Table 51. Snake Creek and ungauged watershed mitigation priority sub-watersheds for sediment, nitrogen and phosphorus, based on watershed assessment and AGNPS modeling.

Priority Ranking	Sediment Sub-watershed	Sediment Export Coefficient (kg/acre)	Nitrogen Sub-watershed	Nitrogen Export Coefficient (kg/acre)	Phosphorus Sub-watershed	Phosphorus Export Coefficient (kg/acre)
1	SC-7	41.06	SC-2	0.71	Ungauged	0.19
2	Ungauged	14.72	Ungauged	0.48	SC-2	0.17
3	SC-2	7.18[1]	SC-6	0.41	SC-6	0.15
4	SC-1	7.02	SC-1	0.20	SC-1	0.12
5	SC-6	3.69	SC-7	0.12	SC-7	0.07
6	SC-8	0.78	SC-8	0.07	SC-8	0.03

[1] = Estimated export coefficient based upon delivered load at site SC-2 divided by acreage drained by the east tributary.

Sub-watersheds that should be targeted for sediment, nitrogen and total phosphorus mitigation, based on water quality and AGNPS modeling export coefficients, are presented in priority ranking in Table 51.

In-lake

Mina Lake was monitored using seventeen water quality parameters, most of which (58.6 percent) had the highest average concentrations and values in the summer for ML-5 (west arm). Nine water quality parameters (52.9 percent) had the highest average concentrations and values for the east arm in the fall. Six parameters (35.3 percent), pH, dissolved oxygen, ammonia, un-ionized ammonia, total and dissolved solids had the highest average values in the spring at ML-5 (west arm).

One parameter, pH, exceeded water quality standards during the project period. The surface sample at site M3L-5 in the west arm of Mina Lake exceeded in-lake water quality standards for pH in October 1999 (9.14 su). The pH value collected on the same date from the east arm (site ML-4) also had the highest pH value (8.93 su) recorded from that site. All other parameters during the project met water quality standards for Mina Lake in 1999 and 2000.

Algal production fluctuated (increased and decreased) while at the same time total nitrogen to total phosphorus ratios varied only slightly (always nitrogen limited), indicating nutrients may not be as limiting as other factors in determining algal population densities in Mina Lake.

All TSI values, except for nine Secchi and seven chlorophyll-*a* values were in the non-supporting and partially supporting beneficial use categories. The long-term trend for all TSI values indicates an increasing trend from the partially supporting category and increasing to the non-supporting category. Mitigation projects in the Mina Lake watershed should, over time, reduce nutrient TSI values, reversing the overall trend observed from 1979 to 1999.

Mina Lake is listed on the impaired waterbodies list for increasing TSI trend. The watershed assessment and AGNPS modeling identified priority areas and critical cells within the watershed for mitigation (treatment). Implementing recommended tributary and in-lake BMPs will lower in-lake TSI values and improve Mina Lake.

Decreasing tributary sediment, nitrogen and phosphorus inputs from Snake Creek and the ungauged watershed will improve (lower) Mina Lake TSI values. Tributary reductions in these parameters will reduce Secchi, total phosphorus and chlorophyll-*a* TSI values and increase transparency. Increasing transparency (algal and non-algal turbidity) should increase the growth of submerged macrophytes, which would increase the uptake of nitrogen and phosphorus reducing available nutrients that cause algal blooms. . These reductions over time should reverse present TSI trends. Increasing densities of submerged macrophytes will also create littoral zone cover for macroinvertebrates and forage fish, and ambush points for predator species

Tributary Recommendations

Tributary recommendations are based on best management practices and best professional judgement. All reductions were modeled or calculated using water quality and/or AGNPS data collected during this study. Reduction percentages given in Table 52 are the expected percent reduction in sediment and nutrients delivered to Mina Lake based on 1999 and 2000 loading data. BMP recommendations, streambank stabilization and conversion of highly erodible land to grass were not modeled due to insufficient data but should be considered in any phase II implementation plan. Watershed priority acreage by sub-watershed for BMP implementation is listed in Table 53.

Minimum Tillage

Minimum tillage reductions were predicted using the AGNPS model. Reductions in sediment, nitrogen and phosphorus were based on mitigating cropped 40-acre critical cells throughout the watershed. Priority areas, critical cell numbers and locations based on water quality sampling sites and AGNPS sub-watersheds can be found in Appendix C. Reduction estimates for each parameter in percent are presented in Table 52.

Riparian Management

Restricting cattle and other livestock access to Snake Creek, establishing riparian and buffer zones in the areas immediately adjacent to the lake, should reduce nutrient loadings to Mina Lake by 8.4 percent (Table 52). Nutrient loading values were calculated using the number animals in and around Snake Creek times the daily waste produced per animal type. Annual nutrient loading reductions were adjusted based upon the estimated number of days animals were in and around Snake Creek throughout the year. Livestock numbers were determined by NRCS personnel based on data from the AGNPS feedlot model. Daily waste values per animal unit were based on the livestock waste facilities handbook (MPS 1976). Treatments should include constructing fences or other barriers to control livestock access to riparian areas, livestock cross-over structures and alternative watering with nose pumps along Snake Creek, especially vulnerable areas frequented by livestock. Other alternatives could include seasonal access or rotational grazing but reductions would tend to be lower because livestock would still impact the riparian area seasonally.

Streambank Stabilization

Sloughing banks and eroding areas were observed in the Snake Creek watershed, however, data specific to these areas were not available to estimate reductions. These areas contribute to the overall sediment and nutrient input to Mina Lake and should be included in any implementation plan. Models are available (Pollutants Controlled Calculation and Documentation manual (MI DEQ 1999), Annualized Agricultural Non Point Source model (AnnAGNPS) and Hydrologic Simulation Program Fortran (HSPF), etc.) to determine sediment and nutrient contributions and can be used to predict/estimate reductions. Field variables such as soil type, total linear distance of impacted areas (left and right streambanks) and bank height and others are used in the models.

Restoration alternatives could include, but are not limited to, laying back steep banks and re-vegetating, riprapping selected areas, replanting barren and susceptible areas and willow planting.

Conversion of Highly Erodible Cropland to Rangeland

Conversion of highly erodible cropland to rangeland will reduce sediment and nutrient loading to Snake Creek and Mina Lake, however, reduction estimations for the conversion of highly erodible land to grass were not modeled due to insufficient data. This Best Management Practice (BMP) should be considered for the phase II implementation project.

Fertilizer Application

Reducing fertilizer and manure application rates and/or altering temporal applications (time of application) could reduce nutrient loading (phosphorus) to Mina Lake 8.5 percent (Table 52). Nutrient reductions were estimated using the AGNPS model with critical cell numbers and locations provided in Appendix C. Altering (reducing) fertilizer application rates (pounds/acre) and applying fertilizers based on seasonal (hydrological) considerations will limit nutrient runoff and loading. Applying less fertilizer during seasons with lower potentials for heavy sustained rains will be more cost effective and reduce the annual nutrient load to Mina Lake. Another area of concern is excessive application of phosphorus-based lawn fertilizer. In a survey of property owners surrounding Mina Lake, 68.1 percent apply fertilizer to their lawns. During runoff events and excessive watering, elevated concentrations of nitrogen and phosphorus are entering Mina Lake. Although specific reductions could not be estimated, reducing or eliminating applications of phosphorus-based lawn fertilizers will reduce nutrient loading to Mina Lake.

Buffer Strips

Buffer strips have been shown to stabilize streambanks, reduce sediment delivery up to 93 percent and remove up to 50 percent of the nutrient and pesticides runoff (CTIC 1999). Personnel from the NRCS office in Ipswich South Dakota, estimated public participation in constructing buffer strips on Snake Creek. It was estimated that three of the six sub-watersheds would construct buffer strips. Calculated reduction percentages were based upon this scenario. Conservative reduction percentages were used to predict sediment and nutrient reductions (35 percent for sediment and 25 percent for nitrogen and phosphorus) in the Mina Lake watershed. Reductions were calculated for the top three priority sub-watersheds for each parameter, and reductions in the overall annual loading to Mina Lake were estimated. Of all the watershed restoration techniques evaluated, buffer strips offered the greatest percent reduction in sediment and nutrients delivered to Mina Lake (Table 52).

Animal Feeding Areas

Seventy-six animal feeding areas were identified by AGNPS as being potential sources of sediment and nutrient enrichment in the Mina Lake watershed. The AGNPS model ranked the animal feeding areas based upon field observation and owner/operator data. Out of the seventy-six feeding areas AGNPS identified (ranked) eleven feeding areas (14.5 percent) that were classified as critical (rated 41 to 62 based on a 0 (low impact) to 100+ (high impact) scale). An additional four feeding areas located in cells with multiple feedlots (feeding areas) rated greater than 40. However, during AGNPS averaging, the cells were not critical for nutrient output. Specific information on all feeding areas in the Mina Lake watershed can be found in Appendix C.

Analysis consisted of running the model in each of the seven AGNPS sub-watersheds with critical feeding areas greater than 40 removed and comparing that data with the original data which included those feeding areas. Removing eleven animal feeding areas will reduce nitrogen and phosphorus loading to the lake by 1.2 percent and 1.4 percent, respectively. Percent reductions are considered conservative because AGNPS underestimates the impact of animal feeding areas near Mina Lake. AGNPS is not equipped to model reductions/impacts of cattle that are not in a specific feeding area, thus underestimating the overall load to the lake.

Eleven feeding areas with AGNPS ratings of 40 or greater should have animal waste management systems constructed to lower nutrient loading to Mina Lake

Table 52. Estimated delivered reduction percentages for select Best Management Practices for Snake Creek, Edmunds County, South Dakota.

	Parameter (Percent Reduction)		
Tributary Best Management Practice (BMP)	**Sediment**	**Nitrogen**	**Phosphorus**
Minimum till (critical cells)	8.6	13.0	11.3
Riparian management (creek, riparian area and buffer strip)	-	2.2	6.2
Streambank stabilization (eroded areas)[1]	-	-	-
Conversion of highly erodible cropland to rangeland[2]	-	-	-
Fertilizer (reduced application rates and temporal application)	-	12.4	8.5
Buffer strips (Three sub-watersheds)	16.1	15.8	11.4
Animal feeding areas (AGNPS rating ≥ 40)	-	1.2	1.4
Estimated Total Reduction to Mina Lake	**24.7**	**44.6**	**38.8**

[1] = Insufficient data to calculate/estimate reductions, however, sloughing banks and eroding areas were observed throughout the watershed and contribute to sediment and nutrient loading.

[2] = Reduction estimations for the conversion of highly erodible land to grass were not modeled/calculated/estimated due to insufficient data, however, this BMP should be considered for implementation.

Table 53. Priority acres by sub-watershed for Best Management Practices (BMPs) for Snake Creek and Mina Lake Brown. Edmunds and McPherson Counties, South Dakota in 1999 and 2000.

Sub-watershed	**Priority 1 Acres**	**Priority 2 Acres**	**Priority 3 Acres**
SC-1	1,160	1,320	3,120
SC-2	280	720	1,120
SC-6	200	200	200
SC-7	440	920	1,880
SC-8	1,280	680	2,520
Site Ungauged	200	320	520
Total Acres	**3,560**	**4,160**	**9,360**

In-lake Recommendations

In-lake recommendations are based on best management practices and best professional judgement. Reductions were estimated or calculated using water quality and/or AGNPS data collected during this study. Reduction percentages given in Table 54 are the expected percent reduction in in-lake nutrients based on 1999 through 2000 data.

Aluminum Sulfate Treatment (Alum)

Alum treatment uses an aluminum sulfate slurry that, when applied to water, creates a 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. Mina Lake received approximately 15,304 kg (16.9 tons) of phosphorus (Snake Creek 13,116 kg, ungauged 2,090.0 kg and precipitation 98 kg) in 1999 and 2000. Watershed BMP techniques would have to be implemented to reduce sediment and phosphorus loading before attempting an alum treatment to attain long-term success. If tributary BMP reduction percentages are not realized, an alum drip system could be installed on both tributary inlets to further reduce the phosphorus loading to Mina Lake.

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. If alum treatment is initiated, it is suggested that approximately the lower 244.8 hectares (605 acres, downstream half) be treated because of favorable water depth ($\geq$ 3.05 m, 10 feet). The percent reductions for alum treatment in Table 54 were calculated using a conservative percent reduction in in-lake phosphorus concentrations.

Aquatic Macrophytes

As lake transparency improves, the maximum depth of macrophyte colonization increases, allowing submerged vegetation to re-colonize littoral zones within Mina Lake naturally. It is estimated that because of the bathymetric morphology (subsurface shape or contour) of Mina Lake, submerged vegetation should not dominate the lake, even with increased transparency. If submergent vegetation does not re-colonize littoral zones, manual planting of desirable aquatic species might be initiated. Indigenous species in Mina Lake to consider are such as sago pondweed (*Stuckenia pectinata*) and clasping-leaf pondweed (*Potamogeton Richardsonii*). Another species to consider might be floating-leaf pondweed (*Potamogeton natans*) as this species is common to other lakes in Ecoregion 46 R (Lake Oliver (Deuel County), Cresbard Lake (Faulk County) and Lake Alvin (Lincoln County)). Because the success of submerged macrophyte plantings is not predictable, estimated TSI reductions as a result of those plantings were not included in this report (Table 54).

Table 54. Estimated reduction percentages using BATHTUB for select in-lake Best Management Practices for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Best Management Practice (BMP)	Estimated In-lake Percent Phosphorus Reduction	Estimated TSI Percent Reduction [2]		
		Phosphorus	Secchi	Chlorophyll-*a*
Aluminum Sulfate Application	30 to 90	4.9	0.1	0.1
Submerged Aquatic Macrophytes	Variable	I [1]	I	I
Estimated In-lake Total Reduction in Mina Lake	**50**	**4.9**	**0.1**	**0.1**

[1] = Conditions should improve but data was unavailable to calculate a viable response.
[2] = Percent TSI reductions was estimated using predicted tributary TSI values based on BATHTUB modeling (Table 41).

Implementing any or all in-lake Best Management Practices will augment tributary mitigation and have an overall positive impact on Mina Lake over time.

Targeted Reduction and TMDL

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 AGNPS data collected during this study. Parameter-specific and mean TSI values were plotted on ecoregion 46 R beneficial use categories and are shown in Figure 69 and Figure 70. Tributary and in-lake TSI reductions were based on best management practices and best professional judgement. Reductions in TSI were based on tributary and in-lake BMP recommendations outlined on pages 131 through 135 of this report. Background loading was estimated as the total phosphorus load minus the estimated load reduction based on BMP and best professional judgement. The margin of safety for phosphorus is implicit. Implicit in that all reduction estimations for both tributary and in-lake reductions were calculated using extremely conservative reduction values/percentages (Appendix J).

Based upon 1999 and 2000 loading data, the phosphorus TSI value was 104.73 (non-supporting) and the chlorophyll-*a* and Secchi TSI values (70.43 and 68.89, respectively) were partially supporting (Figure 69). SD DENR-recommended targets for specific TSI parameters based on tributary BMP attainability for Mina Lake. They are 98.37 for phosphorus, 70.36 for chlorophyll-*a* and 68.28 for Secchi visibility (Table 55). To reach these goals, tributary total phosphorus loads will have to be reduced by 38.8 percent. Reductions should improve phosphorus TSI by 6.1 percent, chlorophyll-*a* TSI by 0.1 percent and Secchi TSI by 0.1 percent, which will improve in-lake water quality. Reductions beyond 38.8 percent would severely alter most agriculture in the watershed and nutrient reductions would be cost prohibitive on a percent reduction basis (Figure 69 and Figure 70). 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.

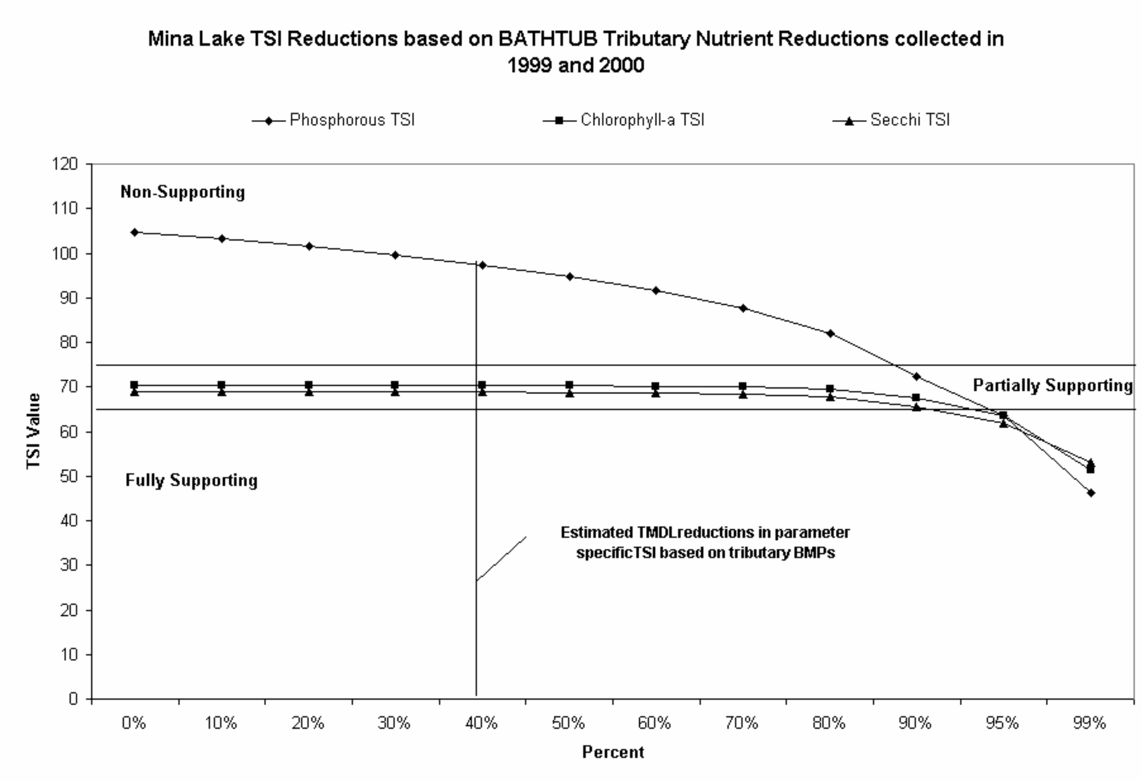


Figure 69. TMDL-predicted parameter specific Trophic State Index (TSI) reductions using the BATHTUB reduction model based on tributary BMPs reductions and ranked by beneficial use categories for Mina Lake, Edmunds County, South Dakota using 1999 and 2000 data.

The average TSI value for phosphorus, chlorophyll-*a* and Secchi combined (81.35) was also in the non-supporting category (Figure 70). The recommended target for an average TSI value in Mina Lake is 79.18 (Table 55). Implementing all tributary BMPs in priority sub-watersheds (priority 1,2 and 3; Unguaged, SC-2 and SC-6 sub-watersheds) will decrease the in-lake mean TSI value by 2.7 percent. Implementing recommended in-lake BMPs (alum treatment) should only occur after all tributary BMPs have been implemented. In-lake BMPs will improve TSI values (an estimated 4.9 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.

Modeled reductions using current data indicate a 94.4 percent reduction is needed to meet ecoregional beneficial uses, however, due to economic and technical limitations the TMDL could not be achieved. Drastic and unrealistic changes in land use and management would have to occur in the watershed in order to achieve ecoregional based beneficial uses. The TMDL should be based on realistic criteria using watershed specific BMP reductions within the Mina Lake watershed resulting in watershed specific criteria. An appropriate TMDL for total phosphorus in Mina Lake is 9,366 kg/yr producing a mean TSI of 79.18 (Equation 6). The load allocation for phosphorus is 5,938 kg/yr and the background load for phosphorus is 3,428 kg/yr based on 1999 through 2000 total phosphorus and hydrologic loads to Mina Lake (Appendix J and Table 56).

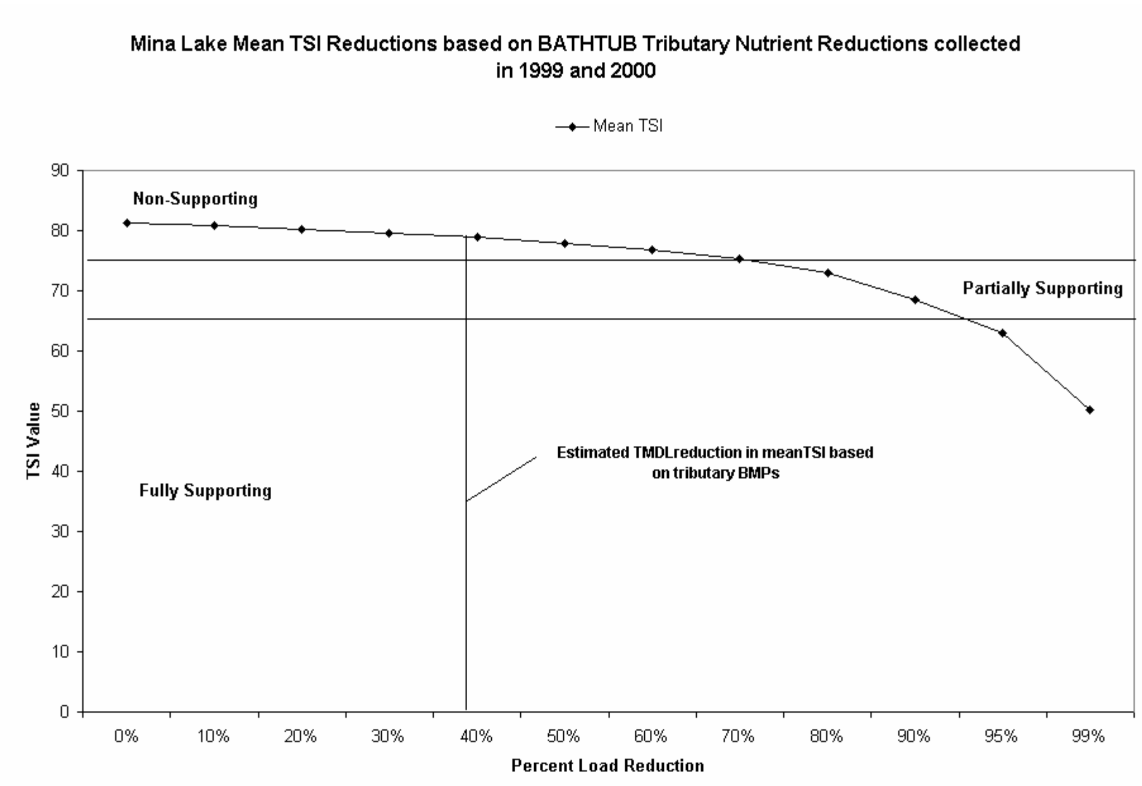


Figure 70. TMDL-predicted mean Trophic State Index (TSI) reduction using the BATHTUB reduction model based on tributary BMPs reductions ranked by Ecoregion 46 R beneficial use categories for Mina Lake, Edmunds County, South Dakota using 1999 and 2000 data.

Over all, average TSI values will be reduced by 2.7 percent for tributary BMPs. In-lake BMPs (alum treatment) should be implemented after tributary BMPs to achieve maximum benefit.

Table 55. Current, targeted and percent reduction for parameter specific and mean TSI values based on 1999 and 2000 data for Mina Lake, Edmunds County, South Dakota.

TSI Parameter	1999 Estimated TSI Values (BATHTUB)	TMDL Targeted TSI Value	Percent TSI Reduction
Total Phosphorus	104.73	98.37	6.1
Chlorophyll-*a*	70.43	70.36	0.1
Secchi	68.89	68.82	0.1
Average	**81.35**	**79.18**	**2.7**

Table 56. Total phosphorus TMDL target and background loading for Mina Lake, Edmunds County, South Dakota in 1999 and 2000.

Parameter	Best Management Practice	Margin of Safety	TMDL	Background
Total Phosphorus	Tributary and In-lake BMPs	Implicit (conservative estimations)	Total Phosphorus TSI 98.37 (9,366 kg/year) (Mean TSI 79.18)	3,428 kg/year

[1] = Calculated based on 1999 and 2000 in-lake and tributary loading/concentration data

Equation 6. TMDL equation for Mina Lake, Edmunds County, South Dakota based on 1999 and 2000.

Component	Maximum Load
Waste Load Allocation (WLA):	0 (kg/yr)
+ **Load Allocation (LA)**	5,938 (kg/yr)
+ **Background:**	3,428 (kg/yr)
+ **Margin of Safety:**	Implicit
TMDL[1]	**9,366 (kg/yr)**

[1] = Represents a total phosphorus tributary load reduction of 38.8 percent, based upon BMP attainability.

4.0 Public Involvement and Coordination

Public involvement and coordination were the responsibility of the Edmunds County/McPherson County Conservation Districts. 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 Edmunds County/McPherson County Conservation District Board, which is also a public setting where the public is invited to attend.

The Edmunds County/McPherson County Conservation Districts were the appropriate lead project sponsors for this project. The Conservation Districts were important to this project because of their 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 the 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 Game, Fish and Parks (SD GF&P) provided current and long-term fisheries data, reports and endangered species list (Heritage List) for Mina Lake. 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 $68,446 of Section 319 funds to cover project costs for the Mina Lake Watershed Assessment. 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 Edmunds County/McPherson County Conservation Districts within the Mina Lake watershed will need to 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

No other funds were secured for this project. The Mina Lake Watershed Assessment project was funded entirely with Section 319 funds. Funding was entirely from Section 319 funds because an implementation project funded by 319 funds (FY 1993) was nearing completion and local monies over-matched the 40 percent required. Additional 319 funds were then secured to fund this project.

Funding Category	Source	Total
EPA SECTION 319 FUNDS	US EPA	$68,446
Total Budget		**$68,446**

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 AGNPS data collection and modeling. AGNPS data collection and entry took much more time than expected due to logistical and computer problems. AGNPS sub-watersheds were delineated within the Mina Lake watershed and did not relate well with watershed assessment sampling sites. This increased the modeling and analysis time required for relating AGNPS data to water quality monitoring data. However, despite these problems, the AGNPS data and report identified critical areas within the Mina Lake watershed.

6.0 Future Activity Recommendations

The Mina Lake watershed is an estimated 63,924.4 ha (157,960 acres) in size. This assessment project documented priority and critical areas for erosion, total nitrogen and total phosphorus in the watershed. As indicated in the report, certain sub-watershed areas in the Mina Lake watershed have been identified as areas of concern. Implementation efforts should be undertaken to implement/install BMPs on critical areas in the Mina Lake watershed.

Data indicate that a 94.4 percent reduction in phosphorus is needed in this watershed to meet designated beneficial uses (fully supporting) based on reference lake criteria for ecoregion 46 (mean TSI $\leq$ 64.99). However, Mina Lake appears not to fit ecoregion-based beneficial use criteria based on the large reduction in total phosphorus needed to meet current ecoregional targets. Economic and technical limitations preclude the realization of a 94.4 percent reduction in total phosphorus. Economically, such reductions would severely alter or eliminated most agriculture in the watershed. Technically, internal loading of in-lake total phosphorous resulting in elevated year round phosphorus concentrations impede reduction attainability even if extensive BMPs are implemented throughout the watershed. Drastic and unrealistic changes in land use and management would have to occur in the watershed in order to achieve ecoregional based beneficial uses. The TMDL should be based on realistic criteria using watershed specific BMP reductions within the Mina Lake watershed resulting in watershed specific criteria.

Current data indicate that a 38.8 percent reduction in phosphorus can be achieved in this watershed to meet the TMDL goal of 9,366 kg/yr or a mean in-lake TSI of 79.18. The recommended reductions will improve compliance with South Dakota's narrative criteria and the designated beneficial uses of the watershed, specifically, domestic water supply, warmwater permanent fish life propagation water, immersion recreation, limited contact recreation water and fish and wildlife propagation, recreation, and stock watering. 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 the sediment, total nitrogen and total phosphorus loading to meet the TMDL set for Mina Lake (9,366 kg/year of phosphorus). Priority areas and sub-watersheds are outlined in Table 51, page 129, and critical cell acreage by priority area are provided in Table 53 on page 133 of this report. Critical cells within these sub-watersheds are listed in the AGNPS section of this report (Appendix C - Attachment A). Implementing any or all of the BMPs outlined in this report on three or more of the six sub-watersheds will reduce sediment, nitrogen and phosphorus loading and improve the trophic status of Mina Lake.

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Appendix K.

Mina Lake Assessment Project Report November, 1992

LAKE ASSESSMENT PROJECT REPORT
MINA LAKE
EDMUNDS COUNTY, SOUTH DAKOTA

SOUTH DAKOTA CLEAN LAKES PROGRAM
OFFICE OF WATER RESOURCES MANAGEMENT
SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT
AND NATURAL RESOURCES

NOVEMBER, 1992

EXECUTIVE SUMMARY

Mina Lake is an artificial impoundment on Snake Creek in extreme eastern Edmunds County about 12 miles west of Aberdeen, South Dakota. The lake covers 806 acres and has mean and maximum depths of 9 and 27 feet respectively. The lake is heavily used for recreation and has been designated a domestic water supply for lakeshore residents. The State of South Dakota has assigned to the lake the beneficial uses of : domestic water supply; warmwater permanent fish life propagation; immersion recreation; stock watering; and wildlife propagation.

The contributing watershed of Mina Lake consists of nearly 142,000 acres located primarily in Edmunds and McPherson Counties with a small area extending into Brown County. As with many artificial lakes of this type the watershed to lake surface area ratio is large - approximately 176.

Past studies conducted by the South Dakota Department of Environment and Natural Resources (DENR) from 1979 to 1982 determined Mina Lake was nutrient enriched especially in phosphorus. Runoff data collected from both branches of Snake Creek indicated extremely high loads of phosphorus and nitrogen entered the lake during the 1979-1982 period (Mina Lake WQSA Report, 1985). Sampling frequently detected excessive fecal coliform bacteria numbers in the two tributaries and occasionally high bacteria levels were found in the lake.

In May 1991, the South Dakota Department of Environment and Natural Resources (DENR) began a Lake Assessment Project under a Contract/Letter of Agreement with the Edmunds County Conservation District signed February 5, 1991. The results of that project are presented in this report.

The lake assessment project consisted of water quality monitoring of Mina Lake and its tributaries from May 6, 1991 through April 14, 1992 to evaluate watershed impacts on the lake. In addition, a sediment depth survey was conducted to measure accumulated soft sediments in the lake basin. Probable sources of these sediments as well as the high nutrient levels found in Mina Lake were investigated by means of a watershed land-use survey and a lake shoreline inspection.

Results of the study indicated that the high phosphorus loads recorded from 1979 to 1982 persisted through 1991 but that nitrogen loading to Mina Lake had declined considerably to the present moderate level during the same 10-year interval. Low dissolved oxygen concentrations measured in both tributaries during the 1991 study suggest, moreover, that the potential for organic pollution in Mina Lake from its drainage remains high at the present time. Major sources of nutrients, organic loading, and bacteria to the lake appear to be watershed livestock operations, overfertilization of cropland and eroding soil in the watershed.

The study recommendations for lake restoration include 1.) establishing ten animal waste management systems (AWMS) in the watershed 2.) implementing best management practices (BMP) on croplands and pasture land 3.) stabilizing stretches of eroding lake banks 4.) promoting planned grazing systems (e.g. rotated grazing) to improve range conditions 5.) planting permanent cover on cropped natural stream channels and 6.) other applicable implementation measures.

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INTRODUCTION

Studies conducted by the South Dakota Department of Environment and Natural Resources (DENR) from 1979 through 1982 determined that Mina Lake (a.k.a. Lake Parmley) is nutrient enriched and has reduced water clarity. Algae blooms are common and two incidences of algal toxicity (1979 and 1991) have been suspected. Large aquatic macrophytes are generally not a problem in the main basin although siltation and subsequent encroachment of macrophytes has occurred in the northern inlet areas. Excessive fecal coliform bacteria levels have frequently been reported in the Mina Lake tributaries and on several occasions in the lake proper. These problems appear to be due to a combination of factors related to nonpoint source pollution and include: eroding crop and grassland, shoreline erosion, poor fertilizer management, feedlot runoff, and failing septic tank systems.

In response to local inquiries for assistance the DENR, working in cooperation with the local community and the Edmunds and McPherson County Conservation Districts, designed a Lake Assessment Project Study (Diagnostic/Feasibility (D/F) study) for Mina Lake under a contractual agreement entered into by DENR and the Edmunds County Conservation District on February 5, 1991. The study was implemented to identify and assess the current condition of the lake, determine water quality problems and pollution sources, and develop lake restoration alternatives.

Water quality monitoring of tributary and in-lake waters was conducted during the period from May 6, 1991 to April 14, 1992. A watershed inspection was carried out during 1991 to collect land use information and identify water quality problem areas in the drainage. In addition, a shoreline vegetative survey was conducted during September 1991 in conjunction with a shoreline inspection to identify significant areas of bank erosion around the Mina Lake shoreline.

Study Area Description/Background

Mina Lake is a U-shaped impoundment on Snake Creek located in extreme eastern Edmunds County about 12 miles west of Aberdeen. The lake covers 806 acres and has mean and maximum depths of 9 and 27 feet respectively.

The reservoir formed behind a dam located a short distance downstream from the previous confluence of the East and West Branches of Snake Creek. Construction of the dam was largely financed through the Federal Emergency Relief Administration (ERA) in the early 1930's. Brown and Edmunds Counties provided equipment and some operating funds. Construction began in September 1933 and was completed by February 1934.

The present Mina Lake drainage covers an estimated 141,858 acres. The watershed is located in Edmunds County (76,603 acres), McPherson County (63,389 acres) and Brown County (1,866 acres). Watershed topography is mostly nearly level to gently sloping, but is steeper along the larger drainageways. The watershed is used mainly for cropland (40%) and pasture (60%).

Approximately 250 residences presently occupy the shoreline of Mina Lake, about one third of which are summer homes. A majority of the residences are situated on the lower east arm of the reservoir, whereas only 15 are located on the west arm. As recently as ten years ago all lakeside residences were served by individual wastewater disposal systems, mainly septic tank drainfields. The present public water supply for lakeshore residences is the WEB Water Development Corporation. All the drinking water is taken from the WEB system. Water for lawns and gardens is pumped directly from the lake.

Mina Lake is located in an area of somewhat impermeable soils, primarily Edgely and Niobell-Noonan loams. Edgely loam is known to contain bedded shale within 40 inches of the surface whereas Niobell-Noonan loams have a massive clay pan subsoil and generally have low permeability. For this reason those soils are not particularly suitable as sites for septic tank drainfields nor, as subsequent experience has made evident, are centralized wastewater systems such as evapotranspiration mounds. A system of three mounds constructed in 1984 began experiencing surface failure soon after it became operational. Pooled, partially treated wastewater was subsequently carried to the east arm of Mina Lake via the old Highway 12 road ditch during periods of snowmelt and stormwater runoff. This source of contamination was eliminated in 1991 when a settling pond system was constructed and brought on-line late in the year. At present, all lakeside residences with the exception of 15 homes on the west arm of the reservoir are served by the new wastewater lagoon system located downstream of the Mina Lake spillway.

Agriculture is the principal enterprise in the Mina Lake watershed. About 40% of the area is cropland and 60% is native grass, tame grass and alfalfa. The main crops are wheat, oats, barley, corn, sunflowers, and alfalfa. Growing cash crops, hay, and raising beef cattle are the main farm activities.

The study area has a continental climate with wide variations in temperature and precipitation. The average annual rainfall in the area is 19 inches and annual lake evaporation is 34 inches. The mean yearly temperature in the Aberdeen area is about 43° oF with extremes of -40° F and 115° F.

Mina Lake provides fishing, boating, swimming, picnicking, and camping opportunities for an estimated 82,000 people residing within a 65-mile radius of the lake. The South Dakota Department of Game, Fish and Parks (GF&P) reports that annual park visitations at the Mina Recreation Area decreased from approximately 49,000 in the mid 1980's to 36,000 in the late 1980's. This decline was due to a decrease in day use of the lake which accounted for the great majority of visitations. GF&P attributed day use decline to fewer swimmers using the beach area because of diminished water quality (algal blooms, water turbidity).

GF&P manages Mina Lake for walleye, northern pike, largemouth bass, perch, and crappie with regular stocking of walleye and pike. To date no major fish kills have been reported.

Water Quality Standards

The water quality standards for Mina Lake are based upon the beneficial uses assigned to the lake by the State of South Dakota. Each beneficial use has an established set of applicable water quality criteria. In those cases where a multiple-use lake has two or more criteria established for the same parameter under different uses, the most stringent criterion will apply.

Mina Lake has the assigned beneficial uses of domestic water supply, warmwater permanent fish life propagation, immersion recreation, limited contact recreation, and wildlife propagation and stock watering. The water quality criteria presented in Table 1 are the water quality standards for Mina Lake.

Mina Lake is one of comparatively few lakes in the state designated as a domestic water supply. That use has assigned to it water quality standards for a number of metals in addition to those for the more routinely tested parameters. Moreover, standards are more stringent for nitrates and total dissolved solids under the domestic water supply use category (Table 1).

Table 1. Mina Lake Water Quality Standards

Parameter	Criterion
Total Chlorine Residual	<0.02 mg/l
Un-Ionized Ammonia Nitrogen	≤ 0.04 mg/l
Total Cyanide	≤ 0.02 mg/l
Free Cyanide	≤ 0.005 mg/l
Dissolved Oxygen	>5.0 mg/l
Undissassociated Hydrogen Sulfide	≤ 0.002 mg/l
pH	>6.5 units and <8.3 units
Total Alkalinity	≤ 750 mg/l
Total Dissolved Solids	≤ 1000 mg/l
Conductivity	≤ 4000 micromhos/cm
Nitrates	≤ 10 mg/l (as N)
Suspended Solids	≤ 90 mg/l
Temperature	$\leq 80°$ F
Polychlorinated Biphenyls	≤ 0.000001 mg/l
Fecal Coliform Organisms	≤ 200 per 100 ml*
Arsenic	$\leq .05$ mg/l
Barium	≤ 1.0 mg/l
Cadmium	$\leq .01$ mg/l
Chloride	≤ 250 mg/l
Chromium	$\leq .05$ mg/l
Fluoride	≤ 4.0 mg/l
Lead	$\leq .05$ mg/l
Mercury	$\leq .002$ mg/l
Selenium	$\leq .01$ mg/l
Silver	$\leq .05$ mg/l
Sulfate	≤ 500 mg/l

* Based on the mean of a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period, and this value may not be exceeded in more than 20 percent of the samples examined in the 30-day period. A sample may not exceed 400 per 100 ml in any one sample from May 1 to September 30.

METHODS AND MATERIALS

Lake and Tributary Sampling

Water samples were collected from five sampling sites in the Mina Lake study area. Sites 1 and 2 were located on the two principal tributaries to Mina Lake upstream of the inlets to the reservoir (Figure 1). Site 3 was located at the outlet of Mina Lake where the lake flows into Snake Creek. Sites 4 and 5 were in-lake sites (Figure 2). Descriptions of the sampling site locations are presented below:

Figure 1. Tributary sampling sites in the Mina Lake (Lake Parmley) watershed (Brown, Edmunds & McPherson Counties)

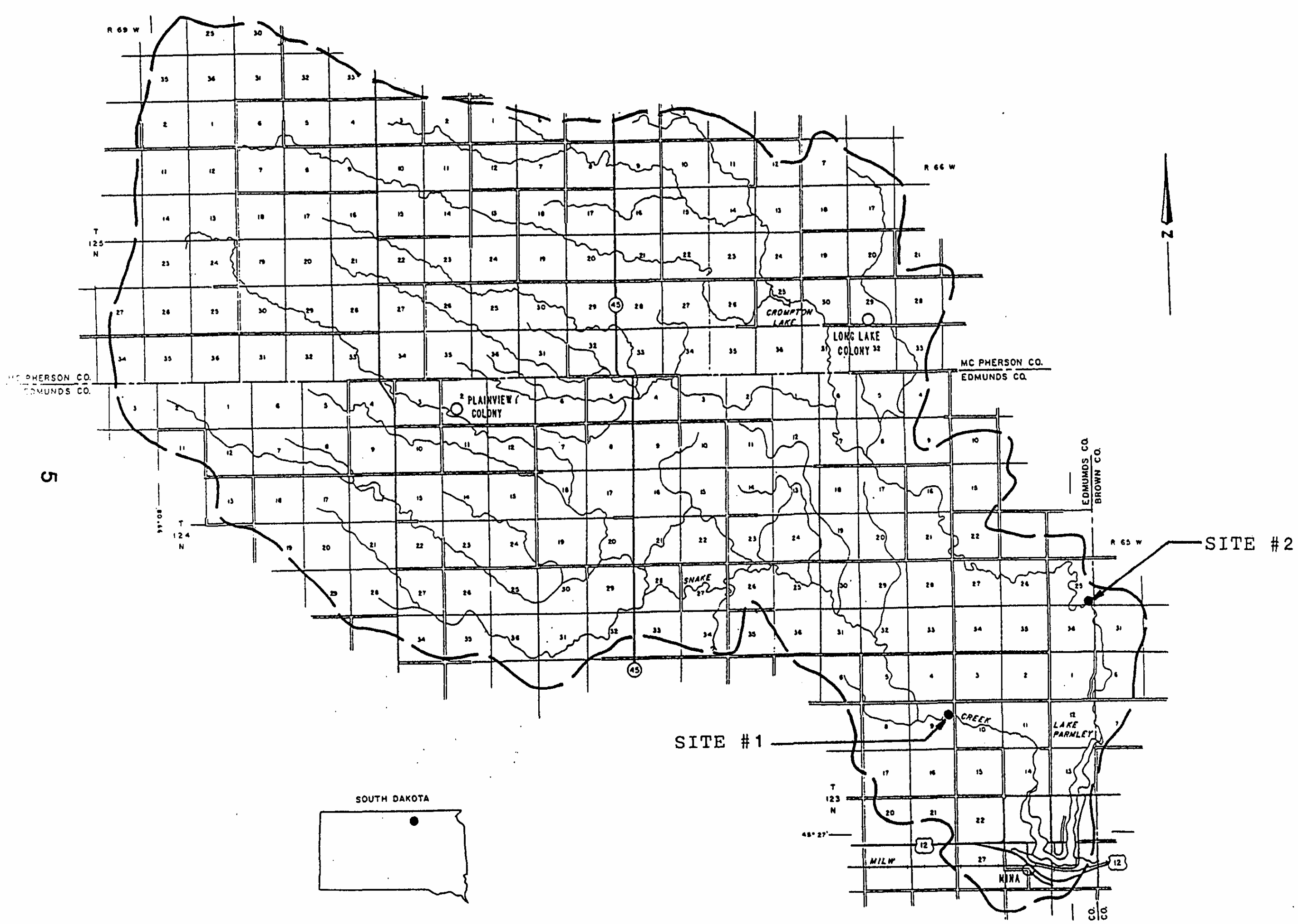
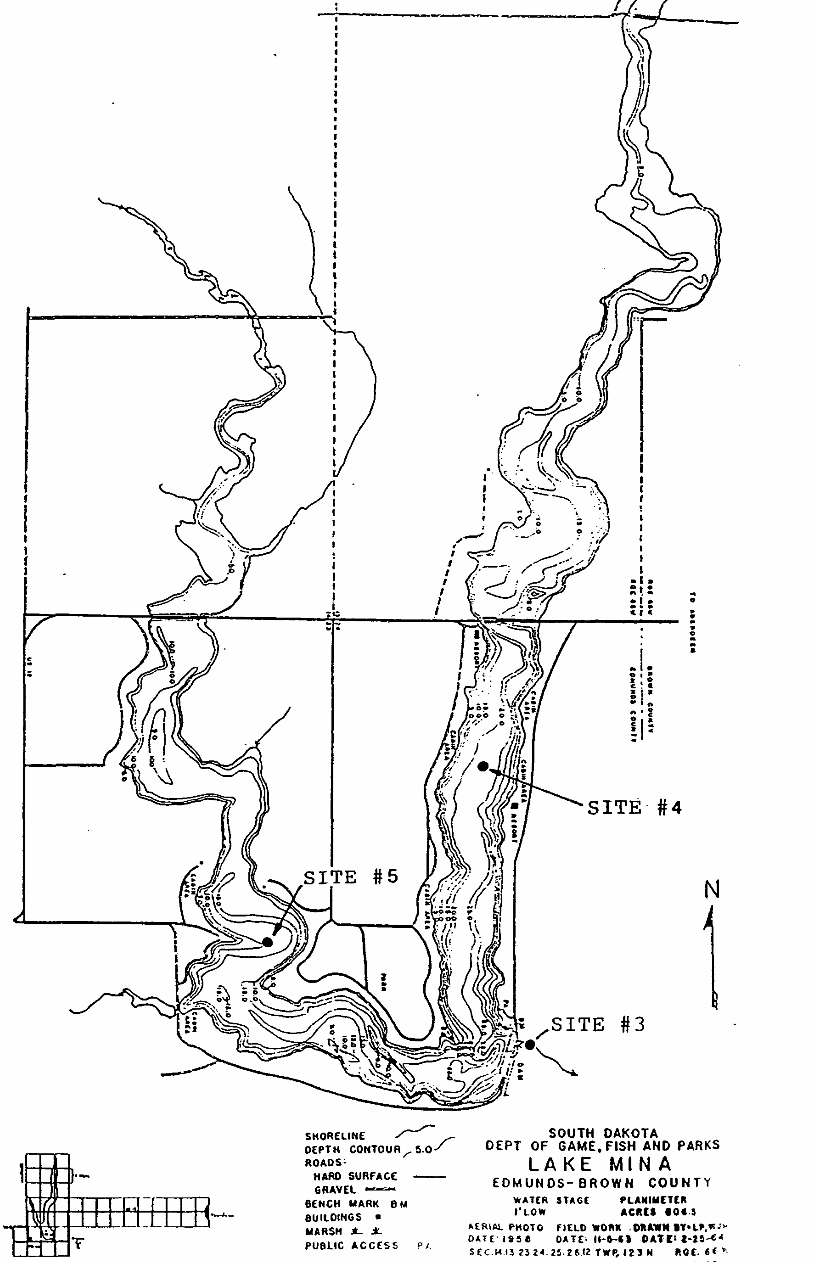


Figure 2. In-Lake and outlet sampling sites, Mina Lake (Lake Parmley), Edmunds County



Site 1 - Latitude 45 Deg., 29 Min., 11 Sec., Longitude 98 Deg., 47 Min., 01 Sec., Township 123N, Range 66 W, Section 10, NW 1/4, NW 1/4, SW 1/4, NW 1/4. West Snake Creek tributary to Mina Lake.

Site 2 - Latitude 45 Deg., 31 Min., 08 Sec., Longitude 98 Deg., 43 Min., 22 Sec., Township 123 N, Range 66 W, Section 25, SE 1/4, SE 1/4, SE 1/4, SE 1/4. East Snake Creek tributary to Mina Lake.

Site 3 - Latitude 45 Deg., 26 Min., 29 Sec., Longitude 98 Deg., 43 Min., 48 Sec., Township 123 N, Range 66 W, Section 25. SE 1/4, NW 1/4, SW 1/4, NE 1/4. Mina Lake outlet to Snake Creek.

Site 4 - Latitude 45 Deg., 27 Min., 15 Sec., Longitude 98 Deg., 44 Min., 15 Sec., Township 123 N, Range 66 W, Section 24, SW 1/4, SW 1/4, SW 1/4, NE 1/4. In-lake site near middle of east arm of Mina Lake approx. 1/2 mile south of Hwy 12 bridge.

Site 5 - Latitude 45 Deg., 26 Min., 43 Sec., Longitude 98 Deg., 44 Min., 53 Sec., Township 123 N, Range 66 W, Section 26, SE 1/4, NW 1/4, NE 1/4, NE 1/4. In-lake site at lower west arm of Mina Lake; west of Mina Recreation Area.

The sampling period for tributary and in-lake sampling extended from May 6, 1991 to April 14, 1992. During that period a total of 74 samples were collected from 5 sites for routine water quality analysis (Table 2). Separate surface and bottom samples collected at the two in-lake sites were combined to yield one surface and one bottom composite sample for each date. In-lake sites were sampled on a monthly basis.

Tributary and lake spillway sites were scheduled to be sampled for water quality twice a week during periods of flow. Tributary stages were measured with a Steven's stage recorder installed at each of the tributary sites. Stage recorders were calibrated for discharge by discrete measurements with a Marsh-McBirney portable flow meter. Daily stream discharges in cubic feet per second (cfs) were obtained by "best-fit" regression lines generated with a computer graphics program that related stage height with stream velocity (ft/sec). Using these generated graphs (Appendix D) the water velocity corresponding to any given stage height can be found. Daily stream flows can then be calculated by multiplying water velocity by a previously determined channel cross-sectional area for each tributary site.

Nutrient and sediment loadings were calculated for each sampling date by multiplying the known nutrient/sediment concentration by the daily water flow (cfs). Daily loads between water quality sampling dates were obtained by assuming constancy in nutrient and sediment concentrations between the given date and the mid-point to the previous and following sampling dates. The derived loadings were then summed and divided by the lake area to provide annual nutrient and sediment loads.

The purpose of the tributary monitoring program (Sites 1, 2 & 3) was to quantify the magnitude and severity of water quality problems associated with tributaries that contribute sediment and nutrient loads to the lake. Data from these sites was used to determine the total loadings from the various sources and will allow restoration efforts to be concentrated in the critical loading areas.

Tributary and lake sampling was carried out by personnel of the Edmunds County Conservation District. Samples were analyzed by the South Dakota State Health Laboratory in Pierre, SD for the parameters listed in Table 3.

TABLE 2. - Sampling Period and Number of Samples

	SAMPLE TIME PERIOD			
SITE #	FROM:		TO:	# OF SAMPLES
1	5/06/91	-	7/17/91	13
2	5/06/91	-	7/10/91	12
3	6/11/91	-	7/30/91	9
4	5/20/91	-	4/14/92	21
5	5/20/91	-	4/14/92	19
			Total Samples:	74

Table 3.-Water Quality Parameters

Water Temperature	Total Solids
Air Temperature	Total Dissolved Solids
Secchi Disk	Total Suspended Solids
Dissolved Oxygen	Ammonia
Field pH	Nitrates + Nitrites
Fecal Coliform Bacteria	Total Kjeldahl Nitrogen
Total Suspended Volatile Solids	Total Phosphorus
Laboratory pH	Total Dissolved Phosphorus
Total Alkalinity	Un-ionized Ammonia

Analytical Methods

The laboratory analyses for parameters listed in Table 3 were conducted by the South Dakota State Health Laboratory using methods of chemical analysis shown in Table 4. Metals were analyzed from two water and sediment samples collected at in-lake sites #4 and #5 on August 8, 1991 by DENR. Laboratory analysis was conducted by the U.S. Army Corps of Engineers (COE) laboratory in Omaha, Nebraska using EPA - approved methodology (Appendix B).

Table 4. Analytical Methods for Physical and Chemical Parameters.

Parameter	Method	Reference
Temperature	Thermometric	APHA (1985)
Secchi disc*	Shaded side of boat	Lind (1974)
Dissolved oxygen	Azide/Winkler	APHA (1985)
pH	pH probe	APHA (1985)
Total alkalinity	Potentiometric	APHA (1985)
Ammonia-N	Phenate	EPA (1983)
Nitrate + Nitrite-N	Cadmium reduction	EPA (1983)
Kjeldahl-N	Colorimetric	APHA (1985)
Total dissolved phosphorus	Filtration Persulfate digestion	EPA (1983)
Total phosphorus	Persulfate digestion	EPA (1983)
Total solids	Gravimetric(103-105° C)	EPA (1983)
Total suspended solids	Gravimetric(103-105° C)	EPA (1983)
Total volatile suspended solids	Gravimetric (550° C)	EPA (1983)
Total dissolved solids	Gravimetric (180° C)	EPA (1983)
Fecal coliforms	Membraned filter (1989)	APHA (1985)

*In-lake samples only

Sediment Sampling and Survey

A sediment and water depth survey of Mina Lake was conducted by DENR and SCS on February 20, 1991. Cross-section transect lines were established on the lake and sediment depths were measured with calibrated rebar and recorded at intervals along the transects.

On August 8, 1991, a sediment core sample and an overlying water sample were collected at each of the two in-lake water quality sites 4 and 5 (Figure 2). Those samples were submitted to the COE laboratory, Omaha, NE, for analysis of metals, pesticides, and other potentially toxic chemicals.

Biological Sampling

An inventory of the aquatic plants present in Mina Lake and surrounding shoreline was conducted during September 1991 by personnel of the Edmunds County Conservation District. Major plant species were identified and areal coverage determined.

Watershed Inspection

The watershed of Mina Lake was inspected by SCS and Conservation District personnel during 1991 to collect land use data for farms/feedlots and any other areas (or activities) that may be contributing sediments or nutrients to the lake.

The purpose for collecting these data is to determine areas that present the most severe problems in terms of water quality degradation and those tracts of land that exhibit critical erosion and nutrient loss. This will allow a focus of initial efforts on the worst problems thereby making the best use of available funding.

During the data collection process extensive use was made of land use information available at the offices of the Soil Conservation Service, the Agricultural Stabilization and Conservation Service, and other local agencies. Additional information was obtained from individual farmer interviews.

Shoreline Inspection

The shoreline of Mina Lake was traversed by SCS and Conservation District personnel during September 1991 to record any areas of significant lakeshore erosion. The stretches of shoreline with noticeable erosion problems were located on a large photographic map of the lake and their lengths measured and recorded.

RESULTS AND DISCUSSION

In-Lake Water Quality

In-lake water quality mean data are summarized in Table 5 and the complete data set is presented in Appendix A. Discussions of the results have been divided into the components of trophic condition, aquatic plants and algae, fecal coliform bacteria (swimming impacts), dissolved oxygen and suspended solids (fisheries impacts), nutrients, and nutrient/sediment loading to the lake.

Trophic Condition

Lakes are commonly classified according to trophic condition. Three categories are used: 1) oligotrophic lakes are low in nutrients, are generally clear and support low numbers of animals and plants, 2) mesotrophic lakes are intermediate in nutrient load, and 3) eutrophic lakes are high in nutrients and support large numbers of plants and animals. These lakes often experience excessive algal and weed growth.

Lakes naturally age from oligotrophic to eutrophic conditions over thousands of years. Human activities, however, tend to greatly accelerate the process by increasing nutrient and sediment inputs.

The Carlson Trophic State Index (TSI) is a method of ranking the trophic condition of a lake based on total phosphorus, Secchi depth and chlorophyll *a* measurements. The scale runs from 0 to 100 and lakes with values over 50 are considered to be eutrophic. Each division of 10 (10, 20, 30 etc.) indicates a doubling of algal biomass.

Table 5. In-Lake Sampling Data Mean Values (n = 21).

Parameter	Combined mean values for sites 4 & 5
Secchi Depth (May '91 - Dec '91)	3.7 ft. (1.13 m.)
Secchi Depth (Feb '92 - Apr '92)	14.0 ft. (4.3 m.)
D.O.	8.0 mg/l
Field pH	7.98
Fecal Coliform	< 11 per/100 ml
Total Solids	504 mg/l
Total Dissolved Solids	486 mg/l
Suspended Volatile Solids	6 mg/l
Total Suspended Solids	14 mg/l
Ammonia	0.04 mg/l
Nitrate + Nitrite	0.20 mg/l
TKN	0.81 mg/l
Total PO4-P	0.687 mg/l
Dissolved PO4-P	0.646 mg/l

TSI's for Mina Lake are based on mean total phosphorus and mean Secchi depth for both in-lake sampling sites during the growing season of the years 1979, 1989, and 1991 (Table 6). Based on these considerations the TSI values were 90.3 for 1989 and 78.6 for 1991. Those values fall on the high end of Carlson's scale classifying the lake as hypereutrophic. Moreover, for the year 1979 the smaller TSI value for chlorophyll *a* relative to that for total phosphorus (Table 6) suggests that lake algae and aquatic plants are not fully utilizing the large amounts of available phosphorus and that this nutrient is present in overabundance in lake water during the growing season.

Aquatic Plants and Algae

Approximately 46 percent of the Mina Lake shoreline is covered with trees, understory vegetation, and emergent aquatic macrophytes according to the vegetative survey conducted during September 1991 (Figure 3, Table 7.). On most of the remaining shoreline, beach front development and riprapped areas have removed the native emergent and lakeshore plant communities. Floating leaved and submergent plant species were sparse or absent over most of the lake. Vegetation was largely confined to the inlet area of the east arm of Mina Lake where duckweed and coontail beds were prevalent.

The algal communities that were collected during June and August of 1979 (Koth, 1981) are fairly typical of eutrophic state lakes which frequently show a summer dominance of the bloom forming blue-green genera Aphanizomenon and Anabaena. In addition, the diatom species Melosira granulata and Stephanodiscus niagarae are often common within blue-green algal blooms in local nutrient enriched, hard water lakes (Table 6).

A mean summer chlorophyll *a* concentration of 30 mg/m^3 (ibid) indicated Mina Lake was well within the eutrophic range during 1979; a conclusion also supported by Carlson's (1971) Trophic State Index (TSI) values calculated for that year as well as 1989 and 1991 (Table 6). Lakes with TSI values over 50 are considered to be eutrophic and over 65, highly eutrophic (hypereutrophic). Algal analysis could not be repeated in 1991 due to loss of algal samples by leakage of containers which sustained damage during shipment to the laboratory. Chlorophyll *a* samples for 1991 remain to be analyzed.

Fecal Coliform Bacteria

Fecal coliform bacteria cell counts are used as indicators of human pathogens in water. Although the fecal coliforms are not usually pathogens themselves, they exhibit a close relationship with the human pathogens Salmonella and Shigella.

Table 6. Algal Species and Volumes from Mina Lake, Edmunds County, 1979.

TAXA	6/23/79 Cells/ml[1]	Volume[2]	8/14/79 Cells/ml	Volume
Anabaena flos-aquae	4,411	507,265	.	
Aphanizomenon flos-aquae	407	81,400		
Characium limneticum	2	3,660		
Closterium sp.			6	3,000
Cosmarium sp.	5	49,000		
Melosira granulata	27	8,100	330	99,000
Merismopedia tenuissima			10	80
Pediastrum duplex var. clathratum			20	12,500
Peridinium bipes			2	51,300
Schroederia Judayi			6	1,590
Spaerocystis Schroeteri			19	9,975
Staurastrum sp.			1	1,420
Stephanodiscus niagarae	18	254,520		
Trachelomonas pulchella			4	4,520
T. volvocina	20	47,200	1	3,050
TOTAL	4,890	951,145	399	186,435
d (Species diversity)	0.55		1.12	
J (Equitability)	0.20		0.34	
V (Variety)	0.71		1.50	

TSI Values	1979	1989	1991
SD[3]	52.0	82.3	59.7
Chl *a*	63.3	-	-
TP[4]	84.3	98.3	97.4

[1]Calculated total number of cells/species/ml original lake water
[2]Total wet cell volume per species units - um3
[3]Secchi disc visibility
[4]Total phosphorus

Figure 3. Mina Lake Macrophytes

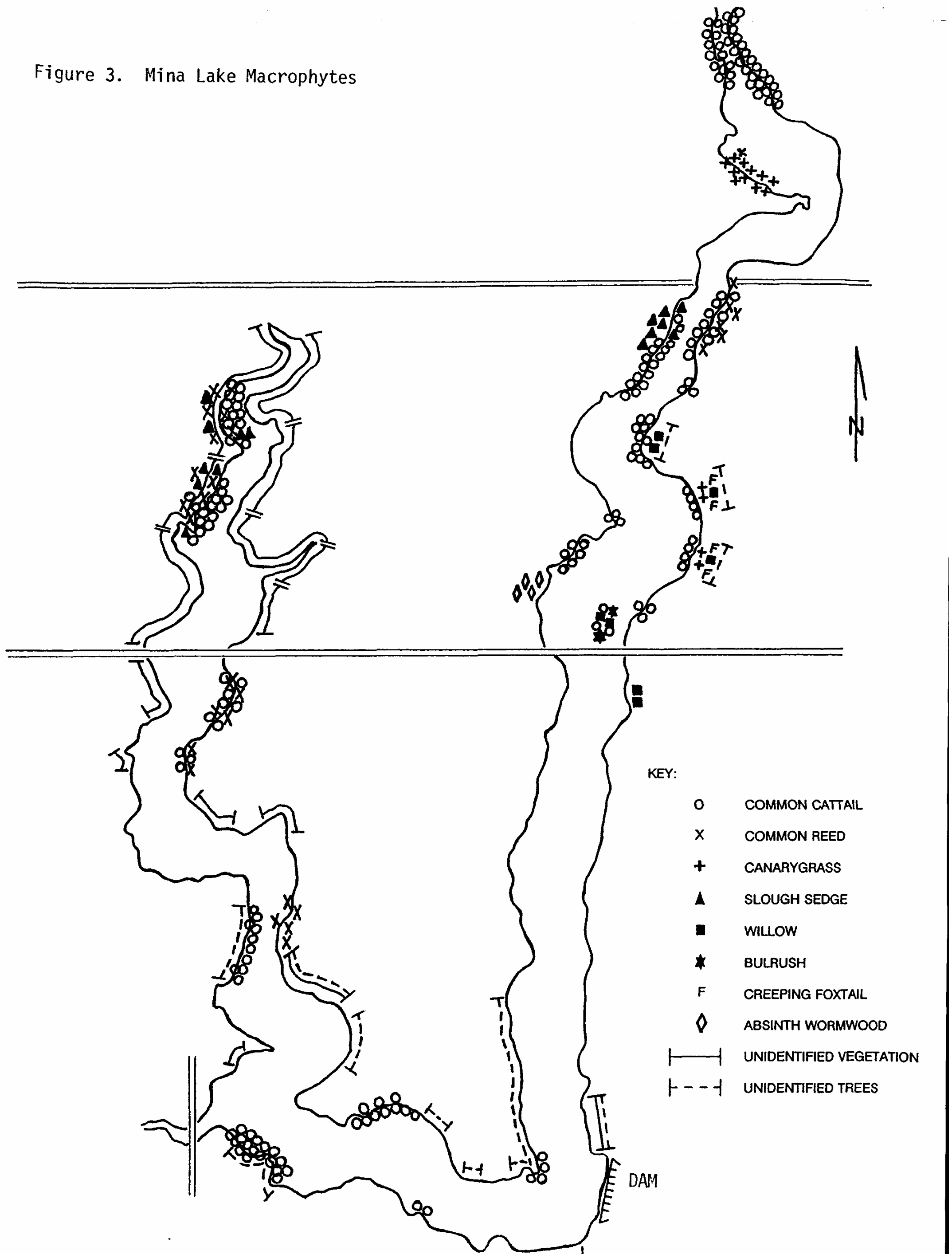


Table 7. Mina Lake Aquatic Plant Inventory

SUMMARY

COMMON NAME	GENUS	SPECIES	DISTRIBUTION	RELATIVE ABUNDANCE
Softstem Bulrush	Scirpus	validus	East Island Northern Tailwaters	Major
Common Cattail	Typha	latifolia	West & South Lakesides Northern Tailwaters	Major
Common Reed	Phragmites	australis	West & South Lakesides	Major
Coontail	Ceratophyllum	demersum	Northern Tailwaters (underwater)	Minor
Garrison Creeping Foxtail	Alopecurus	arundinaceus	Northern Tailwaters	Minor
Duckweed	Lemna	minor	Northern Tailwaters	Minor
Reed Canarygrass	Phalaris	arundinacea	Northern Tailwaters	Minor
Slough Sedge	Carex	atherodes	Northern Tailwaters	Major
Absinth Wormwood	Artemisia	absinthium	Vacant Lots	Major
Willow	Salix	spp.	Eastern Lakesides	Moderate

Mina Lake has been assigned the beneficial use of immersion recreation. Therefore, fecal coliform levels are limited to 200 per 100 ml as a geometric mean based on a minimum of not less than five samples obtained during separate 24-hour periods for any 30-day period, nor shall they exceed this value in more than 20% of the samples examined in the above described 30-day period; nor shall they exceed 400 per 100 ml in any one sample from May 1 to September 30.

Recommended microbiological criteria for South Dakota public swimming beaches are that any single sample exceeding 200 fecal coliform/100 ml of water is considered as "possibly unsafe" and two consecutive samples exceeding 300 fecal coliform/100 ml is considered unsafe for swimming.

Fecal coliform bacteria concentrations in Mina Lake did not exceed the swimming criteria during the study period. Fecal coliform concentrations were low and ranged from <10 to 30 per 100 ml averaging less than 11/100 ml in the surface waters of the lake (Appendix A).

Dissolved Oxygen

The State of South Dakota has assigned the beneficial use of warmwater permanent fish life propagation to Mina Lake. Therefore, dissolved oxygen (DO) concentrations should not decrease below 5.0 mg/l.

During the present study dissolved oxygen levels and other water quality parameters were sufficient to support a healthy warmwater fishery. Oxygen levels averaged 8 mg/l and ranged from 6.6 to 10.0 mg/l in surface waters and from 6.0 to 8.8 mg/l in deepwaters above the lake bottom.

Suspended Solids and Secchi Disk Visibility

The limits for suspended solids established for a warmwater permanent fishery is 90 mg/l. Excessive suspended solids in a body of water can have a detrimental effect on a lake's fishery. In 1965, the European Fisheries Advisory Committee identified four means by which suspended solids can affect fish and fish food populations (EPA, 1976). Fish swimming in waters with high suspended solids can be killed directly, their growth rate reduced, or their resistance to disease reduced. In addition, suspended solids can prevent the successful development of fish eggs and larva and reduce the abundance of food available to fish.

No exceedences of suspended solids (TSS) standards were observed in Mina Lake during the present study. TSS for the combined in-lake sites averaged 14 mg/l and ranged from <1 to 36 mg/l in surface samples and from <2 to 14 mg/l in bottom waters. Suspended volatile solids (algae and other living and dead organic matter) made up 43% of the total suspended solids and ranged from 0 to 12 mg/l in surface waters and from <2 to 14 mg/l in bottom water samples.

The water clarity and aesthetic appearance of a lake is often not apparent on examination of TSS levels. When suspended particles are very small, such as colloidal clays, it does not require a large amount of TSS to make the water turbid. This may represent the situation in Mina Lake whose large drainage area may contain large amounts of dispersed colloidal clay from the predominantly clay-based soils prevalent in the watershed.

Water clarity in Mina Lake as measured by Secchi disk visibility ranged from poor to fair during 1991 (1 ft - 5 ft). However, from February to April 1992 visibility increased dramatically to an average of 14 ft. The excellent visibility in March and April 1992 is unexpected since there was no ice cover during those sampling dates. It may be partially attributed to the lack of snowmelt and storm runoff during this period and/or the absence of strong winds that are typical for the area.

Phosphorus

Phosphorus is an essential nutrient for plant growth and is typically the cause of excessive growth of algae and aquatic plants. Total phosphorus (TP) concentrations as low as 0.03 mg/l can trigger nuisance growth (NIPC, 1989; Wetzel, 1983). According to Reckhow (1980) TP concentrations greater than .05 mg/l are indicative of hypereutrophy.

During the present study, total phosphorus concentrations in Mina Lake far exceeded the above values in both surface and bottom samples. Phosphorus levels ranged from 0.583 to 0.830 mg/l in surface waters and from 0.563 to 0.744 mg/l in deepwater samples. Surface and bottom samples exhibited similarly high phosphorus concentrations indicating the lake remains mixed throughout most of the annual cycle.

The annual TP mean (May 1991 - April 1992) of the combined in-lake samples was 0.687 mg/l (Table 5). It is of interest that 94% of lake TP and 96% of tributary TP during the study period was in the form of dissolved phosphate which may indicate a major watershed pollution source(s). In any case, these are extremely high phosphate levels even for lakes classified as highly eutrophic and represent a large surplus of in-lake phosphorus which is always available to produce algal blooms or nuisance weed growth.

In-lake total phosphorus concentrations appeared to have more than doubled in a little more than 10 years from a summer mean of 0.278 mg/l reported in 1979 (Koth, 1981). Major sources of phosphorus to Mina Lake may be livestock operations, soil erosion and fertilizer applications in the watershed.

Nitrogen

Nitrogen in its various forms is the second most important nutrient for growth of algae and other aquatic vegetation. Inorganic nitrogen concentrations (primarily nitrates and ammonia) in excess of 0.3 mg/l may be sufficient to stimulate algal growth (Sawyer, 1952).

Inorganic nitrogen concentrations in Mina Lake exceeded 0.3 mg/l only during June and July (Appendix A). At other times inorganic nitrogen levels were low, often at or below detection limits. Nitrate + nitrite (NO_3 + NO_2) values ranged from <0.1 to 0.8 mg/l and ammonia (NH_4) values ranged from <0.02 to 0.08 mg/l throughout the study period. High nitrate values (0.6 - 0.8 mg/l) observed in-lake during June and July 1991 may be largely attributed to tributary input during stormwater runoff. Tributary nitrate concentrations during those months were comparable to in-lake readings.

Nitrogen is believed to be the limiting nutrient in algal growth if the ratio of total nitrogen (N) to total phosphorus (P) is less than 10:1 (Wetzel, 1983). Blue-green algae may become dominant in lakes with a low N:P ratio since they are able to utilize atmospheric nitrogen (N_2) present in water. Other algae must rely on inorganic nitrogen. Due to the extremely high phosphorus concentration in Mina Lake, the mean N:P ratio was less than 2:1 indicating a pronounced nitrogen limitation for the lake during the present study.

Nutrient and Sediment Loadings to Mina Lake

Table 8 presents the nutrient and sediment loads for spring and summer of 1991 calculated for tributary sites 1 and 2. Also present are the areal loads. The values suggest that Mina Lake is receiving extremely high loads of phosphorus from its watershed. East Snake Creek (site 2) seems to provide considerably more total phosphorus than West Snake Creek (site 1). Nitrogen and sediment loads are moderate and not expected to degrade the water quality of Mina Lake. Sediment (TSS) loads entering the lake from the drainage appear to be negligible; an estimated 14.6 tons from

East Snake Creek and 10.4 tons from West Snake Creek during the period of tributary flow from May 3 to July 17. While nitrogen and sediment loads are estimated as moderate to minor, watershed phosphorus loads to Mina Lake may have to be reduced by at least 90% in order that acceptable (permissible) levels may be attained.

Table 8. Nutrient and sediment total loads and areal loads to Mina Lake, May 3 to July 17, 1991.

Sites	Total Load (g/yr)			Areal Load ($g/m^2/yr$)		
	Total Phosphorus	Total Nitrogen	Total Sediment (TSS)	Total Phosphorus	Total Nitrogen	Total Sediment
1	483122.1	761755.1	9402496.4	.148	.234	2.882
2	1949113.3	2051978.2	13232827.4	.597	.628	4.055
Total	2432235.4	2813733.3	22635323.8	.745	.862	6.937
Permissible Load[1]	228410.0	3263000.0	-	.070	1.000	-
Dangerous Load[1]	424190.0	6526000.0	-	.130	2.000	-

[1] Vollenweider (1968) phosphorus and nitrogen loadings based on Mina Lake mean depth (<5 meters) and surface area (326.3 ha).

'Permissible' loads are those which would cause the receiving lake to become less eutrophic or mesotrophic.

'Dangerous' loads would cause the receiving lake to become eutrophic or remain eutrophic.

Tributary Water Quality

During the study period, tributary sites #1 and #2 were sampled a total of 13 and 12 times, respectively. Water quality data indicated that these tributaries experience high levels of phosphorus and fecal coliform bacteria contamination and in turn deliver these high concentrations of contamination to Mina Lake (Table 8). Tributary input of sediment (suspended solids) to the lake appears to be a secondary problem at this time.

As previously discussed, fecal coliform concentrations exceeding 200 per 100 ml of water in lakes is considered potentially unsafe. Although this standard does not apply directly to streams, it serves to illustrate the contamination that may be occurring in the tributaries. During the study period, fecal coliform concentrations exceeded 200/100 ml in 82% of samples taken at the east tributary (site #2) but only 23% at the west tributary (site #1) exceeded this standard. Clearly, fecal coliform bacteria are a much greater problem in the eastern tributary to Mina Lake. Fecal coliform concentrations for sites #1 and #2 ranged from 10 to 3,300 and 60 to 1000, respectively (Appendix A). While the frequently high tributary coliform levels were not reflected in lake samples during the present study, sources of fecal coliform contamination should be identified to protect immersion recreation in the lake.

Excessive nutrient concentrations are the primary cause of excessive blue-green algae and aquatic plant growth in lakes. Tributaries #1 and #2 both contributed high concentrations of nutrients, particularly phosphorus, to Mina Lake throughout the study period. High concentrations of nitrogen (in the form of nitrates) were contributed only in June and July. This was probably a delayed effect of nitrogen fertilizer applications in the watershed earlier in the spring of 1991.

Mean phosphorus levels in the tributaries were more than twice as high as those in the lake (Tables 5 and 8). Highest phosphorus concentrations consistently occurred at tributary site #2. Total phosphorus concentrations for the tributaries ranged from 0.176 to 1.81 at site #1 and from 0.210 to 2.58 at site #2. Dissolved phosphorus for the sites made up 95% and 98% of total phosphorus, respectively. This compares to 94% for the in-lake sites. Nitrate concentrations ranged from <0.10 to 0.70 at site #1 and from <0.10 to 0.60 at site #2. Unlike those for phosphorus, there was little difference in nitrate levels between tributary sites (Appendix A, Table 9).

Table 9. Tributary Sampling Data Mean Values (n = 13, 12, 9).

Parameter	Mean values for sites		
	Site 1	Site 2	Site 3
D.O. (mg/l)	3.4	3.2	7.3
Field pH (s.u.)	7.57	7.56	8.34
Fecal Coliform (#per/100 ml)	380	566	33
Total Solids (mg/l)	843	524	474
Total Dissolved Solids (mg/l)	815	505	451
Suspended Volatile Solids (mg/l)	8	6	8
Total Suspended Solids (mg/l)	20	15	22
Ammonia (mg/l)	0.07	0.07	0.03
Nitrate + Nitrite (mg/l)	0.39	0.35	0.61
TKN (mg/l)	1.50	1.68	0.85
Total PO4-P (mg/l)	1.241	1.874	0.622
Dissolved PO4-P (mg/l)	1.180	1.835	0.584

Low dissolved oxygen (<3 mg/l) recorded in both tributaries under flow conditions suggested the presence of considerable quantities of organic matter upstream of sites #1 and #2 (Appendix A, Table 9). This organic material either natural in origin or, more likely, produced by agricultural activities, is subject to decomposition (oxidation) by bacteria which may result in temporary depletion of oxygen supplies in streams and lakes.

Incoming suspended solids levels did not appear to pose a serious pollution problem to Mina Lake. Mean suspended solids calculated for the study were 20mg/l at site #1 and 15 mg/l at site #2 (Table 6). Most tributary TSS concentrations recorded were far below the 90 mg/l standard for Mina Lake (Appendix A).

Elutriate Analysis

Sediment samples collected from both arms of the lake at water quality in-lake sites #4 and #5 were analyzed for a variety of metals, pesticides and other potentially toxic chemicals. Results indicated no toxic levels of chemicals in the sediment or elutriate water (Appendix B). Therefore, the analysis indicated that disturbance of sediments by dredging activities should not present a toxicity problem to the lake.

Sediment Survey

The DENR in cooperation with the Edmunds County Conservation District conducted a sediment survey on February 20, 1991. Cross-section locations were plotted on a large photographic map, reproductions of which are available upon request from the Division of Water Resources Management (WRM), Pierre, SD.

Mina Lake was divided into eastern and western reaches which encompassed the two arms, and a southern reach covering the base of this U-shaped reservoir. Each reach was further divided with a number of transect lines sufficient to characterize sediment depth in each of the three sectors. Tables containing detailed sediment depth sounding data for every transect are included in Appendix C.

Results of the sediment depth survey indicated average sediment depth in Mina Lake is 1.12 ft. (Table 7). Mean sediment depths in the three sectors (reaches) ranged from 1.8 ft. in the east arm to 0.6 ft. in the south reach. The west arm of Mina Lake was intermediate for sediment depth with 1.0 ft. (Table 10).

These depths represent very moderate accumulations of sediment from the watershed and shoreline over the 58-year life of this reservoir and indicate that sediment build-up is presently not a serious problem in the main basin of Mina Lake.

Table 10. Summary of sediment depth survey, Mina Lake, February 20, 1991.

MINA LAKE SEDIMENT SURVEY

Summary Sheet

Section	Avg depth sed orig. to 1980	Volume orig. to 1980	Avg depth sed 1980 to 1991	Volume 1980 to 1991	Avg depth sed orig. to 1991	Volume orig. to 1991
E Reach	1.3 ft.	56148.4 cu/yds	0.5 ft.	10602.4 cu/yds	1.8 ft.	67393.6 cu/yds
S Reach	0.9 ft.	54169.4 cu/yds	-0.4 ft.	-22970.6 cu/yds	0.6 ft.	31198.8 cu/yds
W Reach	0.8 ft.	17210.2 cu/yds	0.1 ft.	5246.3 cu/yds	1.0 ft.	22456.5 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds	0.0 ft.	0.0 cu/yds
	3.0 ft.	127528.0 cu/yds	0.3 ft.	-7121.9 cu/yds	3.4 ft.	121048.9 cu/yds

Total distance of Reaches	38640.0 ft.
Average width of Mina Lake	908.6 ft.
Acres of Mina Lake	805.975758 acres
Average depth of sediment (original to 1980)	1.00920623 ft.
Total Volume (original to 1980)	42509.3175 cu/yds
Average depth of sediment (1980 to 1991)	0.09349429 ft.
Total Volume (1980 to 1991)	-2373.96 cu/yds
Average depth of sediment (original to 1991)	1.1207934 ft.
Total Volume (original to 1991)	40349.6454 cu/yds

Watershed Inspection/Land Use

The contributing watershed of Mina Lake is approximately 141,858 acres in size located mainly in Edmunds (76,603 acres) and McPherson Counties (63,389 acres). A small segment of the southeast drainage (1,866 acres) extends into Brown County (Figure 1).

Watershed topography is nearly level to gently sloping, but is steeper along the larger drainageways. Watershed soils are mostly the medium to moderately drained loams and clay-loams of the Niobell-Noonan, Bryant, Williams-Bowbells, Williams-Vida, and Edgely Loam Associations.

Agriculture is the principal enterprise in the watershed. About 40% of the area is cropland and 60% is native grass, tame grass and alfalfa. The main crops are wheat, oats, barley, corn, sunflowers, and alfalfa. Growing cash crops, hay, and raising beef cattle are the main farm activities.

Nutrient input from the watershed is a major problem and has undoubtedly accelerated the eutrophication of Mina Lake. Likely sources of some of these nutrients are a number of feedlots that border the main drainageways. These operations should be given a high priority in any future mitigation efforts for the improvement of Mina Lake. Livestock operations are also major sources of high levels of fecal coliform bacteria entering Mina Lake via its two major tributaries, as previously discussed. Some sedimentation is occurring in the upper reaches of the lake in the two inlet areas which is related to watershed soil erosion. Rooted aquatic vegetation (mainly cattails) are encroaching in these areas of sedimentation. However, the actual seriousness of this last problem is under investigation and remains to be determined.

There are approximately 132 livestock operations/farmsteads within the Mina Lake watershed at the present time. Of these, 81 or 61% were found to have a relatively low impact on local water quality, 10 or 8% were rated as having a moderate to severe impact and the remaining 41 operations or 31% could not be rated at the time of the survey.

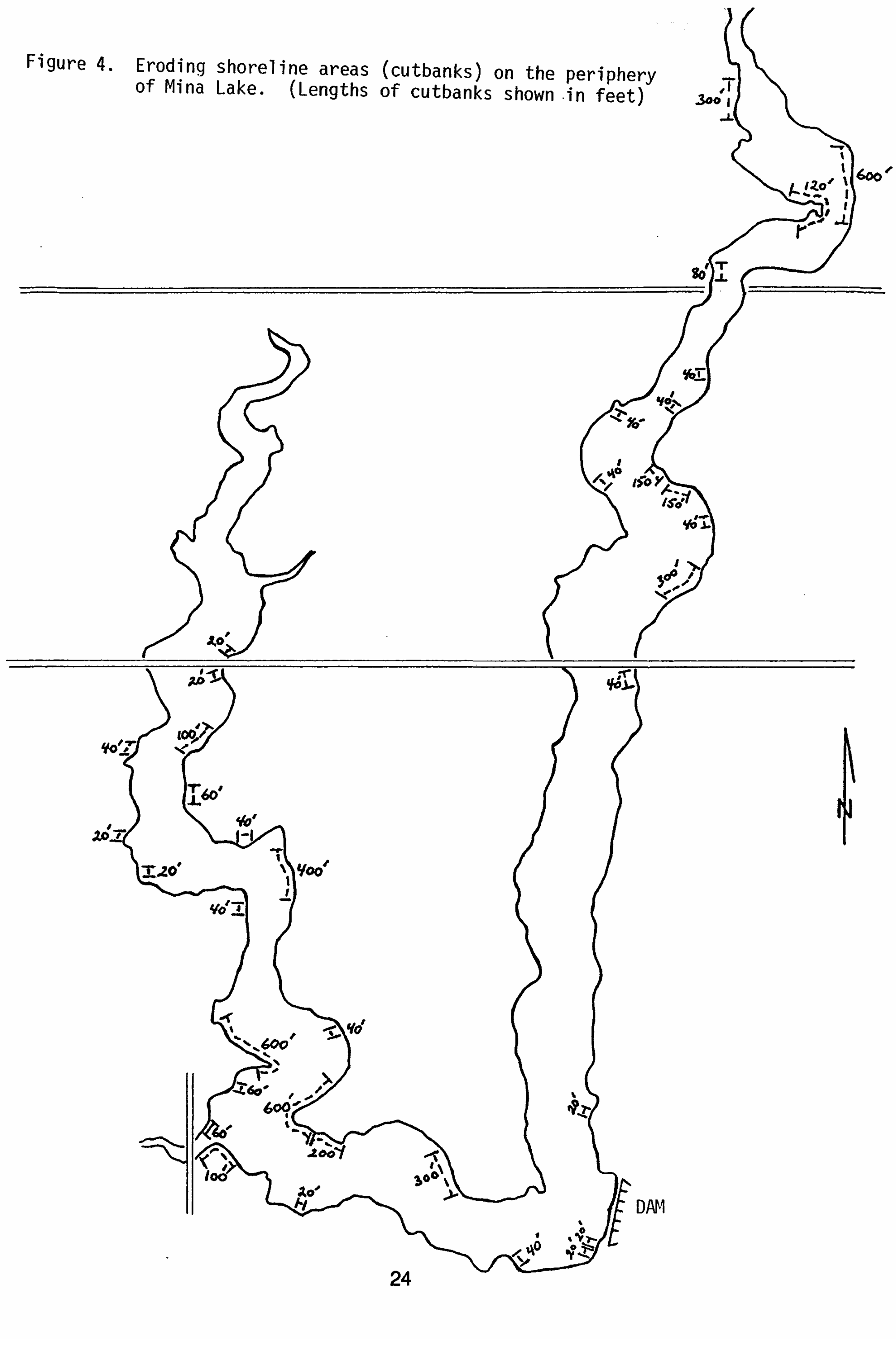
The watershed inspection further indicated there are approximately 19,084 acres of erodible cropland in the drainage where establishment of permanent cover under the CRP program would be beneficial for controlling water and wind erosion; and approximately 50,000 acres of rangeland where planned grazing systems need to be implemented. Sixteen waterways totalling 7500 linear feet were in need of grass cover for retention of waterborne sediments and associated nutrients. Finally, the survey noted 17 natural stream beds within the watershed under cultivation during 1991 and 35 old sediment dams in the drainage that had moderate to severe erosion problems, some of which having been rendered ineffective where waterflows had cut new channels bypassing the dams.

Shoreline Erosion Survey

A shoreline erosion survey was conducted during September 1991 by personnel of the Edmunds County Conservation District to determine those shoreline areas contributing significant sediment loads to the lake. Thirty-six such areas (mainly cutbanks) were identified ranging in length from 20 to 600 feet that were experiencing moderate to severe erosion due to wind and wave action (Figure 4). Those lakeside segments totaled 4780 feet or about 4% of the lake shoreline. Severe erosion problems were noted at a 600 foot cutbank located at the upper end of the east arm of Mina Lake (Figure 4). Sediment yield from eroding lakeshore segments was not quantified during this survey.

In the developed parts of the Mina Lake shoreline most of the lakeshore has been stabilized by private residents. As of 1990, lakeside homeowners have riprapped 35,640 feet of shoreline or slightly less than 1/3 of the entire lake circumference.

Figure 4. Eroding shoreline areas (cutbanks) on the periphery of Mina Lake. (Lengths of cutbanks shown in feet)



CONCLUSIONS

1. Very high concentrations of total phosphorus (mean 0.687 mg/l) were present in Mina Lake from May 20, 1991 to April 14, 1992, the length of the present monitoring period. According to some literature sources, concentrations greater than 0.05 mg/l TP are indicative of extreme lake eutrophy (hypereutrophy).

2. Dissolved phosphorus made up 94% of total phosphorus for in-lake samples during the study suggesting the presence of one or more major pollution sources in the lake watershed.

3. Tributary averages for total phosphorus (TP) were even higher (1.241 and 1.874 mg/l) than that for the lake indicating that the two major tributaries may be the principal contributors of phosphorus to the lake.

4. Similar to in-lake samples, dissolved phosphorus comprised 96% of total phosphorus in tributary samples.

5. In contrast to phosphorus, in-lake organic nitrogen (TKN-ammonia) was present at low to moderate concentrations (mean 0.77 mg/l). Ammonia levels were also low.

6. Organic nitrogen in the tributaries was approximately twice the concentration in the lake, but cannot be considered excessive given the large size of the watershed devoted to agriculture. However, the often low DO (<3 mg/l) readings in the tributaries suggests considerable organic matter was available for oxidation upstream of sites #1 and #2, which may have resulted in the depressed oxygen levels recorded during this study.

7. Nitrate nitrogen concentrations increased sharply in the lake and tributaries (to 0.6-0.8 mg/l) during June and July 1991 from usually low or undetectable levels (<0.10 mg/l). These increases may have been due to runoff following nitrogen fertilizer applications in the watershed.

8. Based on the excessive quantities of phosphorus and relatively moderate amounts of total nitrogen present, Mina Lake can be classified as a nitrogen-limited lake during 1991.

9. Mina Lake is experiencing excessive phosphorus loading and relatively moderate nitrogen loading from its tributaries during periods of stormwater runoff. The lake appears to act as a phosphorus sink and as a nitrogen sink for organic nitrogen but not for nitrate nitrogen.

10. Based on a comparison with in-lake data collected during June and August of 1979, mean TKN for those months declined from 1.34 to 0.85 mg/l between the years 1979 and 1991. However, in-lake total phosphorus appears to have more than doubled from 0.278 to 0.645 mg/l during this interval.

11. The increase in lake phosphorus may be due to increased agricultural activity in the watershed during the past 12 years. However, this cannot account for the concomitant decline in TKN nitrogen, but may partially explain an increase in average lake nitrate from 0.20 to >0.40 (June and August) over the same time period.

12. Average water clarity (Secchi disk visibility) in Mina Lake for 1991 rated as poor (3.7 ft = 1.1 m). From 1979 to 1991 (June and August only) lake water clarity apparently has declined 33% from fair (1.8 m) to poor (1.2m). This decrease may be due to increases in both biotic (algae) and abiotic (suspended clay and silt particles) factors.

13. In-lake and outlet fecal coliform bacteria concentrations were low during the study (<90/100 ml) averaging 14 and 33 organisms/100 ml, respectively. These levels were in compliance with state criteria for surface waters used for immersion recreation.

14. Tributary fecal coliform levels exceeded 200/100 ml in 23% of samples at site #1 and in 82% at site #2. High fecal coliform densities occurred much more frequently at eastern tributary site #2 (Appendix A) even though this subdrainage is only 12% larger in area than the other subdrainage in the watershed monitored by site #1. Although the high tributary fecal densities were not reflected in lake samples (probably owing to the distance of lake sites from the two lake inlets), the source(s) of these high bacterial levels must be identified to protect immersion recreation in Mina Lake.

15. Accumulations of soft sediments in Mina Lake from the watershed and lakeshore erosion appear to be very moderate (mean depth 1.12 ft.) over the 58-year life of this reservoir. However, shoreline bank erosion contributes to water turbidity and degrades nearby littoral lake habitat and sedimentation from the drainage <u>is</u> appreciable in the upper reaches (inlet areas) of the lake where it aids the encroachment of cattails and other aquatic vegetation. Nevertheless, these inlet areas with their cattail beds act as sediment traps that protect the more usable portions of the lake some distance downstream.

16. In general, aquatic vegetation, and particularly floating and submerged macrophytes, are not a serious problem in Mina Lake at the present time.

RECOMMENDATIONS

Based on the results of this study, the DENR recommends the following alternatives for restoration. These recommendations should provide a basis for the development of a complete restoration work plan and subsequent implementation. The recommendations are provided for review only. They are not to be considered as the only possible methods of restoration. In approximate order of importance they are the following:

1. Ag Waste Management Systems:

   Installation of animal waste management systems at the feedlots in the watershed would represent a positive step to reduce nutrient and fecal coliform bacteria input. Approximately 10 systems would be needed to contain most of the feedlot runoff. Another effort should be made to obtain water quality impact estimates for the 31% of watershed livestock operations (41) that could not be rated during the initial survey.

2. Best Management Practices on Cropland:

   Best Management Practices should be applied to cropland and pastures where necessary, to reduce nutrient loading and sedimentation to the lake. Minimum tillage practices should be stressed as a preferred method of crop residue management. Fertilizer application rates and timing should be monitored to determine if they contribute to excessive nutrient loading. Landowners need to maintain established Best Management Practices or else any gains in nutrient and sediment reduction will be lost.

3. Shoreline Erosion:

   Approximately 4,000 linear feet of riprapping is needed to stabilize the severe shoreline erosion areas.

4. Planned Grazing Systems:

   Planned Grazing Systems should be applied on 50,000 acres of native range to improve range condition.

5. Natural Stream Channels Being Cropped:

   Approximately 550 acres of natural stream channels are currently being cropped and should be seeded to permanent vegetation.

6. Grassed Waterways:

   Approximately 12,000 linear feet of grassed waterways are needed in the watershed.

7. Old Dam Site Repair:

   Approximately 35 old dams are located in the watershed. These dams have moderate to severe erosion problems due to poor design. Many of the spillways are eroding and in many cases a new channel is cut around the dam making the dam totally ineffective. Poorly designed sediment dams that have deteriorated to the extent that repair is not practicable should be rebuilt using a more effective design. Many eroding spillways can probably be repaired economically. Dams that have been rendered ineffective should be replaced if their location is in a high sediment area.

8. Elimination of Septic Tank Drainfields on West Side of West Mina Lake:

   Septic tanks of approximately 15 homes should be hooked up to the existing centralized sewer system and individual septic tank drainfields eliminated.

9. Approximately 19,000 acres of eroding crop and rangeland in the Mina Lake drainage may be eligible for protection (permanent grass cover) under the CRP program. For each individual tract appropriate Best Management Practices (BMP) should be applied as needed.

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Appendix L

Snake Creek Tributary Stage Discharge Regression Graphs and Equations 1999 trough 2000

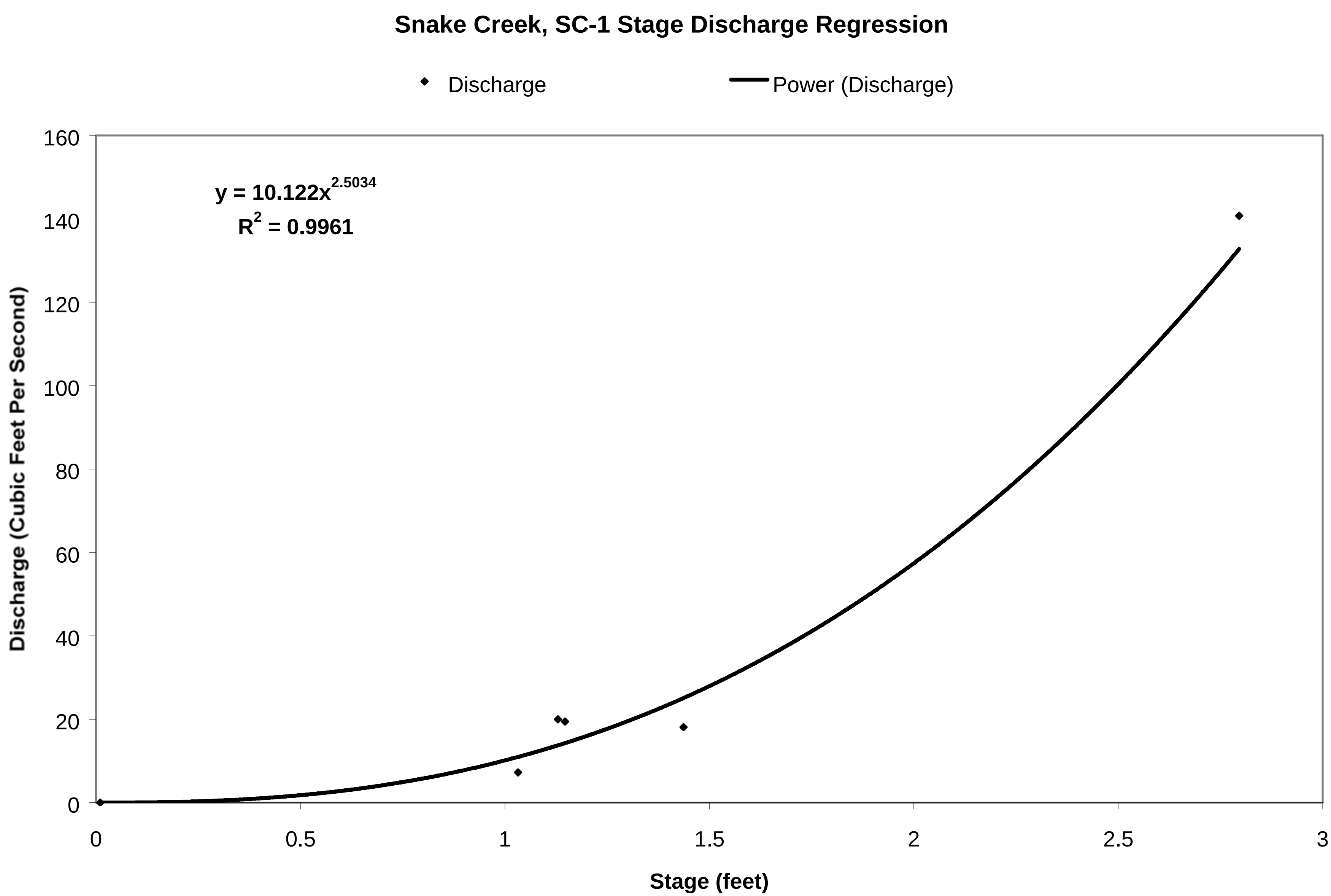

Figure B-1. SC-1 stage discharge regression for 1999 through 2000.

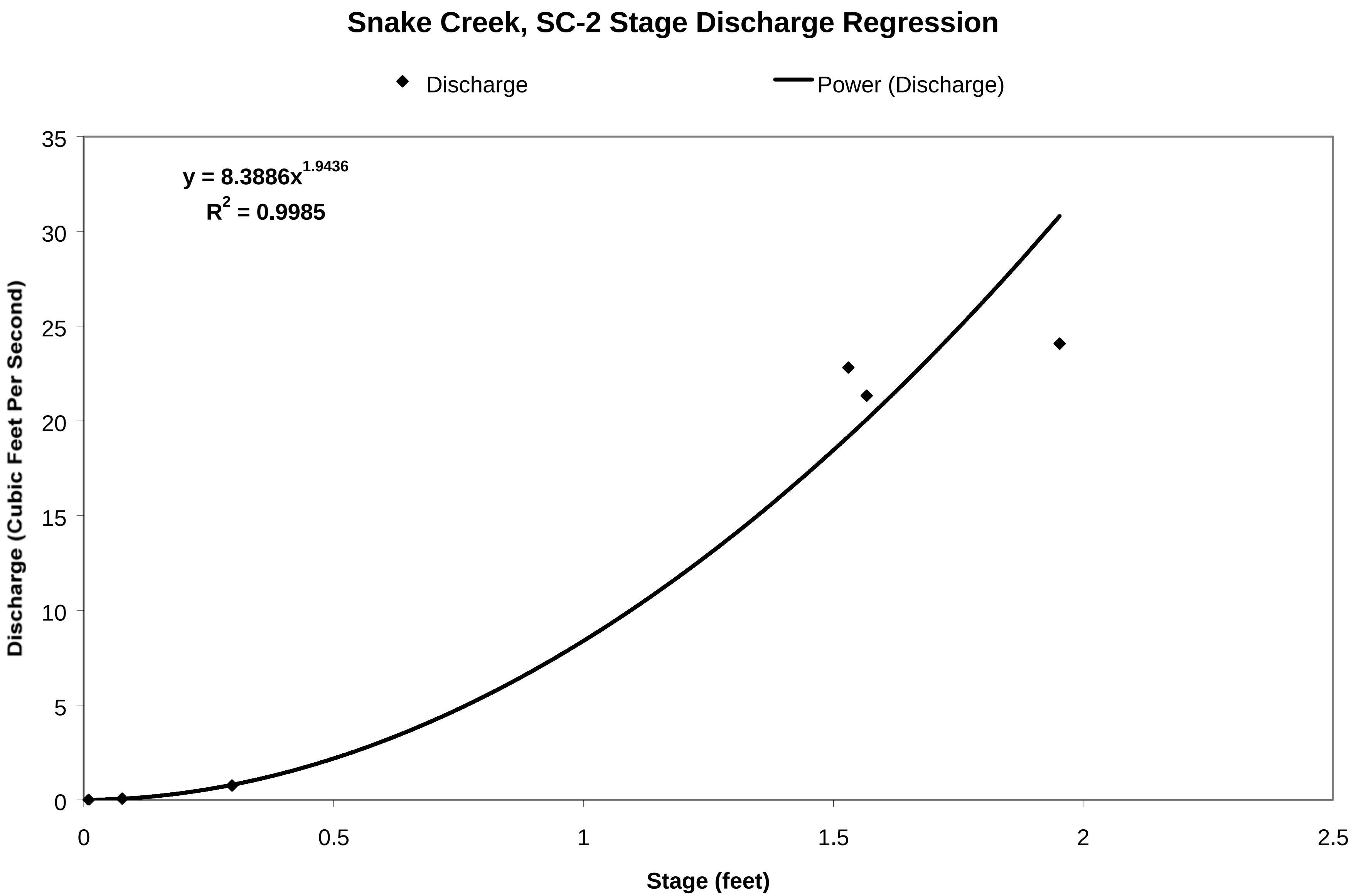

Figure B-2. SC-2 stage discharge regression for 1999 through 2000.

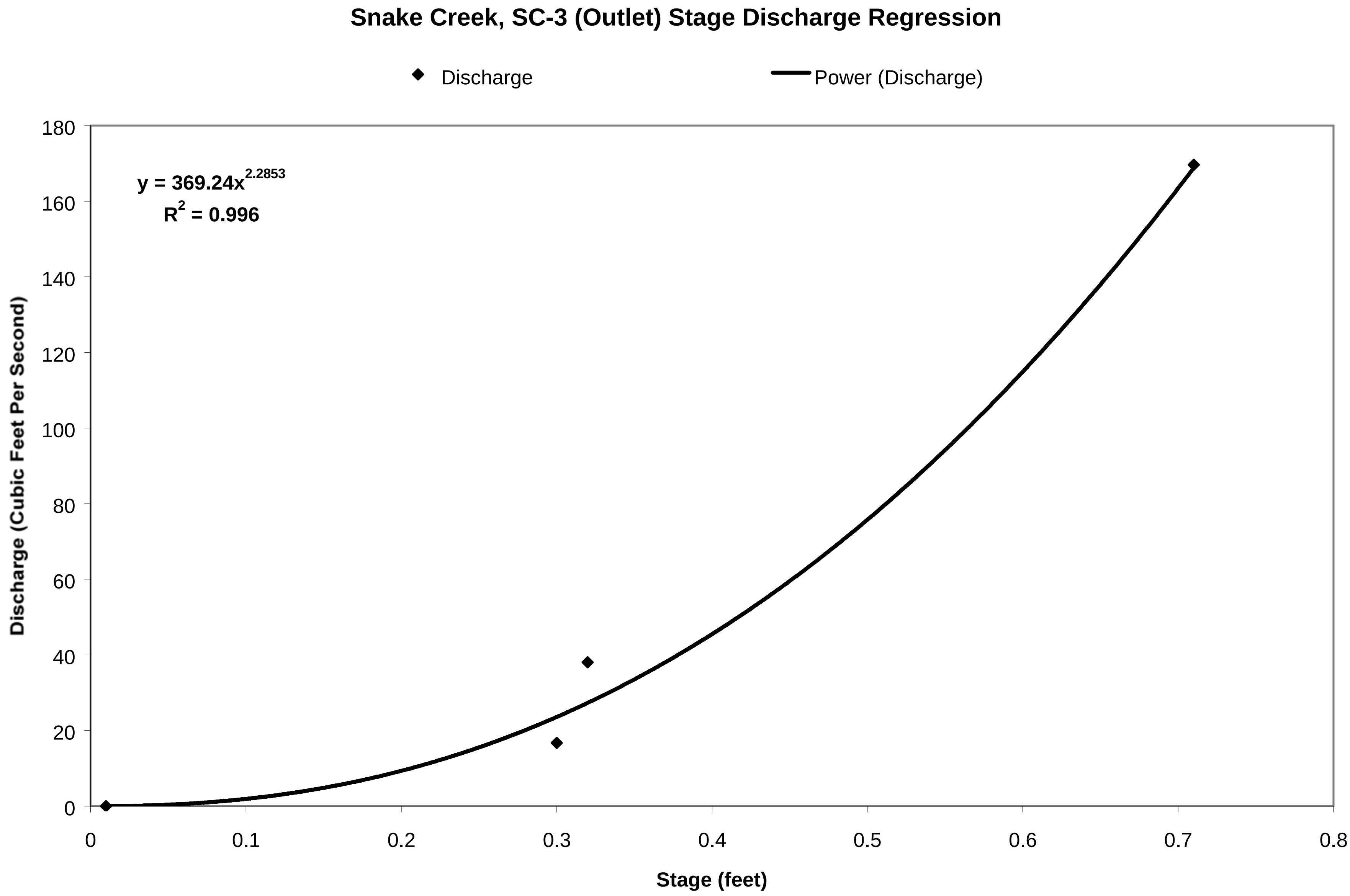

Figure B-3. SC-3 (Outlet) stage discharge regression for 1999 through 2000.

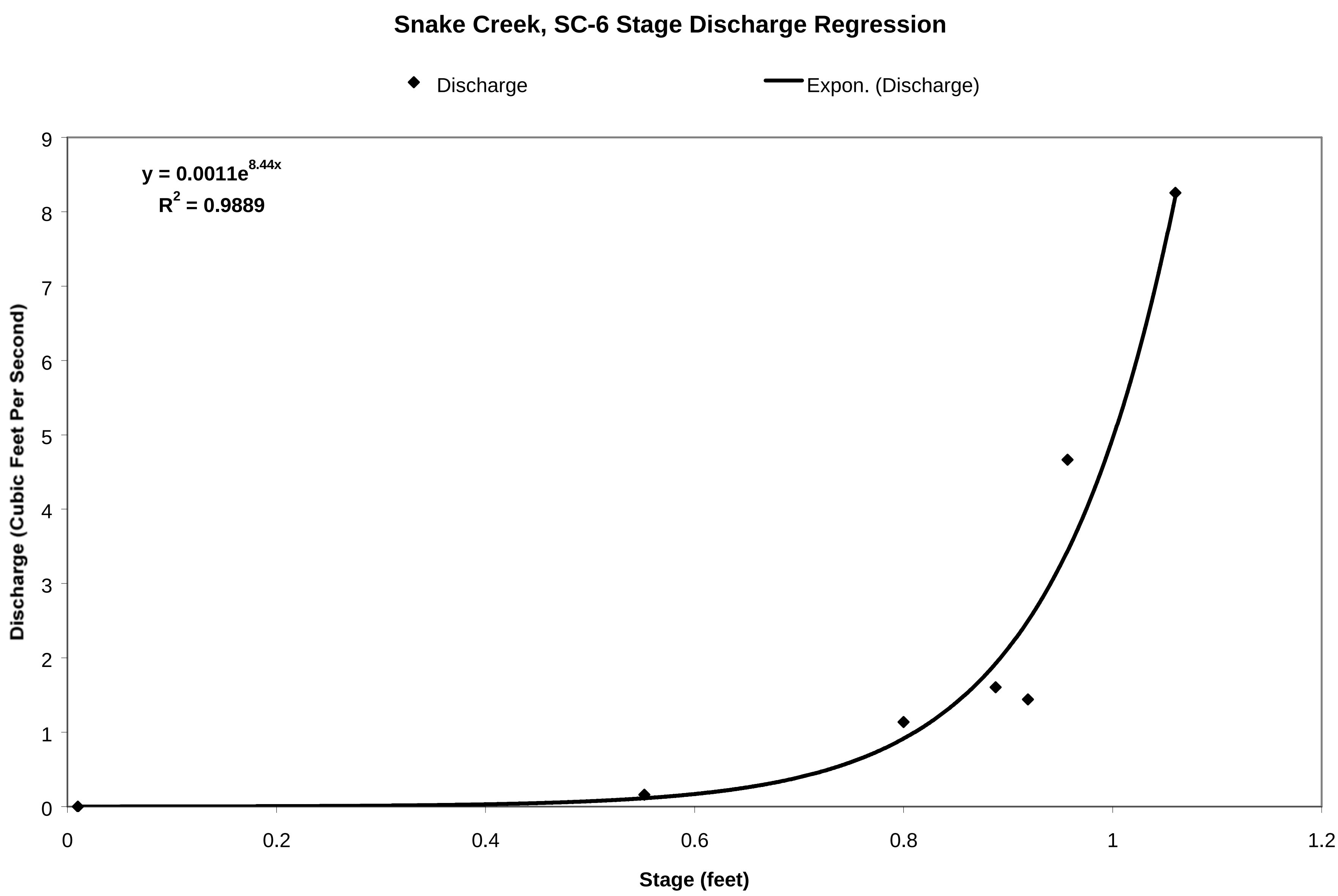

Figure B-4. SC-6 stage discharge regression for 1999 through 2000.

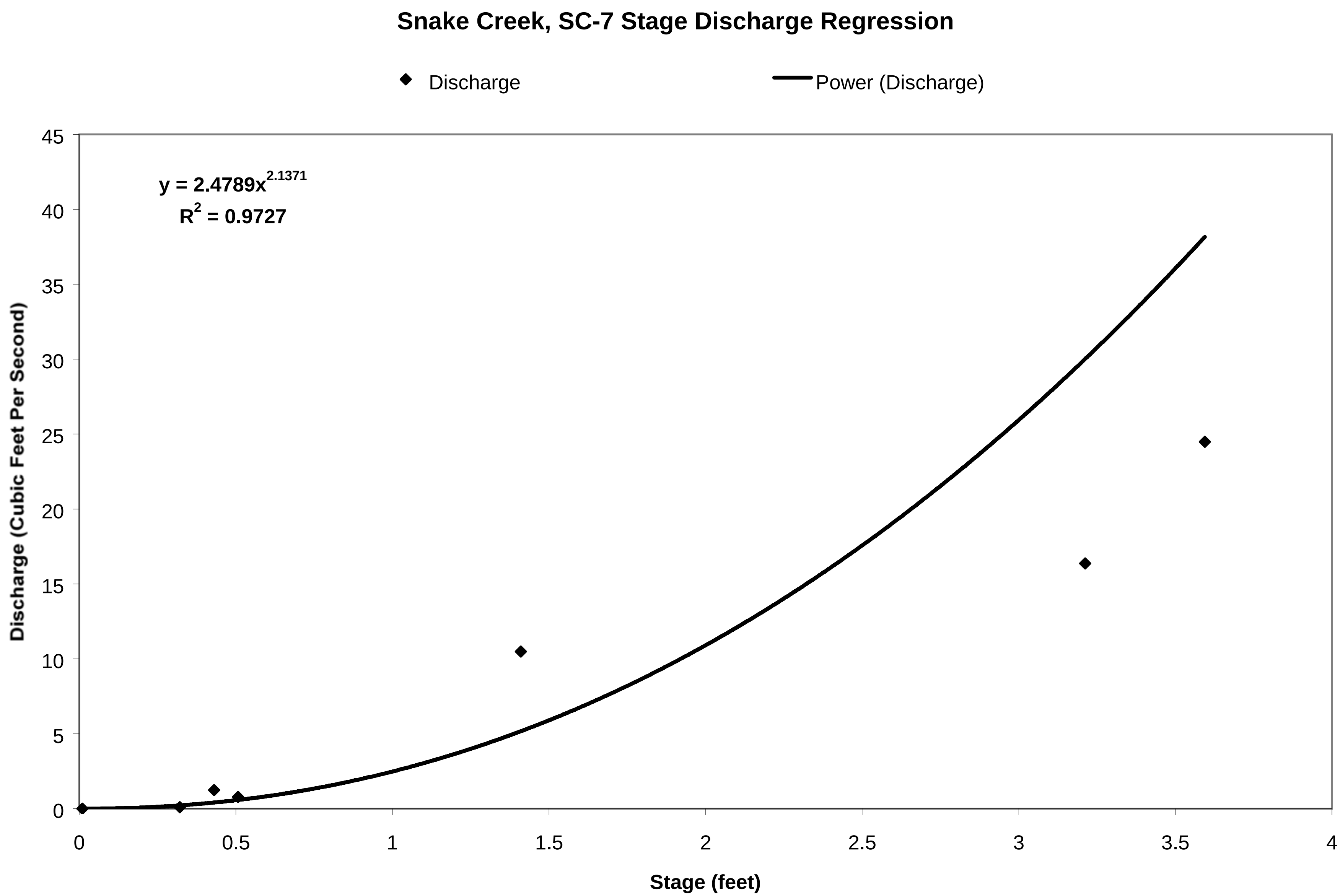

Figure B-5. SC-7 stage discharge regression for 1999 through 2000.

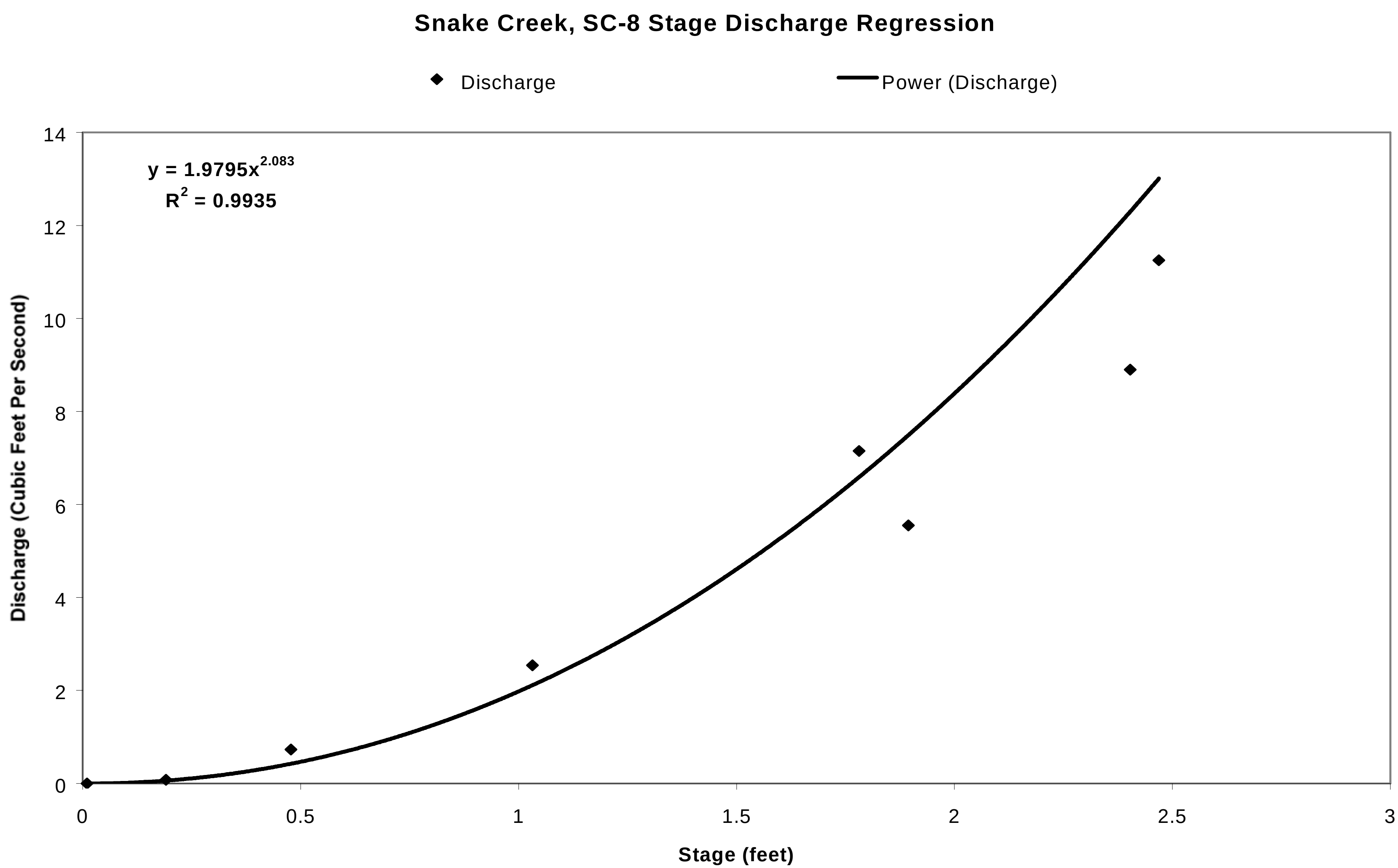

Figure B-6. SC-8 stage discharge regression for 1999 trough 2000.

Appendix M

Agricultural Non-Point Source Pollution Model (AGNPS) Final Report

AGRICULTURAL NON-POINT SOURCE (AGNPS) ANALYSIS OF THE MINA LAKE WATERSHED EDMUNDS, MC PHERSON AND BROWN COUNTIES, SOUTH DAKOTA

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DIVISION OF FINANCIAL & TECHNICAL ASSISTANCE
SOUTH DAKOTA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

March 2002

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Introduction

Agricultural Non-point Source Pollution Model (AGNPS) is a computer simulation model developed to analyze the water quality of runoff from watersheds. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand concentrations in the runoff and the sediment for a single storm event, for all points in the watershed. Proceeding from the headwaters to the outlet, the pollutants are routed in a step-wise fashion so the flow at any point may be examined. AGNPS is used as a tool to objectively evaluate the water quality of the runoff from agricultural watersheds and to provide a means of objectively comparing different watersheds throughout the state. The model is intended for watersheds up to about 320,000 acres (8000 cells @ 40 acres/cell).

The model works on a cell basis. These cells are uniform square areas that divide up the watershed. This division makes it possible to analyze any area in the watershed, down to 1.0 acre. The basic components of the model are hydrology, erosion, sediment transport, nitrogen (N), phosphorus (P), and chemical oxygen demand (COD) transport. In the hydrology portion of the model, calculations are made for runoff volume and peak concentration flow. Total upland erosion, total channel erosion, and a breakdown of these two sources into five particle size classes (clay, silt, small aggregates, large aggregates, and sand) for each of the cells are calculated in the erosion portion. Sediment transport is also calculated for each of the cells in the five particle classes as well as the total. The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment attached pollutants.

This model was developed by the USDA - Agricultural Research Service to analyze the water quality of runoff events from watersheds. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand (COD) concentrations in the runoff and sediment for a single storm event, for all points in the watershed. Proceeding from the headwaters to the outlet, the pollutants are routed in a step-wise fashion so that the flow at any point may be examined. This model was developed to estimate sub-watershed or tributary loadings to a waterbody. The AGNPS model is intended to be used as a tool to objectively compare different sub-watersheds within a watershed and watersheds throughout a river basin.

To further evaluate the water quality status of the Mina Lake watershed, land use and geo-technical information was compiled. This information was then incorporated into the AGNPS computer model. The primary objectives of utilizing a computer model on the Mina Lake watershed were to:

1.) Evaluate and quantify Non-point Source (NPS) yields from each river reach and determine the net loadings into Mina Lake;
2.) Define critical NPS cells within each river reach's watershed (elevated sediment, nitrogen, phosphorus);
3.) Priority-rank each animal feeding area and quantify the nutrient loadings from each area; and

4.) Use the model to estimate the possible reduction (by percentage) in the export of sediment and nutrients by sub-watershed through implementation of Best Management Practices.

Initially, the watershed was divided into cells each of which had an area of 40 acres with dimensions of 1320 feet by 1320 feet. AGNPS analysis of the Mina Lake watershed consisted of the following: collection of 21 field parameters for each cell; the calculation of non-point source pollution yields for each cell and sub-watershed; impact and ranking of each animal feeding area; and an estimated hydrology runoff volume for each of the storm events modeled.

For comparative purposes, the watershed was broken up into the seven separately analyzed sub- watersheds. The Mina Lake Assessment Project monitored five tributary water quality sites within the watershed during the study. In addition, 12,880 acres between the last monitoring sites (SC-1 and SC-2) on Snake Creek and the inlets to Mina Lake were also evaluated as a sub-watershed and are referred to as the "ungauged area" throughout this report.

Methods (Data Requirements)

Preliminary Requirements

A preliminary investigation of the watershed is necessary before the input file can be established. The steps to this preliminary examination are:

1) Detailed topographic map of the watershed (USGS map 1:24,000).
2) Establish the drainage boundaries.
3) Divide watershed up into cells (40 acre, 1320 feet x 1320 feet). Only those cells with greater than 50% of their area within the watershed boundary should be included.
4) Number the cells consecutively from one to the total number of cells in the drainage (begin at the NW corner boundary of watershed and proceed west to east then north to south).
5) Establish the watershed drainage pattern from the cells.

Data Requirements

Once the preliminary examination is completed, the input data file can be established. The data file is composed of the following inputs (21) per cell:

Data Input for Watershed

1) a) Area of each cell (acres)
b) Total number of cells in watershed
c) Precipitation for a 1-month, 6-month and 1-year, 24-hour rainfall events
d) Energy intensity value for storm event previously selected

Data Input for Each Cell

1) Cell number
2) Receiving cell number
3) SCS number-runoff curve number, (use antecedent moisture condition II)
4) Land slope- (topographic maps), average slope if irregular, water or marsh = 0
5) Slope shape factor-water or marsh = 1 (uniform)
6) Field slope length-water or marsh = 0, for S.D. assume slope length area 1
7) Channel slope- (average), topographic maps, if no definable channel, channel slope = 1/2 land slope, water or marsh = 0
8) Channel sideslope-the average sideslope (%), assume 10% if unknown, water or marsh=0
9) Manning roughness coefficient for the channel - If no channel exists within the cell, select a roughness coefficient appropriate for the predominant surface condition within the cell.
10) Soil erodibility factor-water or marsh = 0
11) Cropping factor-assume conditions at storm or worst case condition (fallow or seedbed periods), water or marsh = .00, urban or residential = .01.
12) Practice factor-worst case = 1.0, water or marsh = 0, urban or residential = 1.0.
13) Surface condition constant-a value based on land use at the time of the storm to make adjustments for the time it takes overland runoff to channelize.
14) Aspect-a single digit indicating the principal direction of drainage from the cell (if no drainage = 0).
15) Soil texture-major soil texture and number to indicate each are:

Table C-57. Soil texture values for AGNPS.

Texture	Input Parameter
Water	**0**
Sand	**1**
Silt	**2**
Clay	**3**
Peat	**4**

16) Fertilization level-indication of the level of fertilization on the field as follows:

Table C-58. Fertilization input values by application rate.

	Assume Fertilization (lbs/acre)		
Level	Nitrogen	Phosphorus	Input
No Fertilization	**0**	**0**	**0**
Low Fertilization	**50**	**20**	**1**
Average Fertilization	**100**	**40**	**2**

High Fertilization	**200**	**80**	**3**

Avg. manure - low fertilization
High manure – avg. fertilization
Water or marsh = 0
Urban or residential = 0 (for average practices)

17) Availability factor-the percent of fertilizer left in the top half inch of soil at the time of the storm. Worst case 100 percent, water or marsh = 0, urban or residential = 100 percent.
18) Point source indicator-indicator of feedlot within the cell (0 = no feedlot, 1 = feedlot).
19) Gully source level-tons of gully erosion occurring in the cell or input from a sub-watershed.
20) Chemical oxygen demand (COD)-a value of COD for the land use in the cell.
21) Impoundment factor-number of impoundments in the cell (max. 13)
a) Area of drainage into the impoundment
b) Outlet pipe (diameter in inches)
22) Channel indicator-number designating the type of channel found in the cell.

Data Output at the Outlet of Each Cell

Hydrology
Runoff volume
Peak runoff rate
Fraction of runoff generated within the cell

Sediment Output
Sediment yield
Sediment concentration
Sediment particle size distribution
Upland erosion
Amount of deposition
Sediment generated within the cell
Enrichment ratios by particle size
Delivery ratios by particle size

Chemical Output
Nitrogen
Sediment-associated mass
Concentration of soluble material
Mass of soluble material

Phosphorus
Sediment-associated mass
Concentration of soluble material
Mass of soluble material

Chemical Oxygen Demand (COD)
Concentration
Mass

Parameter Sensitivity Analysis

The most sensitive parameters affecting sediment and chemical yields are:
Land slope (LS)
Soil erodibility (K)
Cover-management factor (C)
Curve number (CN)
Practice factor (P)

Rainfall Specifications (R_{factor}) for the Mina Lake Watershed Assessment AGNPS Analysis

Table C-59. Rainfall specifications for AGNPS modeling analysis for the Mina Lake watershed.

Event	Rainfall	Energy Intensity (EI)
Monthly	**0.8**	**3.0**
6-month	**1.2**	**7.4**
1-year	**1.8**	**17.3**
2-year	**2.2**	**26.8**
5-year	**3.0**	**52.6**
10-year	**3.5**	**73.7**
25-year	**4.1**	**104.0**
50-year	**4.6**	**133.5**
100-year	**5.2**	**174.4**

NRCS R_{factor} for the Mina Lake watershed = 69.5

Table C-60. Mina Lake annualized loading calculations.

Event	Number of events	EI factor	Total
Monthly	**10**	**3.0**	**30.0**
6-month	**3**	**7.4**	**21.6**
1-year	**1**	**17.3**	**17.3**
Modeled Cumulative. R_{factor}			69.5

Results by Sub-watershed

Brooks West Sub-watershed AGNPS Analysis (A Sub-watershed of Mina Lake)

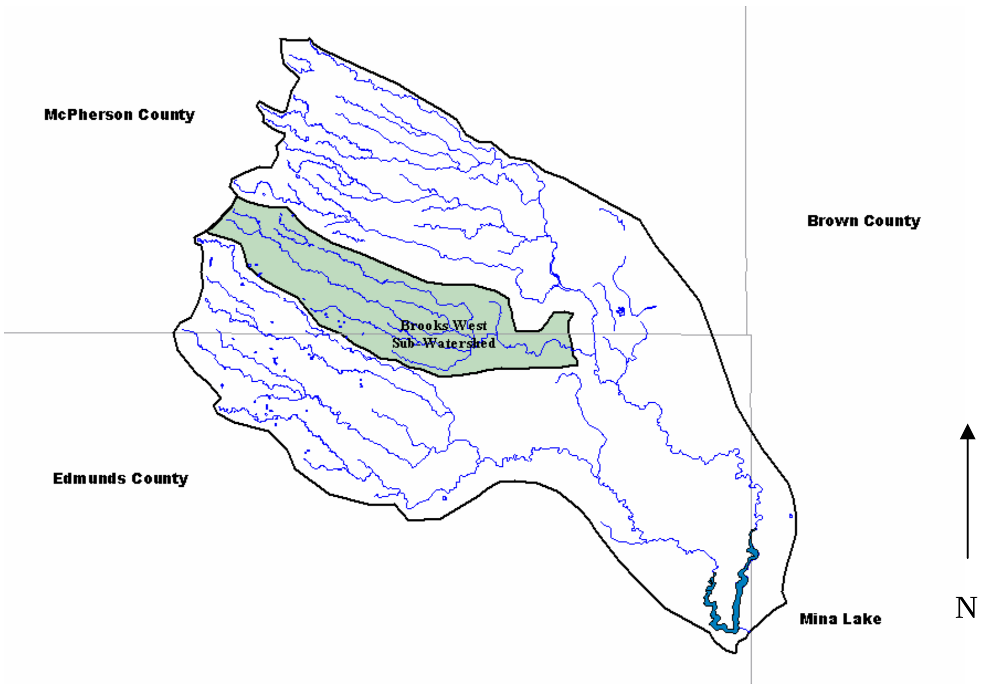


Figure C-71. The Brooks West Sub-watershed within the Mina Lake watershed.

The Brooks West sub-watershed straddles McPherson and Edmunds counties, in northeastern South Dakota, and is a drainage for the eastern tributary of the Snake Creek in the Mina Lake watershed. The sub-watershed contributes 14 percent of total hydrologic input and encompasses approximately 8,790 hectares (21,720 acres). It is a shallow basin that drops 122.2 meters (401 feet) over 25.7 kilometers (16 miles), a 0.5 percent grade, and eventually discharges, by an unnamed intermittent stream, into the eastern branch of Snake Creek. Its confluence is located 1.6 km (1 mile) south of the McPherson/Edmunds county line on Snake Creek. Snake Creek then flows through the East Mina and AGNPS Ungauged sub-watersheds 19.3 km (12 miles) before entering the east arm of Mina Lake (Figure C-1).

This area is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. Five monitoring sites were set up at various locations along Snake Creek to conduct stream gauging and collect water quality parameters within the creek. Site Snake Creek 7 (SC-7) is located approximately 402.3 meters (1,320 feet) upstream of the confluence of Snake Creek.

The AGNPS model was selected to identify/target sediment and nutrient priority areas (areas with increased sediment and nutrient runoff) within each sub-watershed and to assess Non-Point Source (NPS) loads throughout the Mina Lake watershed. Data was used

to model current loading to Snake Creek and Mina Lake and was used for comparisons to other sub-watersheds in the Mina Lake drainage.

Cropping practices, including tillage and fertilizer use, and range management directly influence the intensity of sediment and nutrient runoff. Approximately 8,000 acres, or 37 percent, of the sub-watershed may be used as cropland, with the rest as rangeland. Minimum till, fertilizer reduction and feedlot nutrient reduction Best Management Practices (BMPs) were modeled and analyzed to estimate the runoff/loading reduction potential.

Evaluation/Quantification of Sub-watershed Non-Point Source Loading

Delineation and Location of Sub-watershed

The following AGNPS outlet cell numbers correlate to AGNPS sub-watershed and water quality monitoring sites used in the Mina Lake watershed assessment study during 1999 and 2000 (Table C-5):

Table C-61. AGNPS and water quality outlet cell numbers for the Brooks West sub-watershed.

Sub-watershed/Site	AGNPS outlet cell number
Brooks West	**522**
SC-7	**495**

The following tables estimate the delivery coefficients, annual loading and critical values for priority cells for sediment (Table C-6), nitrogen (Table C-7), and phosphorus (Table C-8) in the Brooks West sub-watershed:

Table C-62. Export coefficients (kg/acre) for the Brooks West and Snake Creek 7 (SC-7) sub-watersheds of Mina Lake♣.

				Export Coefficients					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area Acres	Percent of Watershed	Sediment kg/acre	Attached-N kg/acre	Dissolved-N kg/acre	Total Nitrogen kg/acre	Attached-P kg/acre	Dissolved-P kg/acre	Total Phosphorus kg/acre
Brooks West	**21,720**	**14**	**38.0**	**0.20**	**1.62**	**1.82**	**0.10**	**0.31**	**0.41**
Snake Creek 7 (SC-7)	**21,600**	**14**	**49.7**	**0.21**	**1.61**	**1.82**	**0.11**	**0.31**	**0.43**

Table C-63. Annualized loading (kg) for the Brooks West and Snake Creek 7 (SC-7) sub-watersheds of Mina Lake♣.

				Sub-watershed Loading					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area Acres	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
Brooks West	**21,720**	**14**	**825,221**	**4,236**	**35,270**	**39,507**	**2,069**	**6,798**	**8,867**
Snake Creek 7 (SC-7)	**21,600**	**14**	**1,073,154**	**4,605**	**34,683**	**39,288**	**2,449**	**6,760**	**9,210**

Table C-64. Priority cells threshold values for the Brooks West and Snake Creek 7 sub-watersheds of Mina Lake.

	Critical Values (kg/acre)		
Parameter	Priority-1	Priority-2	Priority-3
Sediment (kg/acre)	**2,309**	**1,792**	**1,276**
Nitrogen (kg/acre)	**3.95**	**3.04**	**2.13**
Phosphorus (kg/acre)	**1.36**	**1.05**	**0.73**

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulative rainfall events during an average year. This includes a 1-year, 24-hour event of 1.85 inches (EI = 17.5), 3 semiannual rainfall events of 1.23 inches (EI = 7.4) and a series of 10 small rainfall events of 0.8 inches (EI = 3.0) for a total "R" factor of 69.7.

Identification of Critical Non-Point Source Cells for the Brooks West Sub-watershed (25-Year Event)

Priority 1, 2, and 3 critical cells for the Brooks West sub-watershed were established based upon statistical variation (1, 2 and 3 standard deviations of the mean) using NPS cell erosion (kg/acre) and delivery data (kg/acre). Twenty-five-year rainfall events were used to identify critical cells (4.1 inches of rain with an Event Intensity (EI) of 104.0). Threshold values for priority 1, 2 and 3 critical cells are listed in Table C-8. Critical cell threshold values (one standard deviation from the mean) are as follows:

Sediment erosion rate > 1,278 kg/acre or 1.41 ton/acre
Total nitrogen cell yields > 2.13 kg/acre or 4.70 lbs/acre
Total phosphorus cell yields > 0.73 kg/acre or 1.61 lbs/acre

The yields for these parameters are listed in Table C-9 and Table C-10 and their general locations in the sub-watershed are documented for sediment (Figure C-2), nitrogen (Figure C-3), and phosphorus (Figure C-4). Priority 1 and 2 critical cells should be given high priority during BMP planning and implementation.

Analysis of the sub-watershed data indicates that 85 of 543 Brooks West cells, or 15.6 percent, have a sediment yield greater than 1,278 kg/acre (1.41 ton/acre). This is approximately 2.1 percent of the cells found within the Mina Lake watershed. The AGNPS model predicted that 2,227,976 kilograms (2,456 tons) of sediment would be generated during a single 25-year event from this sub-watershed.

The model estimated 77 cells, or 14.1 percent, have a total nitrogen yield greater than 2.13 kg/acre (4.70 lbs/acre). The AGNPS model predicted that 0.97 kilograms of nitrogen would be generated per acre, for a total of 20,985 kg (23.1 tons) of nitrogen, during a single 25-year event.

The model also estimated 81 cells, or 14.9 percent, have a total phosphorus yield greater than 0.73 kg/acre (1.61 lbs/acre). The AGNPS model predicted that 0.27 kilograms of phosphorus would be generated per acre, for a total of 5,813 kg (6.4 tons) of phosphorus, during a single 25-year event. A correlation between dissolved and sediment-bound nutrients was not determined.

Table C-65. Brooks West sub-watershed priority-1 and 2 critical cells for sediment, nitrogen and phosphorus.

Brooks West Priority-1 & 2 Cells										
Sediment			Nitrogen				Phosphorus			
				Sediment	Soluble			Sediment	Soluble	
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Outlet (kg/a)	Outlet (kg/a)	Total (kg/a)	Cell Number	Outlet (kg/a)	Outlet (kg/a)	Total (kg/a)
537	**2,795**	**66,969**	301	**0.77**	**4.40**	**5.17**	519	**1.20**	**0.47**	**1.67**
538	**2,795**	**416,770**	300	**0.71**	**4.06**	**4.77**	127	**1.35**	**0.23**	**1.58**
127	**2,759**	**67,205**	328	**0.71**	**4.06**	**4.77**	271	**0.98**	**0.47**	**1.46**
199	**2,405**	**317,750**	519	**2.40**	**2.19**	**4.59**	490	**0.90**	**0.52**	**1.42**
519	**2,359**	**57,958**	329	**1.67**	**2.55**	**4.22**	329	**0.83**	**0.56**	**1.39**
346	**2,359**	**694,174**	490	**1.80**	**2.37**	**4.17**	334	**0.88**	**0.52**	**1.39**
525	**2,350**	**237,668**	271	**1.97**	**2.19**	**4.16**	335	**0.88**	**0.52**	**1.39**
256	**2,296**	**400,154**	334	**1.75**	**2.37**	**4.12**	276	**1.17**	**0.21**	**1.38**
272	**2,296**	**77,260**	335	**1.75**	**2.37**	**4.12**	301	**0.39**	**0.99**	**1.37**
427	**2,296**	**110,889**	516	**1.80**	**2.19**	**3.99**	516	**0.90**	**0.47**	**1.37**
316	**2,223**	**633,485**	517	**1.80**	**2.19**	**3.99**	517	**0.90**	**0.47**	**1.37**
276	**2,142**	**56,461**	491	**1.60**	**2.37**	**3.97**	491	**0.80**	**0.52**	**1.32**
247	**2,051**	**48,875**	344	**1.58**	**2.37**	**3.95**	344	**0.79**	**0.52**	**1.31**
444	**2,042**	**402,078**	127	**2.70**	**1.12**	**3.82**	247	**1.05**	**0.23**	**1.27**
526	**2,033**	**103,221**	520	**1.60**	**2.19**	**3.79**	520	**0.80**	**0.47**	**1.27**
277	**1,942**	**79,347**	492	**1.48**	**2.25**	**3.73**	300	**0.36**	**0.91**	**1.27**
288	**1,942**	**630,799**	431	**1.16**	**2.55**	**3.71**	328	**0.35**	**0.91**	**1.26**
257	**1,906**	**419,855**	518	**1.50**	**2.19**	**3.69**	492	**0.74**	**0.49**	**1.23**
287	**1,906**	**593,485**	299	**1.47**	**2.19**	**3.66**	518	**0.75**	**0.47**	**1.22**
175	**1,851**	**42,868**	464	**1.00**	**2.55**	**3.55**	299	**0.73**	**0.47**	**1.20**
410	**1,851**	**684,946**	508	**1.13**	**2.37**	**3.50**	40	**0.20**	**1.00**	**1.20**
			40	**0.40**	**3.01**	**3.42**	175	**0.94**	**0.21**	**1.15**
			276	**2.35**	**1.05**	**3.40**	380	**0.92**	**0.23**	**1.15**
			521	**1.11**	**2.28**	**3.39**	255	**0.93**	**0.21**	**1.14**
			326	**1.13**	**2.19**	**3.32**	289	**0.93**	**0.21**	**1.14**
			483	**1.07**	**2.19**	**3.26**	431	**0.58**	**0.56**	**1.13**
			247	**2.10**	**1.12**	**3.22**	412	**0.97**	**0.16**	**1.13**
			482	**0.97**	**2.19**	**3.16**	277	**0.88**	**0.21**	**1.09**
			349	**1.41**	**1.66**	**3.06**	508	**0.56**	**0.52**	**1.08**
			481	**0.87**	**2.19**	**3.06**	446	**0.88**	**0.20**	**1.07**
			355	**1.04**	**2.01**	**3.05**	464	**0.50**	**0.56**	**1.06**
							502	**0.88**	**0.18**	**1.06**
							349	**0.70**	**0.35**	**1.05**
							521	**0.55**	**0.49**	**1.05**
Critical Acres			Critical Acres				Critical Acres			
Priority 1		280	Priority 1			520	Priority 1			440
Priority 2		560	Priority 2			720	Priority 2			920

Shaded areas are Priority-1 cells

Table C-66. Brooks West sub-watershed priority-3 critical cells for sediment, nitrogen and phosphorus.

Brooks West Priority-3 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
128	**1,770**	**69,437**	380	**1.84**	**1.12**	**2.96**	500	**0.85**	**0.20**	**1.04**
177	**1,760**	**307,405**	175	**1.89**	**1.05**	**2.94**	200	**0.84**	**0.20**	**1.04**
412	**1,751**	**44,229**	255	**1.86**	**1.05**	**2.91**	326	**0.56**	**0.47**	**1.03**
413	**1,751**	**58,739**	289	**1.86**	**1.05**	**2.91**	501	**0.85**	**0.18**	**1.03**
262	**1,751**	**92,051**	451	**0.64**	**2.19**	**2.83**	128	**0.80**	**0.23**	**1.03**
271	**1,751**	**45,254**	277	**1.77**	**1.05**	**2.83**	496	**0.80**	**0.21**	**1.01**
176	**1,670**	**73,748**	412	**1.93**	**0.85**	**2.78**	483	**0.54**	**0.47**	**1.01**
178	**1,670**	**324,265**	446	**1.76**	**0.98**	**2.74**	229	**0.79**	**0.21**	**1.00**
228	**1,670**	**345,145**	128	**1.59**	**1.12**	**2.71**	126	**0.76**	**0.23**	**0.99**
255	**1,670**	**42,096**	272	**1.25**	**1.43**	**2.69**	184	**0.76**	**0.22**	**0.98**
289	**1,670**	**42,096**	502	**1.76**	**0.92**	**2.68**	324	**0.77**	**0.20**	**0.96**
317	**1,670**	**660,236**	500	**1.69**	**0.98**	**2.68**	139	**0.73**	**0.23**	**0.96**
426	**1,670**	**52,169**	200	**1.69**	**0.98**	**2.67**	482	**0.49**	**0.47**	**0.96**
373	**1,624**	**284,891**	496	**1.61**	**1.05**	**2.66**	355	**0.52**	**0.43**	**0.95**
207	**1,624**	**413,612**	126	**1.52**	**1.12**	**2.64**	343	**0.74**	**0.20**	**0.94**
411	**1,579**	**685,962**	184	**1.52**	**1.12**	**2.64**	272	**0.63**	**0.30**	**0.93**
446	**1,579**	**39,165**	229	**1.59**	**1.05**	**2.64**	305	**0.71**	**0.20**	**0.91**
376	**1,570**	**101,897**	501	**1.69**	**0.92**	**2.61**	481	**0.44**	**0.47**	**0.91**
502	**1,561**	**39,428**	139	**1.46**	**1.12**	**2.58**	49	**0.23**	**0.67**	**0.90**
503	**1,561**	**79,365**	324	**1.53**	**0.98**	**2.52**	473	**0.72**	**0.18**	**0.90**
314	**1,525**	**45,463**	49	**0.46**	**2.05**	**2.51**	475	**0.72**	**0.18**	**0.90**
490	**1,525**	**40,299**	343	**1.49**	**0.98**	**2.48**	246	**0.88**	**0.01**	**0.89**
516	**1,525**	**40,299**	305	**1.43**	**0.98**	**2.41**	403	**0.70**	**0.18**	**0.88**
517	**1,525**	**40,299**	203	**1.27**	**1.12**	**2.39**	537	**0.78**	**0.10**	**0.88**
518	**1,525**	**64,574**	242	**1.32**	**1.05**	**2.37**	242	**0.66**	**0.21**	**0.87**
137	**1,515**	**168,421**	473	**1.45**	**0.92**	**2.36**	203	**0.64**	**0.23**	**0.86**
334	**1,506**	**39,074**	475	**1.45**	**0.92**	**2.36**	413	**0.70**	**0.16**	**0.86**
335	**1,506**	**39,074**	204	**1.24**	**1.12**	**2.36**	204	**0.62**	**0.23**	**0.85**
200	**1,497**	**37,287**	403	**1.40**	**0.92**	**2.31**	106	**0.63**	**0.21**	**0.84**
201	**1,497**	**104,183**	106	**1.26**	**1.05**	**2.31**	543	**0.72**	**0.11**	**0.83**
500	**1,479**	**37,468**	219	**1.24**	**1.05**	**2.30**	290	**0.64**	**0.20**	**0.83**
501	**1,479**	**37,468**	291	**0.86**	**1.43**	**2.29**	219	**0.62**	**0.21**	**0.83**
329	**1,461**	**36,770**	118	**1.15**	**1.12**	**2.27**	514	**0.72**	**0.11**	**0.83**
459	**1,452**	**2,051,497**	233	**1.22**	**1.05**	**2.27**	375	**0.65**	**0.18**	**0.83**
493	**1,452**	**2,242,096**	400	**1.22**	**1.05**	**2.27**	387	**0.63**	**0.20**	**0.83**
495	**1,434**	**2,316,316**	290	**1.28**	**0.98**	**2.27**	465	**0.63**	**0.20**	**0.83**
375	**1,425**	**26,887**	387	**1.26**	**0.98**	**2.25**	233	**0.61**	**0.21**	**0.82**
202	**1,416**	**103,140**	413	**1.39**	**0.85**	**2.24**	400	**0.61**	**0.21**	**0.82**
229	**1,416**	**34,537**	445	**0.54**	**1.71**	**2.24**	318	**0.65**	**0.15**	**0.81**
254	**1,416**	**51,044**	465	**1.26**	**0.98**	**2.24**	118	**0.58**	**0.23**	**0.80**
286	**1,416**	**492,768**	375	**1.30**	**0.92**	**2.21**	451	**0.32**	**0.47**	**0.79**
158	**1,388**	**266,125**	263	**0.91**	**1.29**	**2.20**	445	**0.27**	**0.52**	**0.79**
405	**1,388**	**382,913**	398	**0.90**	**1.30**	**2.20**	159	**0.59**	**0.20**	**0.78**

Table C-10 (Continued). Brooks West sub-watershed priority-3 critical cells for sediment, nitrogen and phosphorus.

Brooks West Priority-3 Cells (Continued)										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
496	**1,388**	**35,045**	159	**1.17**	**0.98**	**2.15**	438	**0.58**	**0.20**	**0.77**
497	**1,388**	**232,396**	262	**0.83**	**1.32**	**2.15**	437	**0.56**	**0.20**	**0.76**
301	**1,370**	**33,430**	438	**1.15**	**0.98**	**2.13**	535	**0.64**	**0.10**	**0.74**
494	**1,370**	**2,247,740**					399	**0.53**	**0.21**	**0.74**
322	**1,361**	**97,142**								
323	**1,361**	**101,434**								
543	**1,361**	**30,753**								
324	**1,352**	**33,103**								
374	**1,352**	**360,935**								
246	**1,352**	**39,256**								
379	**1,343**	**644,546**								
315	**1,334**	**54,510**								
491	**1,325**	**34,855**								
492	**1,325**	**95,345**								
520	**1,325**	**34,855**								
243	**1,316**	**40,136**								
263	**1,316**	**120,272**								
126	**1,316**	**32,804**								
344	**1,307**	**34,365**								
279	**1,298**	**52,831**								
343	**1,279**	**31,987**								
Critical Acres			Critical Acres				Critical Acres			
Priority 3		2,560	Priority 3			1,840	Priority 3			1,880

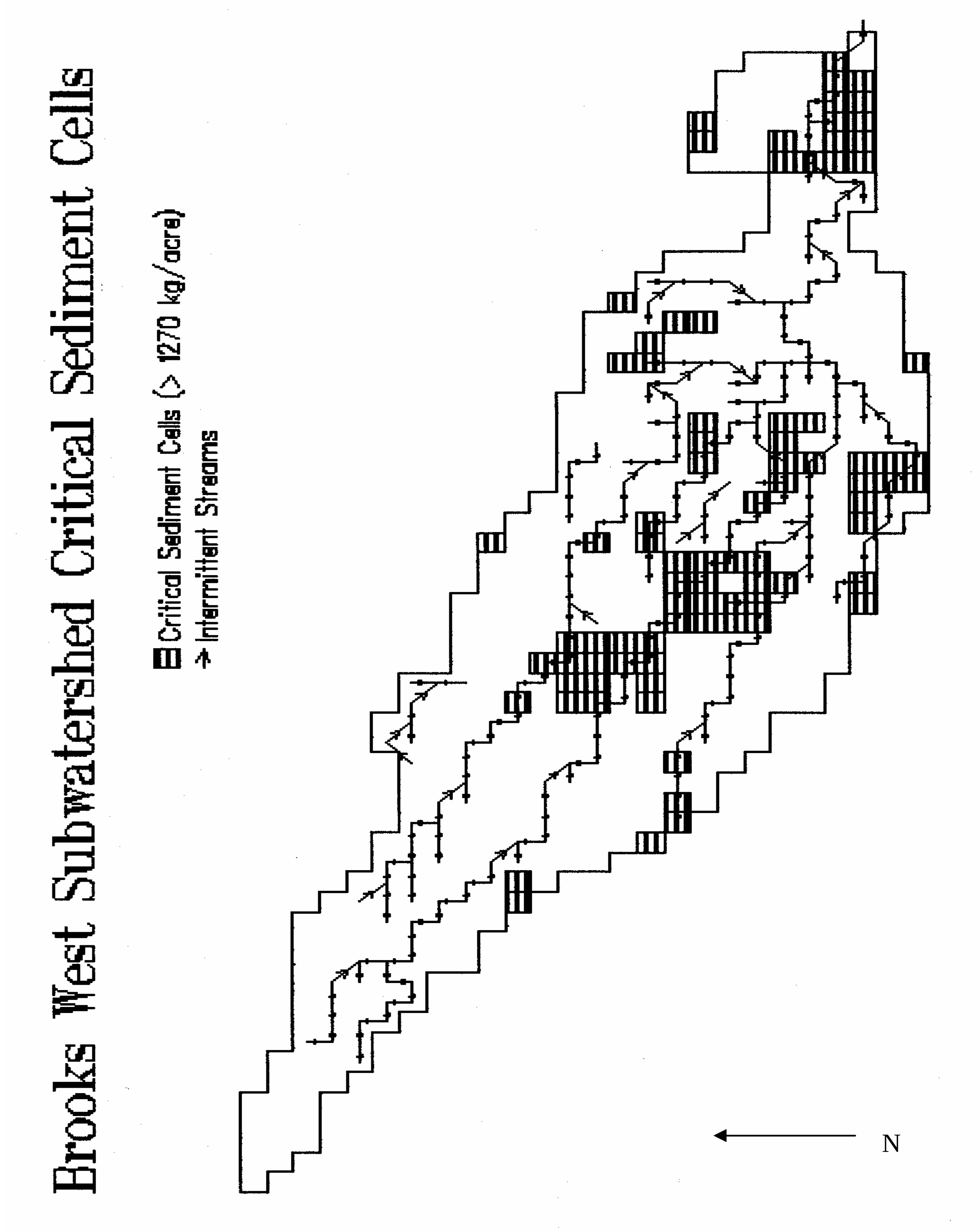


Figure C-72. Critical sediment cells for the Brooks West sub-watershed of Mina Lake.

Sediment Analysis

The AGNPS model calculated/estimated the sediment delivery rate from the Brooks West sub-watershed at 38.0 kg/acre/year. As a result, 825,221 kg (910 tons) of sediment were generated annually from this sub-watershed. AGNPS estimated the sediment delivery rate from water quality monitoring site SC-7 at 49.7 kg/acre/year, resulting in a yield of 1,073,154 kg (1,183 tons), which is higher than the Brooks West sub-watershed yield. In summary, Brooks West was estimated to contribute 14 percent of the east tributary sediment load and 8.5 percent of the total load to Mina Lake. There are a total of 481 sediment (erosion) critical cells in the Mina Lake watershed. Brooks West contains 17.7 percent of all critical erosion cells in the watershed, while encompassing 13.7 percent of the watershed surface area. Based on the export coefficients, the sub-watershed is ranked seventh of eight, on a priority list, for sediment improvements.

Sediment yield within the sub-watershed can be attributed to high intensity land use, land slope, and proximity to surface water conduits. Common critical cell characteristics for the Mina Lake system include croplands with a slope greater than 2 percent and/or are within 152 meters (500 feet) of a stream or tributary.

Total Nutrient Analysis

AGNPS data indicated/estimated that the Brooks West subwatershed had the second-highest total nitrogen (soluble + sediment bound) transport rate of 1.82 kg/acre/year (equivalent to 39,507 kg or 43.5 tons). Eighty-nine percent of the transported nitrogen from this sub-watershed was estimated to be in dissolved form while 77.3 percent of the total nitrogen load to Mina Lake was in the dissolved form. The total nitrogen load delivered from the sub-watersheds to Mina Lake was estimated to be 211,203 kg or 233 tons/year. As a result, the sub-watershed load to Mina Lake was 19 percent of the total nitrogen load. Based on transport coefficients for nitrogen, the sub-watershed was rated second of eight for nitrogen reduction priority.

This sub-watershed had a total phosphorus (soluble + sediment-bound) transport rate of 0.41 kg/acre/year (equivalent to 8,867 kg or 9.8 tons). Seventy-seven percent of the transported phosphorus from this sub-watershed was estimated to be in dissolved form while 56.2 percent of the total phosphorus load to Mina Lake was in the dissolved form was estimated to be in dissolved form. The total phosphorus load delivered from the sub-watersheds to Mina Lake was estimated to be 54,000 kg/year or 58.8 tons/year. Brooks West delivered approximately 17 percent of the annual load of total phosphorus to Mina Lake. Based on transport coefficients for phosphorus, the sub-watershed was rated second of eight for phosphorus reduction priority.

The data indicates that 77 percent of the total nitrogen and 56 percent of the total phosphorus load delivered to Mina Lake was in the soluble (dissolved) form. In comparison, the Brooks West sub-watershed had higher average percentages of soluble (dissolved) nitrogen and phosphorus (89 percent and 77 percent, respectively).

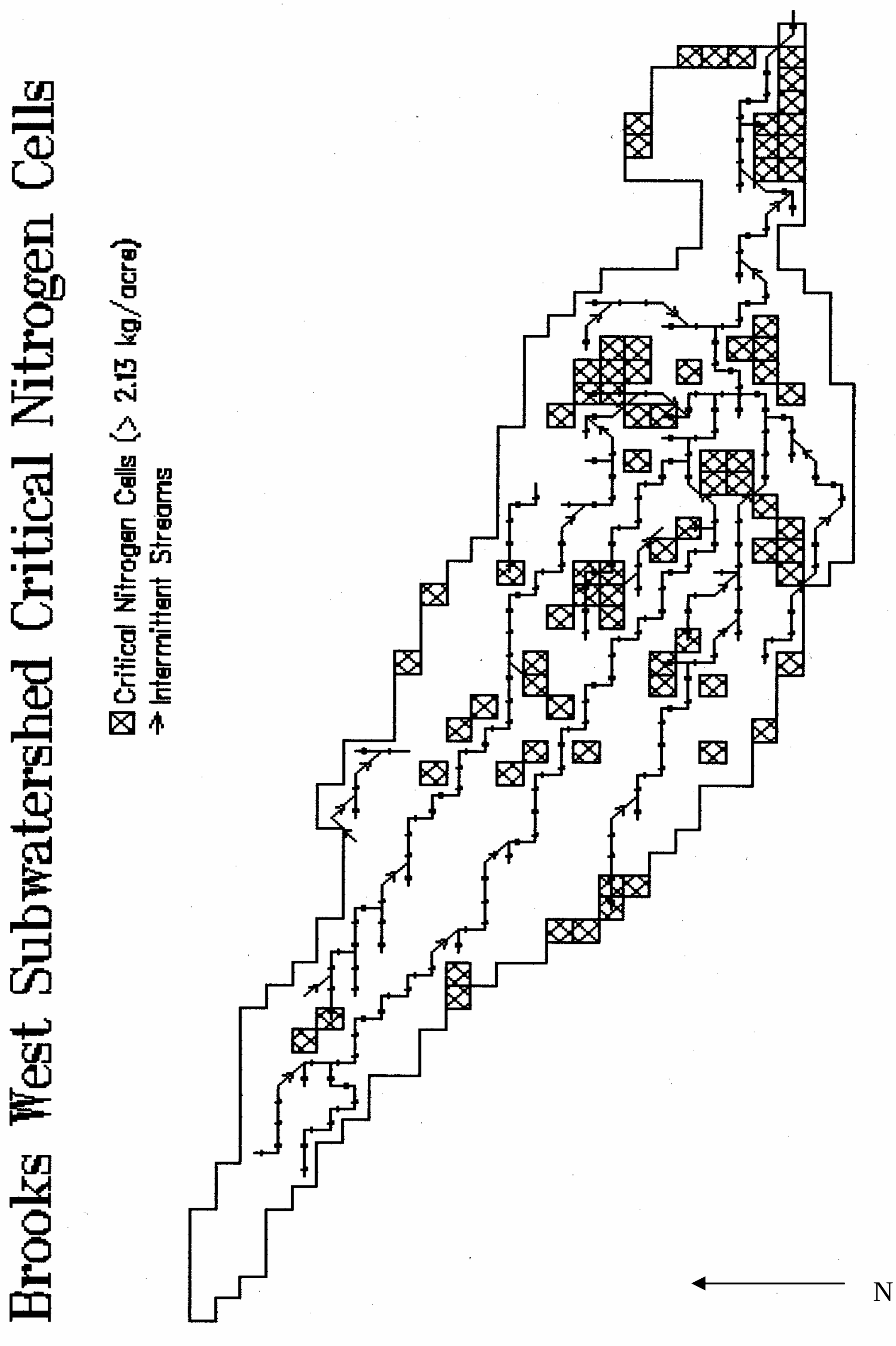


Figure C-73. Critical nitrogen cells for the Brooks West sub-watershed of Mina Lake.

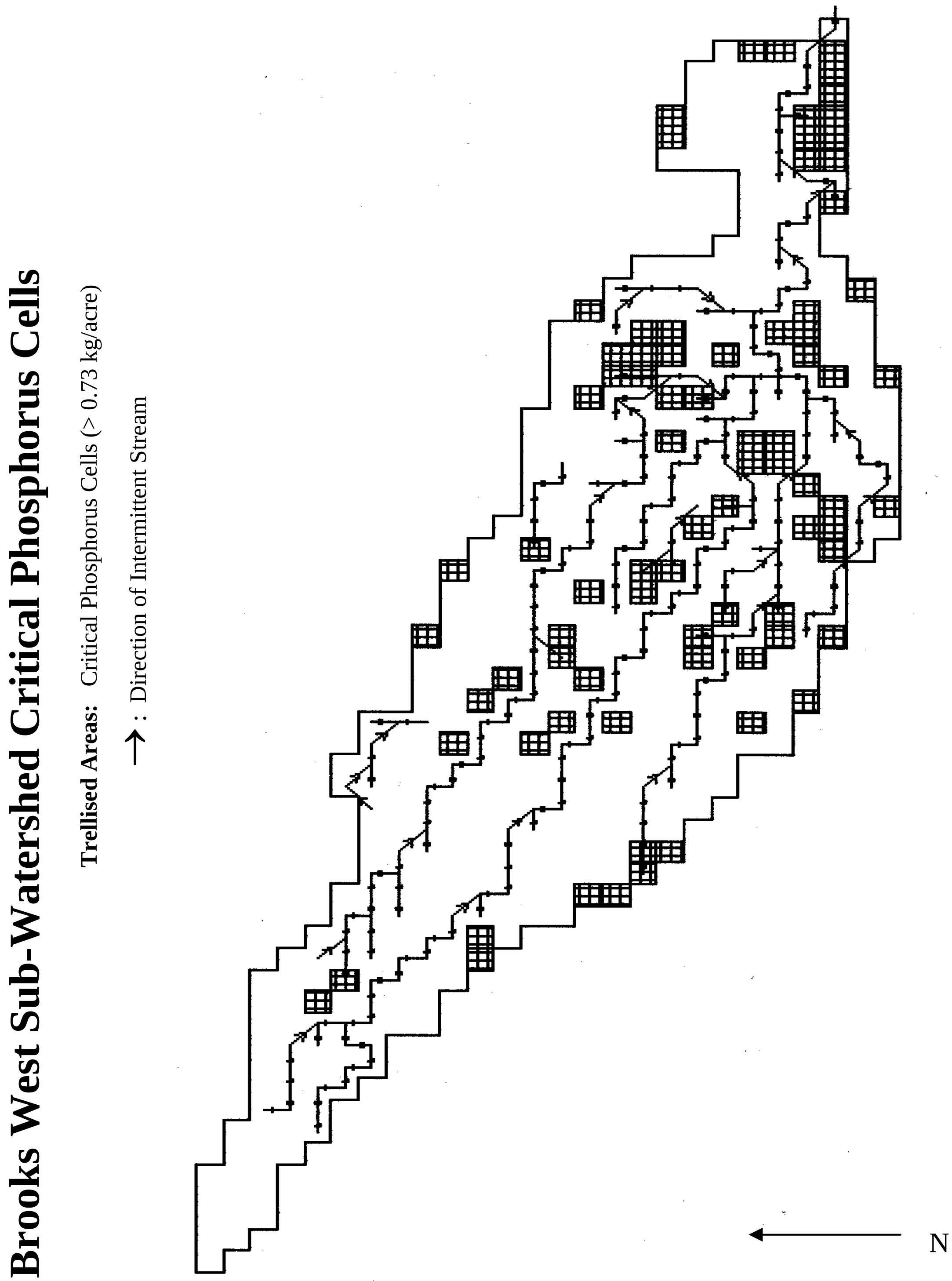


Figure C-74. Critical phosphorus cells for the Brooks West sub-watershed of Mina Lake.

Priority Ranking of Animal Feeding Areas in the Brooks West Sub-watershed (25-Year Event)

A total of five animal feeding areas were identified as potential NPS sources during the AGNPS data acquisition phase of the project. Table C-13 lists the AGNPS analysis of each feeding area. Of these, three were found to have an AGNPS ranking greater than 40, one of which had an AGNPS ranking of 59 (Table C-13). AGNPS ranks feeding areas from zero to 100+ with a zero-ranked feeding area having a smaller pollution potential and 100+ ranking having a large pollution potential. AGNPS estimates the total impact of having a feeding area or multiple feeding areas within a cell by combining and recalculating all values to arrive at nutrient and COD values to the cell. Critical feeding area locations are depicted in Figure C-5.

In order to determine the impact of the feeding areas, AGNPS outputs from nutrient and feeding area critical cell data were analyzed (Table C-11). A reduction efficiency coefficient was determined by calculating a ratio of the difference (per acre) between the overall amount of nutrients generated per cell (acres multiplied by transport coefficient) and feedlot-generated nutrient loads. The results were then used to estimate the cell capacity, or lack of capacity, to reduce nutrient levels under current conditions. Topographical gradient, size, location of buffering zones and proximity to surface conduits were possible influences upon nutrient reduction and diffusion.

Reduction efficiency coefficients range from positive to negative values and were interpreted using a sliding scale with values and ratings based on Table C-12. All feeding areas, critical or not, were analyzed for reduction potential to determine trends and ratings. These values may be used to estimate the sensitivity or resistance potential of the cell to perturbations within feeding area(s) (increasing the number of animal units/area) or within the cell (changes in landscape/land-use, buffer reduction, tillage practices, etc.) based on current conditions. BMP improvements in the feeding areas or cell with favorable/marginally favorable ratings should respond/improve more rapidly than cells with a neutral to unfavorable rating. Another use for this rating may be to prioritize/rank all critical feeding areas (feeding areas needing BMPs) within a watershed by reduction efficiency (improvement potential) to target/select feeding areas to realize maximum nutrient reduction in watersheds when implementation funds are limited.

Cell #40 exceeded critical threshold limits for feeding areas and overall nutrient output. The higher efficiency ratio may indicate that feeding area nutrients had a greater impact on nutrient output than the cell and was not cell-supportable (critical nutrient cell). Conversely, cell #245 exceeded the feeding area nutrient critical threshold (>40), but was not critical for nutrient output (Table C-11). Cell #245's nutrient levels are cell-supportable; however, cell output would be sensitive to elevated (increased) nutrient concentrations. The average cell efficiency ratios for the Brooks West sub-watershed were shown to be marginally favorable for nutrient reduction.

The animal feeding areas rated above 40 should be monitored for animal density or use-intensity. If use intensifies without modification of current conditions, the potential for sediment and nutrient yield will increase, especially in unfavorable to marginally unfavorable cells. Positive steps should be taken to identify and modify existing conditions

within critical feeding areas. Careful study of feeding area size, animal density/intensity of use, and buffering capacity may be needed to reduce the AGNPS feedlot ratings and increase the reduction efficiencies (ratings).

Table C-67. Critical Cell (CC) reduction efficiency ratio for the Brooks West sub-watershed.

Cell Number and Parameter	Feedlot Mass Generated (kg)	Transport Coefficient from (CC) Load Data**	Total Mass Transported (kg)	Difference (kg)	Reduction Efficiency Coefficient (kg/acre)	Rating (Table C-12)
#40 Nitrogen *	**231**	**3.42**	**136.8**	**94.2**	**2.36**	**F**
#40 Phosphorus *	**79.1**	**1.20**	**48.0**	**31.1**	**0.78**	**MF**
#245 Nitrogen *	**35.6**	**0.88**	**35.2**	**0.40**	**0.01**	**N**
#245 Phosphorus *	**12.7**	**0.30**	**12.0**	**0.70**	**0.02**	**N**
#445 Nitrogen	**93.9**	**2.13**	**85.2**	**8.70**	**0.22**	**MF**
#445 Phosphorus	**34.4**	**0.74**	**29.6**	**4.80**	**0.12**	**MF**
Average					0.58	MF

Shaded area indicates critical nutrient cells
* = Indicates critical feedlot cell
** = Indicates threshold values for the Brooks West sub-watershed (nitrogen yields > 2.13 kg/acre or phosphorus yields > 0.73 kg/acre)

Table C-68. Nutrient reduction efficiency rating scale for Mina Lake.

Rating	Criteria
Favorable (F)	**Greater than 2.0 kg/acre**
Marginally Favorable (MF)	**Between 0.1 and 2.0 kg/acre**
Neutral (N)	**Between -0.1 and 0.1 kg/acre**
Marginally Unfavorable (MU)	**Between –2 and –0.1 kg/acre**
Unfavorable (U)	**Less than –2.0 kg/acre**

Improvements in feeding areas and cells with favorable to marginally favorable rating would be expected to show marked improvement. Sources of nutrient loads not modeled through this study were from septic systems and livestock with direct access to Mina Lake or adjacent streams.

Table C-69. AGNPS feedlot ratings and data for the Brooks West sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 40		Cell # 445	
Nitrogen concentration (ppm)	**17.7**	**Nitrogen concentration (ppm)**	**70.6**
Phosphorus concentration (ppm)	**5.19**	**Phosphorus concentration (ppm)**	**26.5**
COD concentration (ppm)	**220**	**COD concentration (ppm)**	**1209**
Nitrogen mass (kg)	**23.1**	**Nitrogen mass (kg)**	**68.2**
Phosphorus mass (kg)	**6.77**	**Phosphorus mass (kg)**	**25.6**
COD mass (kg)	**287**	**COD mass (kg)**	**1169**
Animal feedlot rating number	22	**Animal feedlot rating number**	42
Cell # 40		Cell # 445	
Nitrogen concentration (ppm)	**101**	**Nitrogen concentration (ppm)**	**27.5**
Phosphorus concentration (ppm)	**35.1**	**Phosphorus concentration (ppm)**	**9.35**
COD concentration (ppm)	**1896**	**COD concentration (ppm)**	**419**
Nitrogen mass (kg)	**208**	**Nitrogen mass (kg)**	**25.7**
Phosphorus mass (kg)	**72.3**	**Phosphorus mass (kg)**	**8.71**
COD mass (kg)	**3905**	**COD mass (kg)**	**391**
Animal feedlot rating number	59	**Animal feedlot rating number**	27
Cell # TOTL (Tot. Cell 40 values)		Cell # TOTL (Tot. Cell 445 values)	
Nitrogen concentration (ppm)		**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)		**Phosphorus concentration (ppm)**	
COD concentration (ppm)		**COD concentration (ppm)**	
Nitrogen mass (kg)	**231**	**Nitrogen mass (kg)**	**93.9**
Phosphorus mass (kg)	**78.9**	**Phosphorus mass (kg)**	**34.3**
COD mass (kg)	**4192**	**COD mass (kg)**	**1560**
Animal feedlot rating number	**-**	**Animal feedlot rating number**	**-**
Cell # 245			
Nitrogen concentration (ppm)	**9.4**		
Phosphorus concentration (ppm)	**3.34**		
COD concentration (ppm)	**313**		
Nitrogen mass (kg)	**35.6**		
Phosphorus mass (kg)	**13.6**		
COD mass (kg)	**1184**		
Animal feedlot rating number	44		

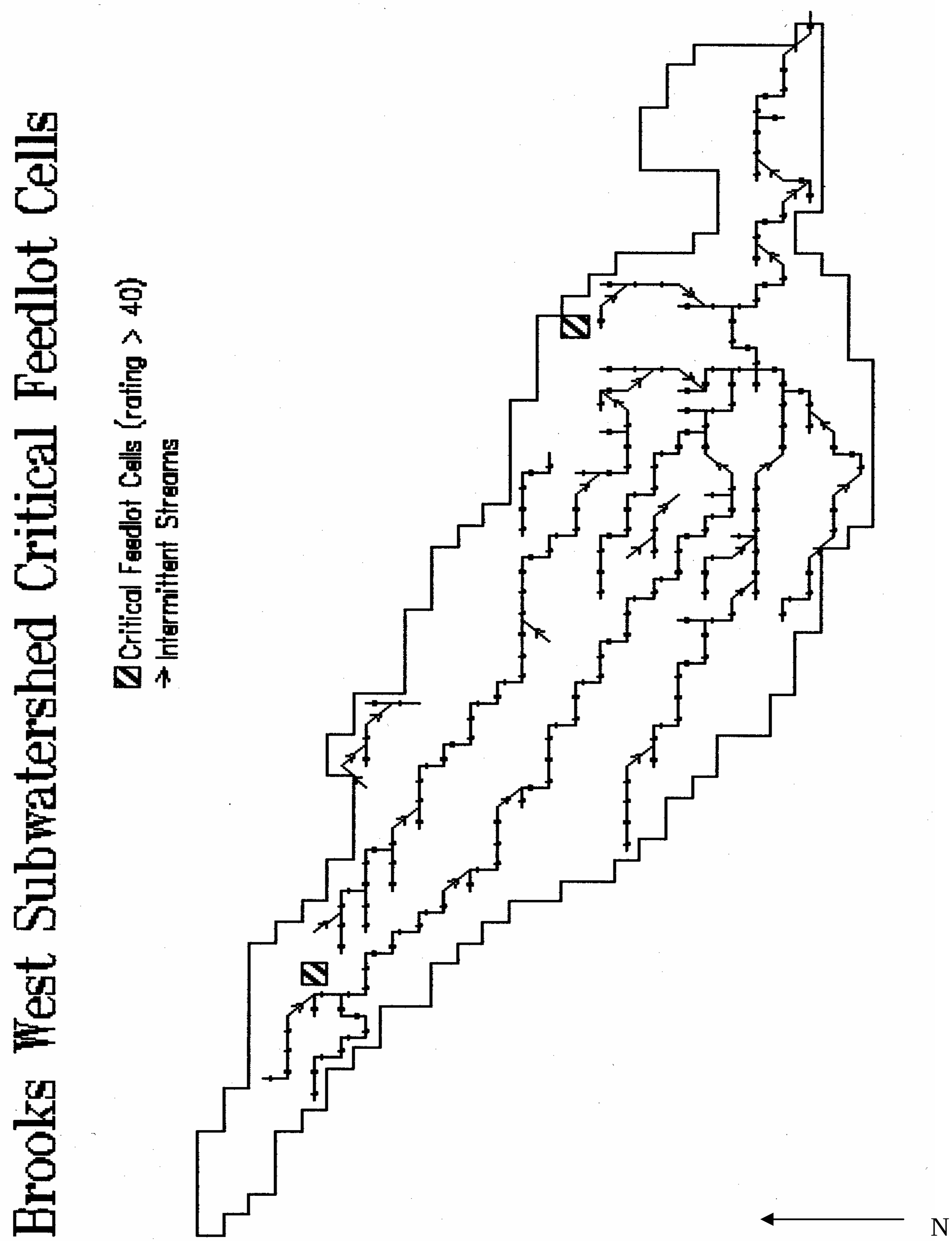


Figure C-75. Critical feedlot cells for the Brooks West sub-watershed of Mina Lake.

Modeled Sediment, Nitrogen and Phosphorus Reductions (Brook West Sub-watershed)

Several Best Management Practices (BMP) were modeled using the AGNPS computer model. These included installation of Animal Waste Management Systems (AWMS), grassed waterways, reduction in fertilizer application levels, and conversion of conventional till practices to minimum or no-till methods.

Five feeding areas within the Brooks West sub-watershed were identified. The AGNPS assessment of feeding area data rated three of the five feeding areas as critical (rated above 40 based on objective criteria). One of two feeding areas within cell #40 and the one feeding area in cell #245 exceeded the threshold value for feeding area nutrient output, causing these cells to be rated critical. One of two feeding areas in cell #445 also exceeded threshold value, but the overall feeding area nutrient output for the cell was not critical. Efforts to improve feeding areas would reduce total nitrogen from 39,507 kg or 43.5 tons/year to 39,033 kg or 43.0 tons/year (approximately 1 percent reduction) and result in minimal reduction in total phosphorus.

AGNPS compared fertilizer application rates using current application rates (approx. 45.4 kg or 100 lbs/acre nitrogen and 18.1 kg or 40 lbs/acre phosphorus) to a reduced rate (22.7 kg/acre or 50 lbs/acre nitrogen and 9.1 kg/acre or 20 lbs/acre phosphorus). The sub-watershed modeling indicated a reduction in the total nitrogen load from 39,507 kg or 43.5 tons/year to 33,186 kg or 36.6 tons/year (16 percent). The reduced rates lowered the total phosphorus load from 8,867 kg or 9.8 tons/year to 7,758 kg or 8.5 tons/year (approximately 12 percent).

The model estimated that modifying tilled acreage within critical erosion and nutrient cells to conservation tillage practices would reduce the sediment load delivered by Snake Creek from 825,221 kg or 910 tons/year to 729,660 kg or 804 tons/year (approximately 11 percent). Modified tillage would reduce the total nitrogen load to Mina Lake from 39,507 kg or 43.5 tons to 33,794 kg or 37.2 tons (approximately 14 percent). This practice will also reduce the total phosphorus yield from 8,867 kg or 9.8 tons/year to 7,758 kg or 8.5 tons/year (approximately 12 percent reduction). Based on AGNPS reduction estimates, conversion from conventional to minimum/no tillage will have the greatest impact on the watershed.

BMP recommendations should be implemented within the sub-watershed and/or site priority critical cells (Table C-14 and Table C-15). Field data for priority critical cells should be field verified prior to BMP planning and implementation. The AGNPS model did not simulate grass waterways, gully and streambank erosion, however, these BMPs should also be evaluated.

Table C-70. AGNPS modeling reductions for Brooks West sub-watershed BMPs[1].

BMP	Unit	Percent Reduction		
		Sediments	Nitrogen	Phosphorus
Feedlot	**Brooks West**	**0**	**1**	**0**
Fertilizer	**Brooks West**	**0**	**16**	**12**
Minimum Till	**Brooks West**	**11**	**14**	**12**
Sub-watershed Total		**11**	**31**	**24**

[1] = Reductions calculated using 1999-2000 field data

Table C-71. AGNPS modeling reductions for water quality monitoring site SC-7 BMPs[1].

BMP	Unit	Percent Reduction		
		Sediments	Nitrogen	Phosphorus
Feedlot	**SC-7**	**0**	**0**	**0**
Fertilizer	**SC-7**	**0**	**14**	**11**
Minimum Till	**SC-7**	**10**	**13**	**11**
Site Total		**10**	**27**	**22**

[1] = Reductions calculated using 1999-2000 field data

East Mina Sub-watershed AGNPS Analysis (A Sub-watershed of Mina Lake)

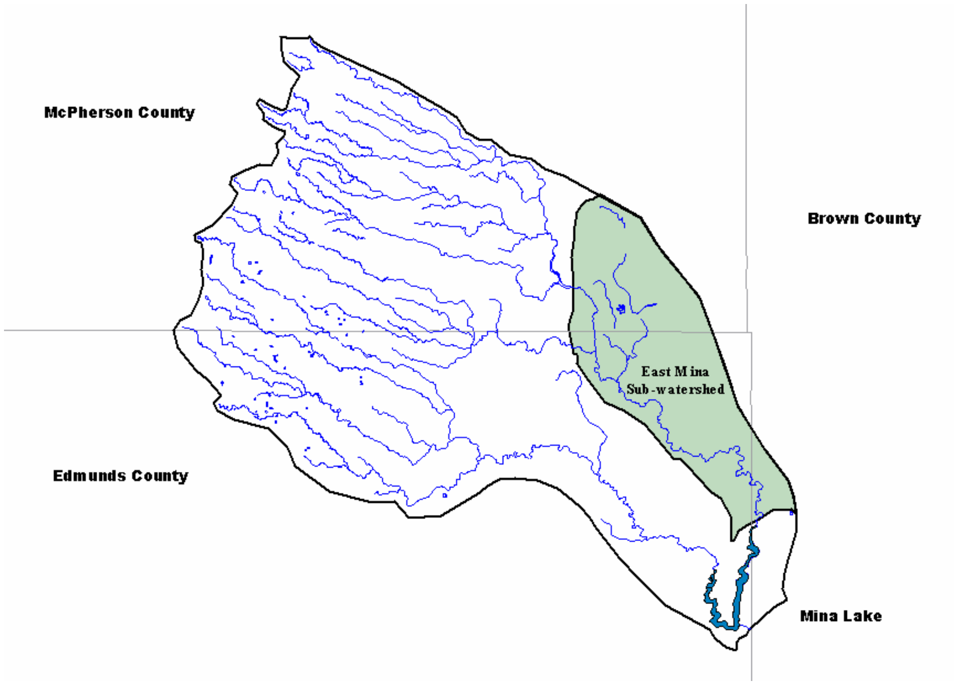


Figure C-76. The East Mina Sub-watershed within the Mina Lake watershed.

The East Mina sub-watershed straddles McPherson, Edmunds, and Brown counties, in northeastern South Dakota, and is the main conduit for the eastern tributary of Snake Creek and empties into Mina Lake. The eastern-most basin within the main watershed, East Mina contributes approximately 13 percent of total hydrologic input to Mina Lake and encompasses an approximate area of 8,239 hectares (20,360 acres). This sub-watershed is a very shallow basin that drops 15.2 meters (50 feet) over 17 kilometers (10.5 miles), less than a 0.1 percent grade, and serves as a discharge for Crompton Lake. Crompton Lake flows into the Snake Creek tributary, which meanders through East Mina for approximately 24 kilometers (15 miles) before reaching Mina Lake (Figure C-6).

The East Mina watershed is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. Five monitoring sites were set up at various locations along Snake Creek to collect water quantity and quality parameters within the creek. Sites SC-8, located on Snake Creek at the McPherson/Edmunds county line, and SC-2, located west of the Edmunds/Brown county line and approximately two miles upstream of Mina Lake on Snake Creek, provided water quality monitoring for the east tributary of Snake Creek and the East Mina sub-watershed.

Due to the lack of site-specific water quality data with each sub-watershed, a computer model was selected to assess the Non-point Source (NPS) loads throughout the Mina Lake watershed. The data was used to model current loading to Snake Creek and was used for comparisons to other sub-watersheds in the Mina Lake drainage.

Cropping practices, including tillage, fertilizer use and range management directly influence the intensity of sediment and nutrient runoff. Approximately 3,520 acres, or 17 percent, of the East Mina sub-watershed has been identified as cropland; the remaining acreage might be used as rangeland. Tillage, fertilizer, and feedlot Best Management Practices (BMPs) were modeled and analyzed to estimate the runoff reduction potential.

Evaluation/Quantification of Sub-watershed Non-Point Source Loading

Delineation and Location of Sub-watershed

The following AGNPS outlet cell numbers correlate to AGNPS sub-watershed and water quality monitoring sites used in the Mina Lake watershed assessment study during 1999 and 2000 (Table C-16):

Table C-72. AGNPS and water quality outlet cell numbers for the East Mina sub-watershed.

Sub-watershed/Site	AGNPS outlet cell number
East Mina	**515**
SC-2	**427**
SC-8	**230**

The following tables estimate the delivery coefficients, annual loading and critical values for priority cells for sediment (Table C-17), nitrogen (Table C-18), and phosphorus (Table C-19) in the East Mina sub-watershed:

Table C-73. Export coefficients (kg/acre) for the East Mina, Snake Creek 2 (SC-2) and the Snake Creek 8 (SC-8) sub-watersheds of Mina Lake♣.

				Export Coefficients					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area Acres	Percent of Watershed	Sediment kg/acre	Attached-N kg/acre	Dissolved-N kg/acre	Total Nitrogen kg/acre	Attached-P kg/acre	Dissolved-P kg/acre	Total Phosphorus kg/acre
East Mina	**20,360**	**13**	**40.5**	**0.23**	**1.37**	**1.60**	**0.11**	**0.25**	**0.36**
Snake Creek 2 (SC-2)	**15,600**	**10**	**37.1**	**0.27**	**1.53**	**1.80**	**0.13**	**0.27**	**0.40**
Snake Creek 8 (SC-8)	**49,400**	**31**	**91.0**	**0.44**	**0.54**	**0.98**	**0.21**	**0.10**	**0.31**

Table C-74. Annualized loading (kg) for the East Mina, Snake Creek 2 (SC-2) and the Snake Creek 8 (SC-8) sub-watersheds of Mina Lake♣.

				Sub-watershed Loading					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area (Acres)	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
East Mina	**20,360**	**13**	**824,232**	**4,725**	**27,875**	**32,600**	**2,309**	**5,079**	**7,388**
Snake Creek 2 (SC-2)	**15,600**	**10**	**578,593**	**4,228**	**23,915**	**28,143**	**1,988**	**4,207**	**6,195**
Snake Creek 8 (SC-8)	**49,400**	**31**	**4,493,703**	**21,924**	**26,516**	**48,440**	**10,408**	**4,863**	**15,271**

Table C-75. Priority cells threshold values for the East Mina and Snake Creek 2 (SC-2) and the Snake Creek 8 (SC-8) sub-watersheds of Mina Lake♣.

	Critical Values (kg/acre)		
Parameter	Priority-1	Priority-2	Priority-3
Sediment	**3,654**	**2,670**	**1,687**
Nitrogen	**4.13**	**3.13**	**2.12**
Phosphorus	**1.51**	**1.13**	**0.75**

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulative rainfall events during an average year. This includes a 1- year 24-hour event of 1.85 inches (EI = 17.5), 3 semiannual rainfall events of 1.23 inches (EI= 7.4) and a series of 10 small rainfall events of 0.8 inches (EI = 3.0) for a total "R" factor of 69.7.

Identification of Critical NPS Cells for East Mina Sub-watershed (25-Year Event)

Priority 1, 2, and 3 critical cell thresholds were established based upon 1, 2 and 3 standard deviations of the mean using NPS cell yield data, event rainfall amount of 4.1 inches, and Event Intensity (EI) of 104.5, as follows:

Sediment erosion rate > 1,687 kg/acre or 1.86 tons/acre
Total nitrogen cell yields > 2.12 kg/acre or 4.67 lbs/acre
Total phosphorus cell yields > 0.75 kg/acre or 1.65 lbs/acre

The yields for each of these cells are listed in Table C-20 and Table C-21, and their locations in the sub-watershed are documented for sediment (Figure C-7), nitrogen (Figure C-8), and phosphorus (Figure C-9). Priority 1 and 2 critical cells should be given high priority during BMP planning and implementation.

Analysis of the Mina Lake watershed data indicates that 63 of 584 East Mina sub-watershed cells, or 10.8 percent, have a sediment yield greater than 1,687 kg/acre (1.86 tons/acre). This is approximately 1.6 percent of the cells found within the Mina Lake watershed. The AGNPS model predicted that 2,030,319 kilograms (2,238 tons) of sediment would be generated during a single 25-year event from the East Mina sub-watershed.

The model estimated that 69 cells, or 12 percent, have a total nitrogen yield greater than 2.12 kg/acre (4.67 lbs/acre). The AGNPS model predicted that 0.82 kilograms of nitrogen would be generated per acre, for a total of 16,716 kg (18.4 tons) of nitrogen, during a single 25-year event.

The model also estimated that 66 cells, or 11.3 percent, have a total phosphorus yield greater than 0.75 kg/acre. The AGNPS model predicted that 0.22 kilograms of phosphorus would be generated per acre, for a total of 4,525 kg (9,976 lbs) of phosphorus, during a single 25-year event. A correlation between dissolved and sediment-bound nutrients was not determined.

Table C-76. East Mina sub-watershed priority-1 and 2 critical cells for sediment, nitrogen and phosphorus.

East Mina Priority-1 & 2 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
447	**15,068**	**316,680**	447	**9.34**	**0.63**	**9.97**	447	**4.67**	**0.11**	**10.54**
146	**5,706**	**170,878**	66	**3.26**	**2.19**	**5.45**	66	**1.63**	**0.47**	**4.63**
144	**4,799**	**49,569**	104	**0.91**	**4.40**	**5.31**	188	**2.07**	**0.01**	**4.59**
445	**4,509**	**1,837,288**	146	**2.85**	**2.30**	**5.14**	145	**1.46**	**0.47**	**4.26**
129	**4,354**	**138,409**	145	**2.92**	**2.19**	**5.11**	146	**1.42**	**0.49**	**4.23**
188	**4,309**	**114,696**	119	**2.24**	**2.37**	**4.61**	119	**1.12**	**0.52**	**3.60**
143	**4,146**	**134,064**	378	**2.23**	**2.37**	**4.60**	378	**1.11**	**0.52**	**3.59**
201	**3,738**	**478,087**	225	**2.15**	**2.37**	**4.53**	225	**1.08**	**0.52**	**3.52**
66	**3,293**	**84,876**	132	**2.00**	**2.37**	**4.38**	132	**1.00**	**0.52**	**3.35**
328	**3,275**	**1,136,967**	188	**4.15**	**0.18**	**4.32**	106	**0.96**	**0.52**	**3.25**
211	**3,121**	**428,491**	103	**0.60**	**3.71**	**4.31**	527	**1.00**	**0.47**	**3.25**
407	**3,121**	**170,859**	106	**1.91**	**2.37**	**4.29**	104	**0.45**	**0.99**	**3.18**
394	**3,121**	**84,105**	83	**1.02**	**3.18**	**4.20**	187	**1.43**	**0.01**	**3.18**
133	**3,084**	**316,553**	527	**2.00**	**2.19**	**4.20**	87	**1.22**	**0.18**	**3.09**
372	**3,075**	**1,442,816**	110	**0.40**	**3.71**	**4.11**	129	**1.38**	**0.01**	**3.08**
532	**2,966**	**2,426,469**	235	**1.71**	**2.37**	**4.08**	235	**0.85**	**0.52**	**3.02**
233	**2,930**	**562,301**	96	**0.35**	**3.71**	**4.06**	92	**0.89**	**0.47**	**3.00**
409	**2,858**	**1,533,217**	52	**1.60**	**2.37**	**3.97**	510	**1.01**	**0.35**	**2.99**
187	**2,858**	**72,294**	92	**1.77**	**2.19**	**3.96**	421	**1.05**	**0.29**	**2.94**
145	**2,785**	**74,045**	385	**1.59**	**2.37**	**3.96**	52	**0.80**	**0.52**	**2.90**
373	**2,731**	**1,321,997**	157	**0.40**	**3.45**	**3.85**	385	**0.79**	**0.52**	**2.89**
			82	**0.25**	**3.58**	**3.83**	232	**1.18**	**0.11**	**2.86**
			123	**0.36**	**3.45**	**3.81**	101	**1.10**	**0.18**	**2.82**
			53	**0.33**	**3.45**	**3.78**	439	**1.25**	**0.01**	**2.78**
			415	**1.41**	**2.33**	**3.74**	83	**0.51**	**0.73**	**2.72**
			510	**2.02**	**1.66**	**3.67**	415	**0.71**	**0.50**	**2.67**
			442	**0.87**	**2.76**	**3.63**	394	**0.93**	**0.26**	**2.63**
			64	**1.33**	**2.28**	**3.61**	64	**0.66**	**0.49**	**2.55**
			223	**1.20**	**2.37**	**3.57**	128	**1.12**	**0.01**	**2.49**
			224	**1.20**	**2.37**	**3.57**				
			421	**2.10**	**1.39**	**3.49**				
			87	**2.45**	**0.92**	**3.37**				
			234	**0.43**	**2.91**	**3.33**				
			394	**1.86**	**1.28**	**3.14**				
Critical Acres			Critical Acres				Critical Acres			
Priority 1		320	Priority 1			560	Priority 1			360
Priority 2		520	Priority 2			800	Priority 2			800

Shaded areas are Priority-1 cells

Table C-77. East Mina sub-watershed priority-3 critical cells for sediment, nitrogen and phosphorus.

East Mina Priority-3 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
468	**2,658**	**2,226,425**	101	**2.20**	**0.92**	**3.12**	103	**0.30**	**0.83**	**2.48**
191	**2,513**	**187,651**	65	**0.49**	**2.58**	**3.07**	223	**0.60**	**0.52**	**2.47**
416	**2,504**	**1,692,900**	232	**2.37**	**0.63**	**3.00**	224	**0.60**	**0.52**	**2.47**
131	**2,449**	**224,828**	80	**0.52**	**2.48**	**2.99**	317	**0.88**	**0.21**	**2.42**
130	**2,449**	**133,883**	129	**2.77**	**0.23**	**2.99**	110	**0.20**	**0.87**	**2.36**
362	**2,449**	**76,013**	187	**2.86**	**0.11**	**2.98**	134	**1.06**	**0.01**	**2.36**
222	**2,431**	**528,427**	514	**1.60**	**1.30**	**2.90**	514	**0.80**	**0.26**	**2.34**
232	**2,422**	**57,098**	236	**1.19**	**1.68**	**2.87**	431	**0.94**	**0.11**	**2.33**
317	**2,422**	**47,174**	317	**1.77**	**1.08**	**2.85**	96	**0.18**	**0.87**	**2.30**
439	**2,422**	**60,972**	114	**1.28**	**1.56**	**2.84**	442	**0.44**	**0.60**	**2.29**
147	**2,341**	**517,668**	386	**1.12**	**1.62**	**2.75**	396	**0.99**	**0.01**	**2.22**
528	**2,295**	**107,583**	237	**0.46**	**2.26**	**2.72**	157	**0.20**	**0.80**	**2.21**
547	**2,295**	**109,788**	226	**0.73**	**1.96**	**2.69**	362	**0.86**	**0.14**	**2.19**
235	**2,295**	**75,687**	182	**0.56**	**2.12**	**2.69**	284	**0.98**	**0.01**	**2.18**
87	**2,268**	**59,403**	439	**2.50**	**0.19**	**2.69**	130	**0.98**	**0.01**	**2.18**
434	**2,186**	**1,661,693**	238	**0.67**	**1.99**	**2.65**	123	**0.18**	**0.80**	**2.16**
134	**2,132**	**49,823**	78	**0.63**	**1.99**	**2.62**	114	**0.64**	**0.33**	**2.14**
454	**2,050**	**1,881,458**	73	**1.28**	**1.30**	**2.58**	53	**0.17**	**0.80**	**2.13**
128	**2,023**	**52,880**	528	**1.30**	**1.25**	**2.54**	82	**0.13**	**0.83**	**2.11**
119	**2,014**	**52,989**	431	**1.89**	**0.63**	**2.52**	143	**0.78**	**0.17**	**2.08**
531	**2,005**	**83,497**	128	**2.23**	**0.23**	**2.46**	236	**0.59**	**0.35**	**2.08**
101	**2,005**	**52,127**	362	**1.71**	**0.74**	**2.46**	161	**0.92**	**0.01**	**2.05**
83	**1,960**	**59,693**	143	**1.55**	**0.88**	**2.43**	144	**0.78**	**0.12**	**2.00**
378	**1,960**	**52,735**	134	**2.13**	**0.19**	**2.31**	386	**0.56**	**0.34**	**2.00**
284	**1,941**	**44,960**	407	**1.36**	**0.89**	**2.25**	528	**0.65**	**0.25**	**1.99**
73	**1,923**	**52,989**	248	**0.50**	**1.74**	**2.24**	73	**0.64**	**0.26**	**1.99**
225	**1,923**	**50,657**	144	**1.56**	**0.66**	**2.23**	234	**0.21**	**0.66**	**1.92**
541	**1,860**	**1,296,559**	244	**0.20**	**2.01**	**2.22**	407	**0.68**	**0.17**	**1.88**
422	**1,860**	**1,514,157**	396	**1.99**	**0.23**	**2.21**	540	**0.72**	**0.11**	**1.84**
523	**1,860**	**285,927**	538	**0.47**	**1.74**	**2.21**	65	**0.24**	**0.58**	**1.80**
431	**1,860**	**43,010**	217	**0.90**	**1.30**	**2.20**	80	**0.26**	**0.54**	**1.77**
216	**1,851**	**508,224**	130	**1.95**	**0.23**	**2.17**	202	**0.79**	**0.01**	**1.77**
421	**1,823**	**49,015**	189	**1.09**	**1.08**	**2.17**	226	**0.36**	**0.42**	**1.73**
455	**1,805**	**1,882,520**	284	**1.96**	**0.19**	**2.15**	238	**0.34**	**0.44**	**1.70**
132	**1,805**	**46,230**	397	**1.07**	**1.06**	**2.12**	285	**0.76**	**0.01**	**1.69**
510	**1,769**	**46,657**					189	**0.54**	**0.22**	**1.68**
54	**1,760**	**75,723**					397	**0.54**	**0.21**	**1.65**
161	**1,760**	**41,540**								
396	**1,751**	**45,786**								
527	**1,733**	**46,339**								
430	**1,724**	**1,736,136**								
446	**1,724**	**1,710,145**								
Critical Acres			Critical Acres				Critical Acres			
Priority 3		1,680	Priority 3			1,400	Priority 3			1,480

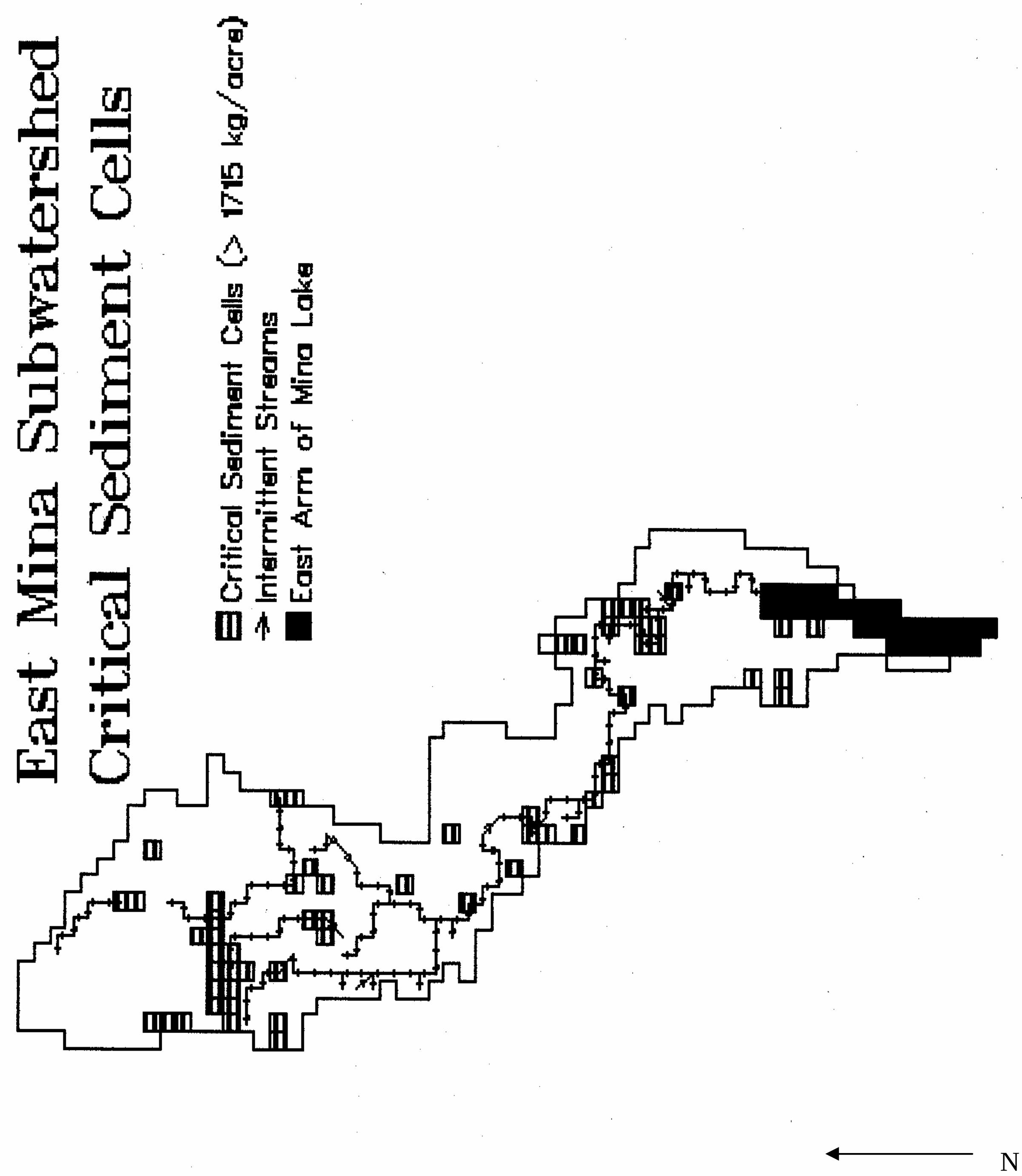


Figure C-77. Critical sediment cells for the East Mina sub-watershed of Mina Lake.

Sediment Analysis

The AGNPS model calculated that the sediment delivered from the sub-watershed was 40.5 kg/acre/year. As a result, 824,232 kg (908 tons) of sediment would be generated annually from this sub-watershed. In summary, the East Mina was estimated to contribute 14 percent of the east tributary sediment load, 8.5 percent of the total sediment load to Mina Lake. East Mina sub-watershed contained 13 percent of the critical erosion cells and comprised 13 percent of the watershed. Based on the export coefficient, the sub-watershed is ranked sixth of eight on a list of priorities for sediment improvements.

Sediment yield within the sub-watershed critical cells can be attributed to the land use, land slope, and proximity to surface water conduits. Common critical cell characteristics for the Mina Lake system include croplands with a slope greater than 2 percent that are closer than 152 meters (500 feet) to a stream.

Total Nutrient Analysis

The AGNPS data indicates that the East Mina sub-watershed had a total nitrogen (soluble + sediment-bound) transport rate of 1.60 kg/acre/year (equivalent to 32,600 kg or 36 tons). Eighty-six percent of the transported nitrogen from this sub-watershed was estimated to be in dissolved form while 77 percent of the *total* nitrogen load to Mina Lake was estimated to be in dissolved form. The total nitrogen load delivered from the sub-watersheds to Mina Lake was estimated to be 211,203 kg (233 tons/year). As a result, the East Mina load to Mina Lake was 15 percent of the total nitrogen load. Based on the transport coefficients for nitrogen, East Mina was rated fourth of eight for nitrogen reduction priority.

This sub-watershed had a total phosphorus (soluble + sediment-bound) transport rate of 0.36 kg/acre/year (equivalent to 7,388 kg or 8 tons). Sixty-nine percent of the transported phosphorus from this sub-watershed was estimated to be in dissolved form while 56 percent of the *total* phosphorus load to Mina Lake was estimated to be in dissolved form. The total phosphorus load delivered from all sub-watersheds to Mina Lake was estimated to be 53,300 kg/year (59 tons/year). As a result, the East Mina total phosphorus load to Mina Lake was 14 percent. Based on the transport coefficients for phosphorus, East Mina was rated fifth of eight for phosphorus reduction priority.

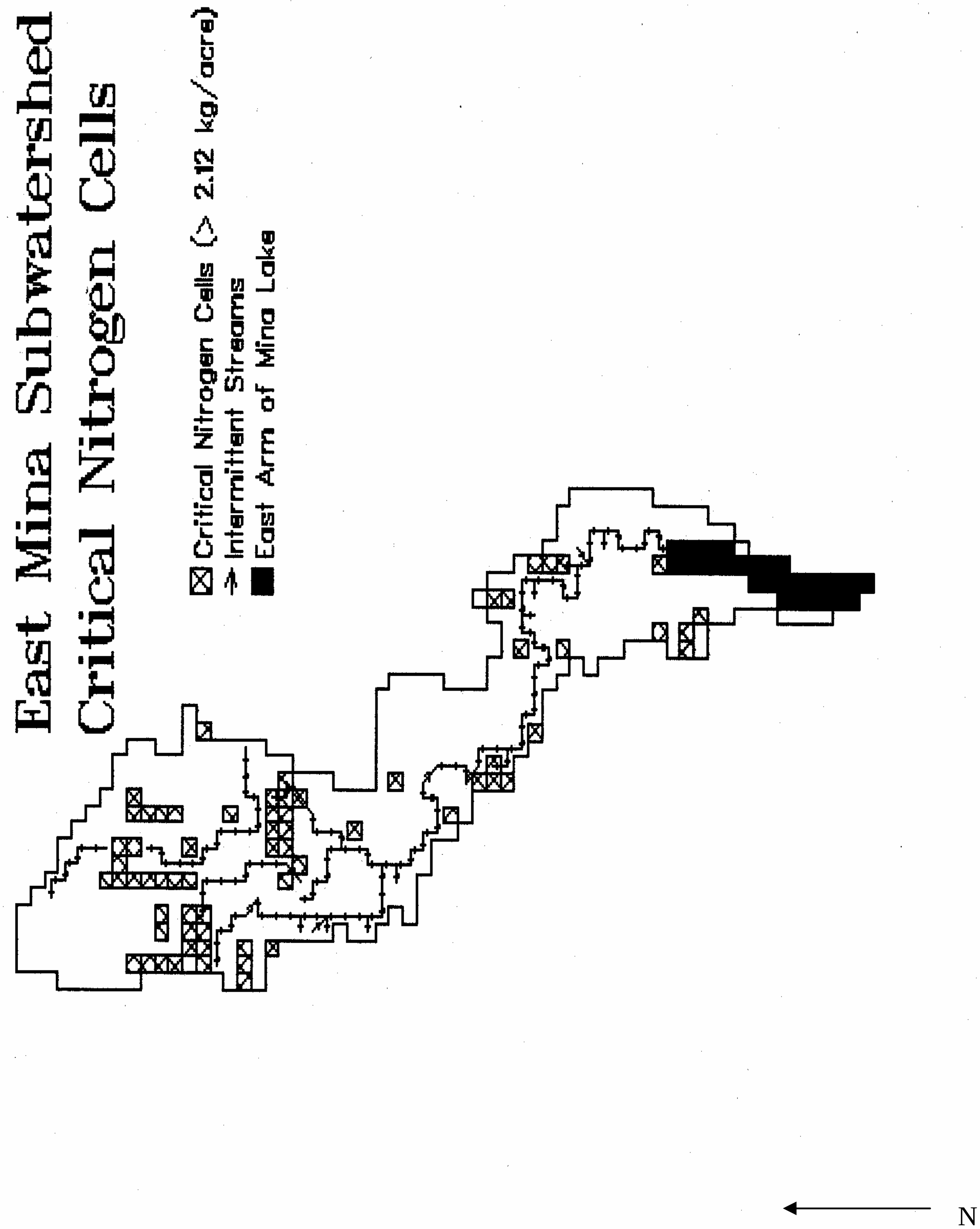


Figure C-78. Critical nitrogen cells for the East Mina sub-watershed of Mina Lake.

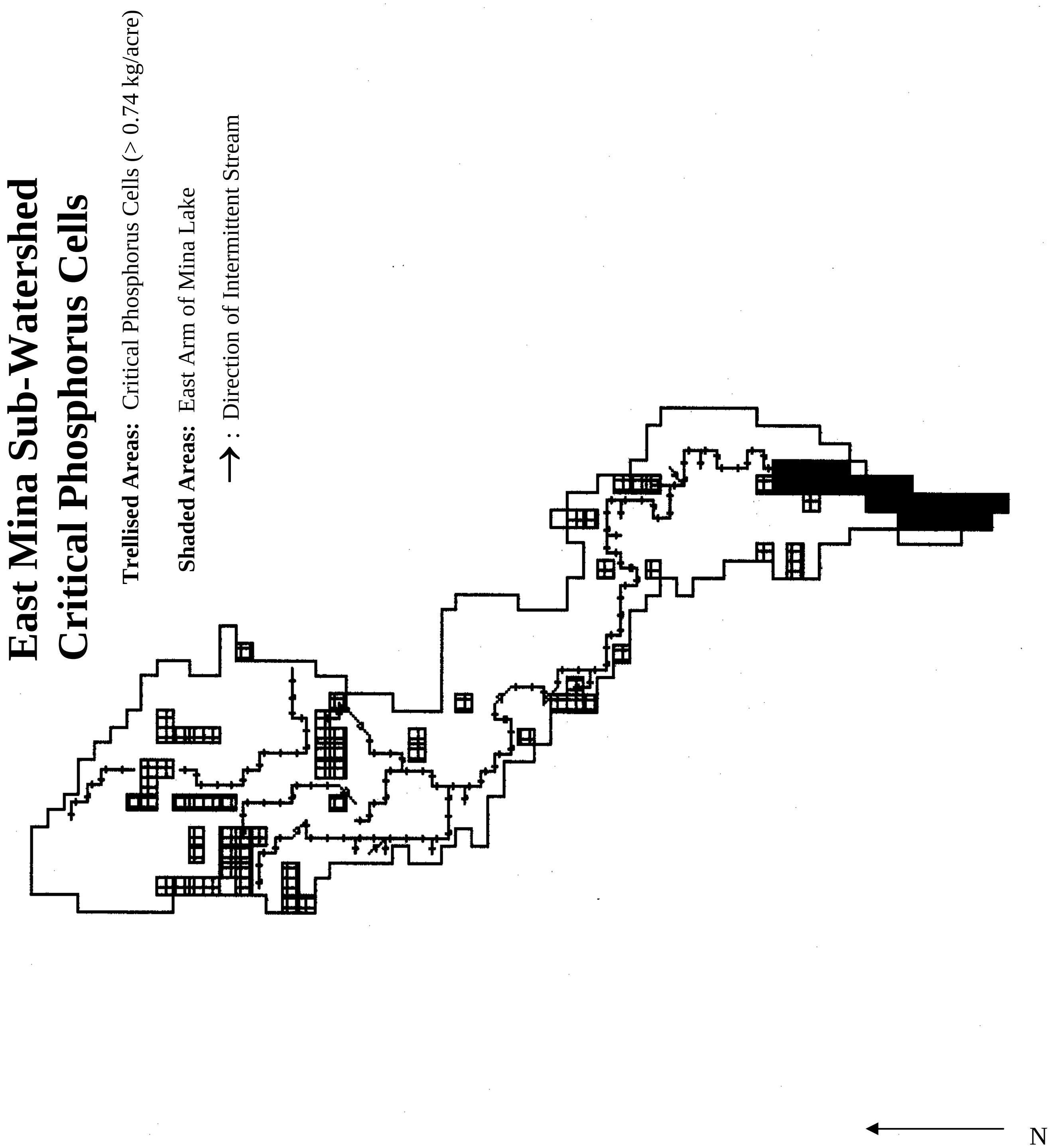


Figure C-79. Critical phosphorus cells for the East Mina sub-watershed of Mina Lake.

Priority Ranking of Animal Feeding Areas in the East Mina Sub-watershed (25-Year Event)

A total of 14 animal feeding areas were identified during the AGNPS data acquisition phase of the project. Table C-24 lists the AGNPS analysis of each feeding area. Of these, one was found to have an AGNPS ranking greater than 40. AGNPS ranks feeding areas from 0 to 100 with a zero ranked feeding area having a smaller pollution potential and a 100 ranking having a large pollution potential. AGNPS estimates the total impact of having a feeding area or multiple feeding areas within a cell by combining and recalculating all values to arrive at nutrient and COD values to the cell. Critical feeding area locations are depicted in Figure C-10.

In order to determine the impact of the feeding areas, AGNPS outputs from nutrient and feeding area critical cell data were analyzed (Table C-22). A reduction efficiency coefficient was determined by calculating a ratio of the difference (per acre) between the overall amount of nutrients generated per cell (acres multiplied by transport coefficient) and feedlot-generated nutrient loads. The results were used to estimate the cell capacity, or lack of capacity, to reduce nutrient levels under current conditions. Topographical gradient, size, location of buffering zones and proximity to surface conduits were possible influences on nutrient reduction and diffusion.

Reduction efficiency coefficients range from positive to negative values and were interpreted using a sliding scale with values and ratings based on Table C-23. All feeding areas, critical or not, were analyzed for reduction potential to determine trends and ratings. These values may be used to estimate the sensitivity or resistance potential of the cell to perturbations within the feeding area(s) (increasing the number of animal units/area) or within the cell (changes in landscape/land-use, buffer reduction, tillage practices, etc.) based on current conditions. BMP improvements in the feeding areas or the cell with favorable/marginally favorable ratings should respond/improve more rapidly than the cell with a neutral to unfavorable rating. Another use for this rating may be to prioritize/rank all critical feeding areas (feeding areas needing BMPs) within a watershed by reduction efficiency (improvement potential) to target/select feeding areas to realize maximum nutrient reduction in the sub-watershed when implementation funds are limited.

None of the cells with feedlot areas exceeded critical nutrient threshold limits. However, cell #525 exceeded critical feedlot nutrient threshold limits and data showed a marginally unfavorable reduction capacity. Feedlot and overall nutrient levels may be cell-supportable, but the proximity of the feedlot to Snake Creek may have resulted in reduction of the local buffering capacity to a non-supportable level. Over all, nutrient levels are cell-supportable; however, cell output would be sensitive to elevated (increased) nutrient concentrations. The average cell efficiency ratios in the East Mina sub-watershed were shown to be marginally unfavorable for nutrient reduction.

The animal feeding areas should be monitored for animal density or use-intensity. If use intensifies without modification of current conditions, the potential for sediment and nutrient yield will increase, especially in unfavorable to marginally unfavorable cells. Positive steps should be taken to identify and modify existing conditions within critical feeding areas. Careful study of feeding area size, animal density/intensity of use, and

buffering capacity may be needed to reduce the AGNPS feedlot ratings and increase the reduction efficiencies (ratings).

Table C-78. Critical Cell (CC) reduction efficiency ratio for the East Mina sub-watershed

Cell Number and Parameter	Feedlot Mass Generated (kg)	Transport Coefficient from (CC) Load Data **	Total Mass Transported (kg)	Difference (kg)	Reduction Efficiency Coefficient (kg/acre)	Rating (Table C- 23)
#310 Nitrogen	**7.51**	**1.08**	**43.2**	**-35.7**	**-0.89**	**MU**
#310 Phosphorus	**10.6**	**0.66**	**26.4**	**-15.8**	**-0.40**	**MU**
#350 Nitrogen	**45.0**	**1.55**	**62.0**	**-17.0**	**-0.43**	**MU**
#350 Phosphorus	**23.8**	**0.71**	**28.4**	**-4.60**	**-0.12**	**MU**
#324 Nitrogen	**12.8**	**1.37**	**54.8**	**-42.0**	**-1.05**	**MU**
#324 Phosphorus	**4.39**	**0.55**	**22.0**	**-17.6**	**-0.44**	**MU**
#411 Nitrogen	**25.1**	**0.89**	**35.6**	**-10.5**	**-0.26**	**MU**
#411 Phosphorus	**8.41**	**0.24**	**9.60**	**-1.19**	**-0.03**	**N**
#365 Nitrogen	**6.28**	**0.87**	**34.8**	**-28.5**	**-0.71**	**MU**
#365 Phosphorus	**2.44**	**0.23**	**9.20**	**-6.76**	**-0.17**	**MU**
#525 Nitrogen *	**33.9**	**1.04**	**41.6**	**-7.70**	**-0.19**	**MU**
#525 Phosphorus *	**16.7**	**0.44**	**17.6**	**-0.90**	**-0.02**	**N**
#537 Nitrogen	**17.3**	**0.79**	**31.6**	**-14.3**	**-0.36**	**MU**
#537 Phosphorus	**12.4**	**0.35**	**14.0**	**-1.60**	**-0.04**	**N**
Average					-0.36	MU

Shaded area indicates critical nutrient cells
* = Indicates critical feedlot cell
** = Indicates threshold values for the East Mina sub-watershed (nitrogen yields > 2.12 kg/acre or phosphorus yields > 0.75 kg/acre)

Table C-79. Nutrient reduction efficiency rating scale for Mina Lake.

Rating	Criteria
Favorable (F)	**Greater than 2.0 kg/acre**
Marginally Favorable (MF)	**Between 0.1 and 2.0 kg/acre**
Neutral (N)	**Between -0.1 and 0.1 kg/acre**
Marginally Unfavorable (MU)	**Between –2 and –0.1 kg/acre**
Unfavorable (U)	**Less than –2.0 kg/acre**

Application of BMPs in feeding areas and cells with favorable to marginally favorable rating would be expected to show marked improvement. Sources of nutrient loads not modeled through this study were from septic systems and livestock with direct access to the lake or adjacent streams.

Table C-80. AGNPS feedlot ratings and data for the East Mina sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 310		Cell # 310 TOTAL	
Nitrogen concentration (ppm)	**1.11**	**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)	**5.74**	**Phosphorus concentration (ppm)**	
COD concentration (ppm)	**302.151**	**COD concentration (ppm)**	
Nitrogen mass (kg)	**0.37**	**Nitrogen mass (kg)**	**7.51**
Phosphorus mass (kg)	**1.92**	**Phosphorus mass (kg)**	**10.6**
COD mass (kg)	**101**	**COD mass (kg)**	**671**
Animal feedlot rating number	9	**Animal feedlot rating number**	-
Cell # 310		Cell # 350	
Nitrogen concentration (ppm)	**0.16**	**Nitrogen concentration (ppm)**	**15.7**
Phosphorus concentration (ppm)	**6.78**	**Phosphorus concentration (ppm)**	**8.25**
COD concentration (ppm)	**362**	**COD concentration (ppm)**	**389**
Nitrogen mass (kg)	**0.06**	**Nitrogen mass (kg)**	**37.5**
Phosphorus mass (kg)	**2.37**	**Phosphorus mass (kg)**	**19.7**
COD mass (kg)	**127**	**COD mass (kg)**	**927**
Animal feedlot rating number	12	**Animal feedlot rating number**	40
Cell # 310		Cell # 350	
Nitrogen concentration (ppm)	**125**	**Nitrogen concentration (ppm)**	**18.3**
Phosphorus concentration (ppm)	**50.4**	**Phosphorus concentration (ppm)**	**9.91**
COD concentration (ppm)	**2322**	**COD concentration (ppm)**	**469**
Nitrogen mass (kg)	**6.94**	**Nitrogen mass (kg)**	**7.57**
Phosphorus mass (kg)	**2.80**	**Phosphorus mass (kg)**	**4.11**
COD mass (kg)	**129**	**COD mass (kg)**	**194**
Animal feedlot rating number	11	**Animal feedlot rating number**	17
Cell # 310		Cell # 350 TOTAL	
Nitrogen concentration (ppm)	**0.21**	**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)	**3.98**	**Phosphorus concentration (ppm)**	
COD concentration (ppm)	**378**	**COD concentration (ppm)**	
Nitrogen mass (kg)	**0.19**	**Nitrogen mass (kg)**	**45.0**
Phosphorus mass (kg)	**3.52**	**Phosphorus mass (kg)**	**23.8**
COD mass (kg)	**334**	**COD mass (kg)**	**1122**
Animal feedlot rating number	25	**Animal feedlot rating number**	-

Table C-24 (Continued). AGNPS feedlot ratings and data for the East Mina sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 324		Cell # 411	
Nitrogen concentration (ppm)	**8.79**	**Nitrogen concentration (ppm)**	**7.36**
Phosphorus concentration (ppm)	**3.01**	**Phosphorus concentration (ppm)**	**2.47**
COD concentration (ppm)	**246**	**COD concentration (ppm)**	**239**
Nitrogen mass (kg)	**12.8**	**Nitrogen mass (kg)**	**25.1**
Phosphorus mass (kg)	**4.39**	**Phosphorus mass (kg)**	**8.41**
COD mass (kg)	**359**	**COD mass (kg)**	**817**
Animal feedlot rating number	25	**Animal feedlot rating number**	39

Cell # 365		Cell # 525	
Nitrogen concentration (ppm)	**7.62**	**Nitrogen concentration (ppm)**	**6.33**
Phosphorus concentration (ppm)	**1.78**	**Phosphorus concentration (ppm)**	**1.48**
COD concentration (ppm)	**103**	**COD concentration (ppm)**	**68.0**
Nitrogen mass (kg)	**3.78**	**Nitrogen mass (kg)**	**3.88**
Phosphorus mass (kg)	**0.88**	**Phosphorus mass (kg)**	**0.91**
COD mass (kg)	**51**	**COD mass (kg)**	**41.6**
Animal feedlot rating number	0	**Animal feedlot rating number**	0

Cell # 365		Cell # 525	
Nitrogen concentration (ppm)	**1.63**	**Nitrogen concentration (ppm)**	**11.1**
Phosphorus concentration (ppm)	**1.02**	**Phosphorus concentration (ppm)**	**5.84**
COD concentration (ppm)	**94.4**	**COD concentration (ppm)**	**572**
Nitrogen mass (kg)	**2.49**	**Nitrogen mass (kg)**	**30.0**
Phosphorus mass (kg)	**1.56**	**Phosphorus mass (kg)**	**15.8**
COD mass (kg)	**144**	**COD mass (kg)**	**1547**
Animal feedlot rating number	14	**Animal feedlot rating number**	47

Cell # 365 TOTAL		Cell # 525 TOTAL	
Nitrogen concentration (ppm)		**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)		**Phosphorus concentration (ppm)**	
COD concentration (ppm)		**COD concentration (ppm)**	
Nitrogen mass (kg)	**6.28**	**Nitrogen mass (kg)**	**33.9**
Phosphorus mass (kg)	**2.44**	**Phosphorus mass (kg)**	**16.7**
COD mass (kg)	**195**	**COD mass (kg)**	**1589**

Animal feedlot rating number	-	Animal feedlot rating number	-

Table C-24 (Continued). AGNPS feedlot ratings and data for the East Mina sub-watershed of Mina Lake.

Feedlot Analysis	
Cell # 537	
Nitrogen concentration (ppm)	**5.17**
Phosphorus concentration (ppm)	**8.68**
COD concentration (ppm)	**438**
Nitrogen mass (kg)	**3.98**
Phosphorus mass (kg)	**6.68**
COD mass (kg)	**337**
Animal feedlot rating number	25
Cell # 537	
Nitrogen concentration (ppm)	**13.6**
Phosphorus concentration (ppm)	**5.85**
COD concentration (ppm)	**265**
Nitrogen mass (kg)	**13.4**
Phosphorus mass (kg)	**5.76**
COD mass (kg)	**261**
Animal feedlot rating number	21
Cell # 537 TOTAL	
Nitrogen concentration (ppm)	
Phosphorus concentration (ppm)	
COD concentration (ppm)	
Nitrogen mass (kg)	**17.3**
Phosphorus mass (kg)	**12.4**
COD mass (kg)	**599**
Animal feedlot rating number	**-**

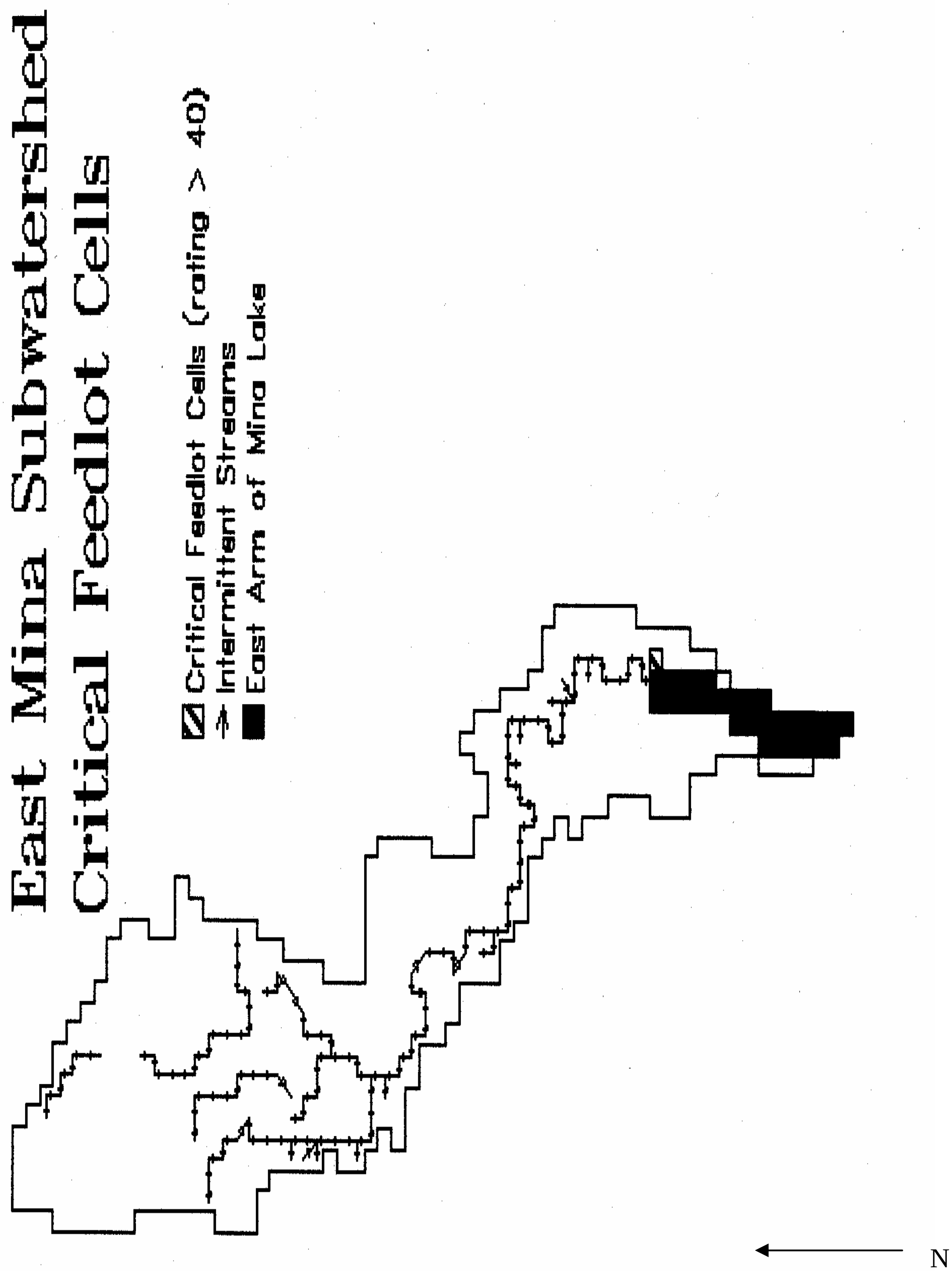


Figure C-80. Critical feedlot cells for the East Mina sub-watershed of Mina Lake.

Modeled Sediment, Nitrogen and Phosphorus Reductions (East Mina Sub-watershed)

Several Best Management Practices (BMPs) were modeled using the AGNPS computer model. These included installation of Animal Waste Management Systems (AWMS), grassed waterways, reduction in fertilizer application levels, and conversion of conventional till practices to minimum or no-till methods.

Fourteen feeding areas within the East Mina sub-watershed were identified. The AGNPS assessment of field feedlot data rated one feeding area as critical (rated above 40 based on objective criteria). Cell #525 exceeded threshold value, but the overall feeding area nutrient output for the cell was not critical. Efforts to improve feeding areas would reduce total nitrogen by less than 1 percent, from 32,600 kg/year (35.9 tons) to 32,365 kg/year (35.7 tons). Total phosphorus would be reduced from 7,388 kg/year (8.1 tons) to 7,197 kg/year (7.9 tons), a 2 percent reduction.

AGNPS compared fertilizer application rates using the current rate of application (approx. 45.4 kg or 100 lbs/acre nitrogen and 18.1 kg or 40 lbs/acre phosphorus) to a reduced rate (22.7 kg/acre or 50 lbs/acre nitrogen and 9.1 kg/acre or 20 lbs/acre phosphorus). Sub-watershed modeling indicated a reduction in the total nitrogen load from 32,600 kg/year (35.9 tons) to 26,696 kg or 29.4 tons/year (18 percent) and reduced the total phosphorus from 3,232 kg/year (7,125 lbs) to 2,771kg or 6,109 lbs/year, a 14 percent reduction.

The model estimated that modifying tilled acreage within critical erosion cells to conservation tillage practices would reduce the sediment load delivered by Snake Creek from 824,232 kg/year (909 tons) to 652,792 kg or 719 tons/year (12 percent reduction). This practice will also reduce the total nitrogen yield from 32,600 kg/year (35.9 tons) to 26,696 kg or 29.4 tons/year (18 percent reduction). The estimated phosphorus yield would be reduced from 7,388 kg/year (8.1 tons) to 6,122 kg/year or 6.75 tons (17 percent reduction). Based on AGNPS reduction estimates, conversion from conventional to minimum/no tillage will have the greatest impact on the watershed.

BMP recommendations should be implemented within sub-watershed and site priority critical cells (Tables C-25, C-26, and C-27). Field data for priority critical cells should be field verified prior to BMP planning and implementation. The AGNPS model did not simulate grass waterways, gully and streambank erosion; however, these BMPs should also be evaluated.

Table C-81. AGNPS modeling reductions for East Mina sub-watershed BMPs[1].

BMP	Unit	Percent Reduction		
		Sediments	Nitrogen	Phosphorus
Feedlot	**East Mina**	**0**	**0**	**2**
Fertilizer	**East Mina**	**0**	**18**	**14**
Minimum Till	**East Mina**	**12**	**18**	**17**
Sub-watershed Total		**12**	**36**	**33**

[1] = Reductions calculated 1999-2000 field data

Table C-82. AGNPS modeling reductions for water quality monitoring site SC-2 BMPs[1].

BMP	Unit	Percent Reduction		
		Sediments	Nitrogen	Phosphorus
Feedlot	**SC-2**	**0**	**0**	**0**
Fertilizer	**SC-2**	**0**	**17**	**15**
Minimum Till	**SC-2**	**9**	**16**	**17**
Site SC-2 Total		**9**	**33**	**32**

[1] = Reductions calculated 1999-2000 field data

Table C-83. AGNPS modeling reductions for water quality monitoring site SC-8 BMPs[1].

BMP	Unit	Percent Reduction		
		Sediments	Nitrogen	Phosphorus
Feedlot	**SC-8**	**0**	**0**	**0**
Fertilizer	**SC-8**	**0**	**8**	**2**
Minimum Till	**SC-8**	**0**	**8**	**2**
Site SC-8 Total		**0**	**16**	**4**

[1] = Reductions calculated 1999-2000 field data

North Crompton Sub-watershed AGNPS Analysis (A Sub-watershed of Mina Lake)

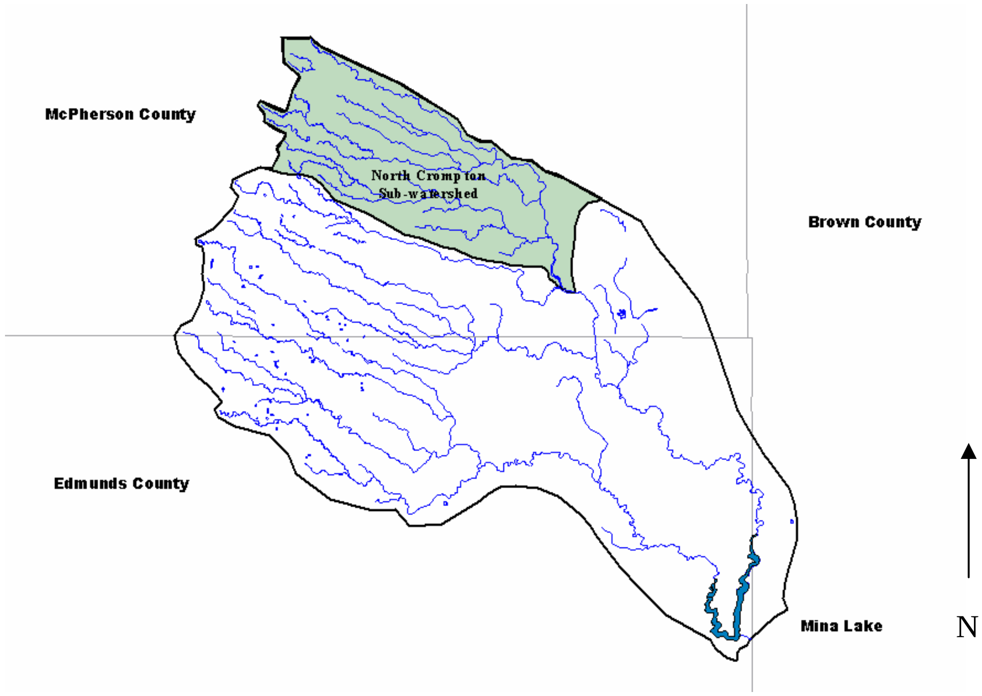


Figure C-81. The North Crompton Sub-watershed within the Mina Lake watershed.

The North Crompton sub-watershed is located in McPherson County, in northeastern South Dakota, and is the northern-most drainage for the eastern tributary of the Mina Lake watershed. The basin of the North Crompton sub-watershed is the largest in the Mina Lake system (23 percent of total hydrologic input) and encompasses an approximate area of 14,892 hectares (36,800 acres). The North Crompton sub-watershed is a shallow basin (0.6 percent grade) that drops 143 meters (470 feet) over 25 kilometers (15.6 miles). North Crompton eventually, along with the West Crompton sub-watershed, drains into Crompton Lake (an impoundment on Snake Creek). Crompton Lake discharges into the Snake Creek tributary, which flows through the East Mina and the AGNPS Ungauged watershed for approximately 24 kilometers (15 miles) before entering Mina Lake (Figure C-11).

The North Crompton watershed is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. Five monitoring sites were set up at various locations along Snake Creek to collect water quantity data and measure selected water quality parameters within the creek. No water quality monitoring sites are located within the North Crompton sub-watershed.

Due to the lack of site-specific water quality data with each sub-watershed, a computer model was selected to assess the Non-point Source (NPS) loads throughout the Mina Lake watershed. The data was used to model current loading to Snake Creek and was used for comparisons to other sub-watersheds in the Mina Lake drainage.

Cropping practices, including tillage and fertilizer use, and range management directly influence the intensity of sediment and nutrient runoff. None of the North Crompton sub-watershed was considered cropland; the acreage may instead be used as rangeland. Till, fertilizer, and feedlot Best Management Practices (BMPs) were modeled and analyzed to estimate the runoff reduction potential.

Evaluation/Quantification of Sub-watershed Non-Point Source Loading

Delineation and Location of Sub-watershed

The following AGNPS outlet cell numbers correlate to AGNPS sub-watershed and water quality monitoring sites used in the Mina Lake watershed assessment study during 1999 and 2000 (Table C-28):

Table C-84. AGNPS outlet cell number for the North Crompton sub-watershed of Mina Lake.

Sub-watershed	AGNPS outlet cell number
North Crompton	**920**

The following tables estimate the delivery coefficients, annual loading and critical values for priority cells for sediment (Table C-29), nitrogen (Table C-30), and phosphorus (Table C-31) in the North Crompton sub-watershed:

Table C-85. Export coefficients (kg/acre) for the North Crompton sub-watershed of Mina Lake♣.

				Export Coefficients					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area acres	Percent of Watershed	Sediment kg/acre	Attached-N kg/acre	Dissolved-N kg/acre	Total Nitrogen kg/acre	Attached-P kg/acre	Dissolved-P kg/acre	Total Phosphorus kg/acre
North Crompton	**36,800**	**23**	**86.2**	**0.43**	**0.48**	**0.91**	**0.20**	**0.09**	**0.29**

Table C-86. Annualized loading (kg) for the North Crompton sub-watershed of Mina Lake♣.

				Annualized Sub-watershed Loading					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area Acres	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
North Crompton	**36,800**	**23**	**3,171,373**	**15,691**	**17,694**	**33,384**	**7,178**	**3,338**	**10,516**

Table C-87. Priority cell threshold values for the North Crompton sub-watershed of Mina Lake♣.

	Critical Values (kg/acre)		
Parameter	Priority-1	Priority-2	Priority-3
Sediment	**2,023**	**1,550**	**1,077**
Nitrogen	**2.48**	**1.91**	**1.33**
Phosphorus	**0.96**	**0.73**	**0.51**

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulative rainfall events during an average year. This includes a 1-year, 24-hour event of 1.85 inches (EI = 17.5), 3 semiannual rainfall events of 1.23 inches (EI = 7.4) and a series of 10 small rainfall events of 0.8 inches (EI = 3.0) for a total "R" factor of 69.7.

Identification of Critical Non-Point Source Cells for North Crompton Sub-watershed (25-Year Event)

Priority 1, 2, and 3 critical cell thresholds were established based upon 1, 2 and 3 standard deviations of the mean using NPS cell yield data, event rainfall amount of 4.1 inches, and Event Intensity (EI) of 104.5, as follows:

> **Sediment erosion rate > 1,077 kg/acre or 1.19 ton/acre**
> **Total nitrogen cell yields > 1.33 kg/acre or 2.93 lbs/acre**
> **Total phosphorus cell yields > 0.51 kg/acre or 1.12 lbs/acre**

The yields for each of these cells are listed in Table C-32 and Table C-33 and their general locations in the sub-watershed are documented for sediment (Figure C-12), nitrogen (Figure C-13), and phosphorus (Figure C-14). Priority 1 and 2 critical cells should be given high priority during BMP planning and implementation.

Analysis of the Mina Lake watershed data indicates that 103 of 920 North Crompton cells, or 11.2 percent, have a sediment yield greater than 1.19 tons/acre. This is approximately 2.6 percent of the cells found within the entire watershed. The AGNPS model predicted that 2,838,494 kilograms of sediment (3,129 tons) would be generated during a single 25-year event from this sub-watershed.

The model estimated that 77 cells, or 8.4 percent, have a total nitrogen yield greater than 1.33 kg/acre. The AGNPS model predicted that 0.54 kilograms of nitrogen would be generated per acre, for a total of 19,864 kg (21.9 tons) of nitrogen, during a single 25-year event.

The model also estimated that 80 cells, or 8.7 percent, have a total phosphorus yield greater than 0.51 kg/acre. The AGNPS model predicted that 0.16 kilograms of phosphorus would be generated per acre, for a total of 5,842 kilograms (6.43 tons) of phosphorus, during a single 25-year event. A correlation between dissolved and sediment-bound nutrients was not determined.

Table C-88. North Crompton sub-watershed priority-1 and 2 critical cells for sediment, nitrogen and phosphorus.

North Crompton Priority-1 & 2 Cells											
Sediment			Nitrogen				Phosphorus				
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
99	6,976	121,917	374	1.15	4.45	5.60	99	1.89	0.01	1.90
618	2,876	73,065	910	2.24	2.55	4.79	910	1.12	0.56	1.67
25	2,731	159,111	847	2.15	2.55	4.70	847	1.08	0.56	1.64
208	2,731	84,704	418	1.70	2.55	4.25	618	1.44	0.16	1.61
585	2,731	65,617	704	1.50	2.55	4.05	374	0.57	1.02	1.59
315	2,549	58,278	705	1.38	2.55	3.93	585	1.32	0.20	1.52
247	2,440	196,052	99	3.78	0.12	3.90	700	1.32	0.18	1.49
361	2,295	159,547	618	2.89	0.85	3.74	418	0.85	0.56	1.41
865	2,295	151,681	585	2.65	0.98	3.63	114	1.17	0.21	1.38
875	2,277	2,561,186	700	2.64	0.92	3.55	1	1.11	0.23	1.34
114	2,268	56,318	114	2.35	1.05	3.40	704	0.75	0.56	1.31
145	2,268	144,016	1	2.22	1.12	3.34	115	1.08	0.21	1.28
206	2,268	91,227	115	2.15	1.05	3.20	315	1.21	0.07	1.28
917	2,186	2,138,110	586	2.15	0.98	3.13	586	1.08	0.20	1.27
1	2,023	52,571	537	1.97	0.98	2.95	705	0.69	0.56	1.25
883	2,014	132,939	208	1.87	1.05	2.92	537	0.98	0.20	1.18
910	2,014	52,989	699	1.99	0.92	2.91	699	0.99	0.18	1.17
115	2,005	50,449	315	2.41	0.44	2.86	208	0.93	0.21	1.14
586	2,005	101,051	400	1.85	0.98	2.83	400	0.93	0.20	1.12
701	2,005	686,921	257	1.75	1.05	2.80	257	0.88	0.21	1.08
822	1,923	345,720	817	1.75	1.05	2.80	817	0.88	0.21	1.08
847	1,923	50,657	867	1.75	1.05	2.80	867	0.88	0.21	1.08
14	1,760	61,997	207	1.69	1.05	2.74	207	0.84	0.21	1.05
213	1,760	41,431	858	1.54	1.12	2.66	816	0.80	0.21	1.01
537	1,760	45,232	816	1.61	1.05	2.66	858	0.77	0.23	1.00
700	1,751	65,091	706	0.73	1.76	2.49	906	0.99	0.01	1.00
705	1,751	57,906	495	1.29	0.98	2.27	28	0.93	0.01	0.93
823	1,751	347,117	145	1.37	0.87	2.24	145	0.68	0.17	0.85
846	1,751	303,245	859	1.12	1.12	2.24	587	0.71	0.13	0.84
906	1,751	45,396	530	1.07	1.12	2.19	495	0.64	0.20	0.84
328	1,678	38,465	906	1.97	0.20	2.17	191	0.83	0.01	0.83
450	1,678	221,108	587	1.43	0.69	2.12	505	0.78	0.01	0.79
699	1,669	45,867	531	0.96	1.12	2.08	859	0.56	0.23	0.78
334	1,660	220,238	28	1.85	0.17	2.02	530	0.54	0.23	0.76
864	1,642	116,428	457	1.24	0.70	1.95	457	0.62	0.13	0.75
44	1,633	195,444					706	0.36	0.38	0.74
619	1,624	93,758					128	0.73	0.01	0.73
38	1,588	77,610								
400	1,588	41,912								
Critical Acres			Critical Acres				Critical Acres			
Priority 1		600	Priority 1			1,040	Priority 1			1,040
Priority 2		960	Priority 2			360	Priority 2			440

Shaded areas are Priority-1 cells

Table C-89. North Crompton sub-watershed priority-3 critical cells for sediment, nitrogen and phosphorus.

North Crompton Priority-3 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
144	**1,533**	**69,300**	144	**1.15**	**0.74**	**1.89**	371	**0.62**	**0.11**	**0.73**
207	**1,533**	**37,303**	371	**1.23**	**0.63**	**1.86**	413	**0.62**	**0.11**	**0.73**
257	**1,533**	**39,054**	413	**1.23**	**0.63**	**1.86**	144	**0.58**	**0.14**	**0.72**
550	**1,533**	**403,870**	719	**0.87**	**0.98**	**1.85**	214	**0.61**	**0.10**	**0.71**
817	**1,533**	**39,054**	191	**1.65**	**0.18**	**1.83**	531	**0.48**	**0.23**	**0.70**
866	**1,533**	**195,426**	800	**1.06**	**0.72**	**1.78**	886	**0.69**	**0.01**	**0.70**
867	**1,533**	**39,054**	146	**1.03**	**0.74**	**1.77**	792	**0.59**	**0.10**	**0.68**
418	**1,506**	**37,594**	214	**1.22**	**0.54**	**1.76**	800	**0.53**	**0.13**	**0.66**
818	**1,506**	**120,928**	718	**0.95**	**0.80**	**1.75**	456	**0.54**	**0.11**	**0.66**
876	**1,433**	**2,645,291**	505	**1.56**	**0.18**	**1.74**	146	**0.51**	**0.14**	**0.65**
796	**1,424**	**28,667**	613	**1.01**	**0.72**	**1.72**	798	**0.64**	**0.01**	**0.65**
43	**1,415**	**187,434**	456	**1.09**	**0.63**	**1.72**	8	**0.64**	**0.01**	**0.64**
191	**1,415**	**36,351**	792	**1.17**	**0.54**	**1.71**	107	**0.64**	**0.01**	**0.64**
377	**1,415**	**37,984**	415	**0.98**	**0.68**	**1.66**	891	**0.59**	**0.05**	**0.64**
378	**1,415**	**51,274**	886	**1.38**	**0.27**	**1.65**	613	**0.50**	**0.13**	**0.64**
420	**1,415**	**38,791**	619	**0.98**	**0.64**	**1.62**	15	**0.63**	**0.01**	**0.64**
505	**1,415**	**33,847**	128	**1.45**	**0.15**	**1.60**	651	**0.63**	**0.01**	**0.64**
214	**1,406**	**74,680**	328	**0.99**	**0.56**	**1.55**	379	**0.62**	**0.01**	**0.63**
180	**1,388**	**60,437**	399	**1.01**	**0.54**	**1.55**	536	**0.62**	**0.01**	**0.63**
256	**1,388**	**353,095**	329	**0.81**	**0.72**	**1.53**	549	**0.61**	**0.01**	**0.63**
321	**1,388**	**45,804**	147	**1.11**	**0.39**	**1.51**	718	**0.48**	**0.15**	**0.62**
755	**1,388**	**39,925**	883	**0.64**	**0.86**	**1.50**	147	**0.55**	**0.07**	**0.62**
756	**1,388**	**54,486**	891	**1.18**	**0.32**	**1.50**	719	**0.44**	**0.19**	**0.62**
816	**1,388**	**35,036**	798	**1.29**	**0.19**	**1.47**	415	**0.49**	**0.12**	**0.62**
880	**1,388**	**81,901**	549	**1.23**	**0.23**	**1.46**	399	**0.50**	**0.10**	**0.60**
335	**1,379**	**237,910**	536	**1.24**	**0.19**	**1.43**	619	**0.49**	**0.12**	**0.60**
219	**1,343**	**261,605**	15	**1.25**	**0.18**	**1.42**	100	**0.59**	**0.01**	**0.60**
882	**1,343**	**102,213**	248	**0.98**	**0.45**	**1.42**	328	**0.49**	**0.10**	**0.60**
293	**1,334**	**337,183**	379	**1.24**	**0.18**	**1.42**	890	**0.54**	**0.05**	**0.59**
329	**1,315**	**44,516**	620	**0.86**	**0.56**	**1.42**	213	**0.53**	**0.05**	**0.58**
858	**1,315**	**33,294**	10	**0.96**	**0.45**	**1.41**	248	**0.49**	**0.08**	**0.57**
859	**1,315**	**44,516**	8	**1.27**	**0.13**	**1.40**	551	**0.55**	**0.01**	**0.57**
539	**1,297**	**552,821**	107	**1.27**	**0.13**	**1.40**	10	**0.48**	**0.08**	**0.56**
704	**1,270**	**32,205**	890	**1.08**	**0.32**	**1.40**	51	**0.51**	**0.05**	**0.56**
407	**1,243**	**33,267**	869	**0.88**	**0.51**	**1.39**	329	**0.40**	**0.14**	**0.54**
584	**1,243**	**388,040**	651	**1.25**	**0.13**	**1.38**	691	**0.49**	**0.05**	**0.54**
399	**1,234**	**58,758**	860	**0.59**	**0.79**	**1.38**	363	**0.49**	**0.04**	**0.53**
375	**1,225**	**251,454**	213	**1.05**	**0.32**	**1.37**	794	**0.52**	**0.01**	**0.53**
651	**1,188**	**25,682**	884	**0.55**	**0.81**	**1.36**	419	**0.52**	**0.01**	**0.53**
726	**1,188**	**417,070**	51	**1.03**	**0.32**	**1.34**	620	**0.43**	**0.10**	**0.53**
727	**1,188**	**433,671**	551	**1.11**	**0.23**	**1.34**	717	**0.51**	**0.01**	**0.52**
8	**1,179**	**26,209**	868	**0.72**	**0.62**	**1.34**	869	**0.44**	**0.08**	**0.52**
28	**1,179**	**41,930**					659	**0.47**	**0.04**	**0.51**

Table C-33 (Continued). North Crompton sub-watershed priority-3 critical cells for sediment, nitrogen and phosphorus.

North Crompton Priority-3 Cells (Continued)										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
107	**1,179**	**26,209**								
763	**1,179**	**74,816**								
784	**1,179**	**54,377**								
881	**1,179**	**88,750**								
561	**1,161**	**34,854**								
562	**1,161**	**52,190**								
371	**1,143**	**25,265**								
Critical Acres			Critical Acres				Critical Acres			
Priority 3		2,000	Priority 3			1,680	Priority 3			1,720

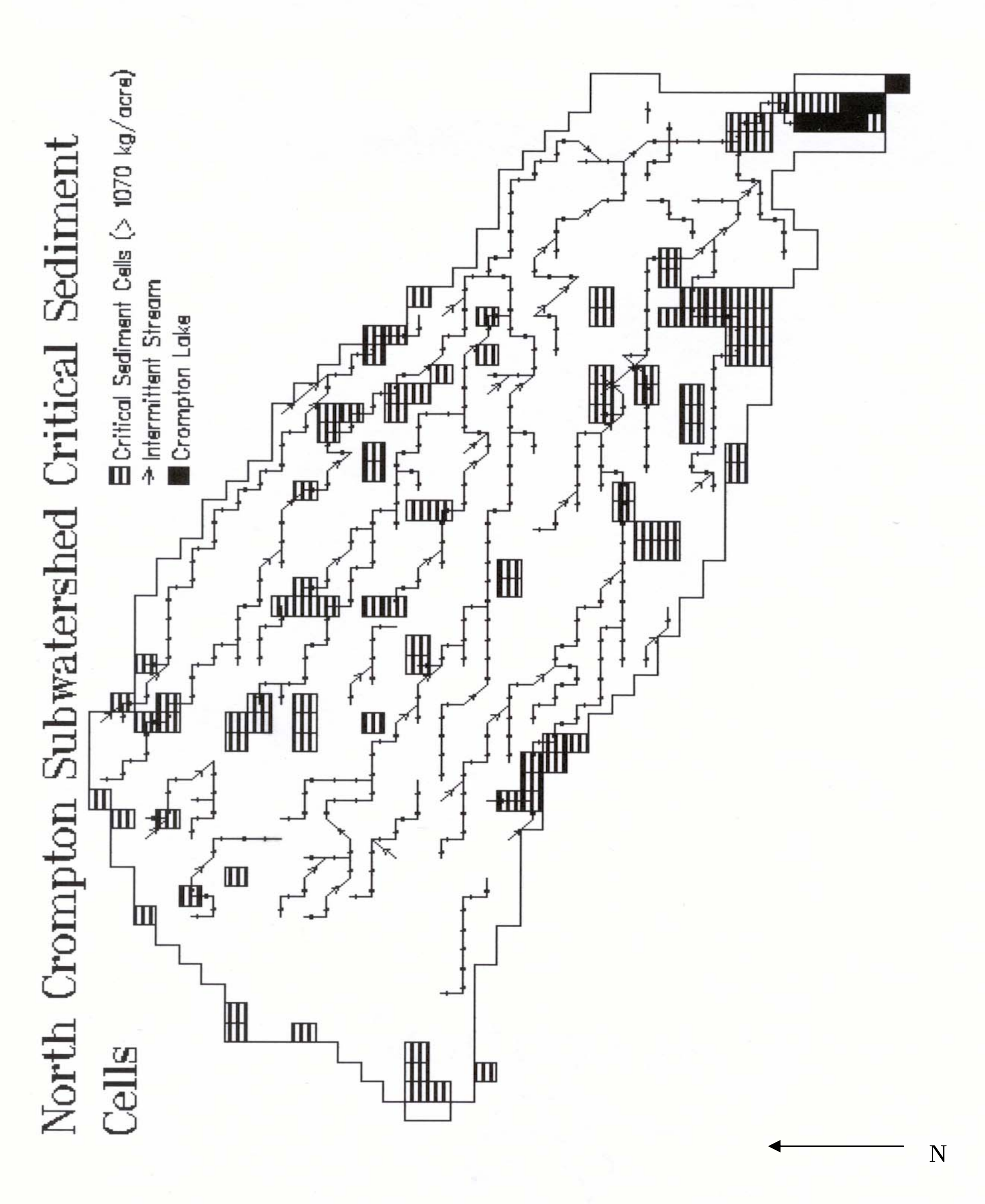


Figure C-82. Critical sediment cells for the North Crompton sub-watershed of Mina Lake.

Sediment Analysis

The AGNPS model calculated that the sediment delivered from the sub-watershed is 86.2 kg/acre/year. As a result, 3,171,373 kilograms (3,496 tons) of sediment (highest amount in the Mina system) would be generated annually from this sub-watershed. In summary, North Crompton was estimated to contribute 52 percent of the eastern tributary load, 33 percent of the total load to Mina Lake (highest over all). North Crompton contains 21 percent of the critical erosion cells and is 23 percent (largest over all) of the watershed surface area. Based on the export coefficient, the sub-watershed is ranked third of eight on a list of priorities for sediment improvements.

The high sediment yield within the sub-watershed critical cells can be attributed to land use, land slope, and proximity to surface water conduits. Common critical cell characteristics for the Mina Lake system include croplands with a slope greater than 2 percent that are closer than 152 meters (500 feet) to a stream.

Total Nutrient Analysis

The AGNPS data indicates/estimates that the North Crompton sub-watershed has a total nitrogen (soluble + sediment-bound) transport rate of 0.91 kg/acre/year (equivalent to 33,384 kilograms or 37 tons). Fifty-three percent of the transported nitrogen from this sub-watershed was estimated to be in dissolved form while 77 percent of the *total* nitrogen load to Mina Lake was estimated to be in dissolved form. The total nitrogen load delivered from the sub-watersheds to Mina Lake was estimated to be 211,203 kilograms (233 tons/year). As a result, the North Crompton load to Mina Lake is 16 percent of the total nitrogen (similar to sub-watershed Y). Based on the transport coefficients for nitrogen, North Crompton was rated seventh of eight for nitrogen reduction priority.

This sub-watershed had a total phosphorus (soluble + sediment-bound) transport rate of 0.29 kg/acre/year (equivalent to 10,516 kilograms or 12 tons). Thirty-two percent of the transported phosphorus from this sub-watershed was estimated to be in dissolved form while 56 percent of the *total* phosphorus load to Mina Lake was estimated to be in dissolved form. The total phosphorus load delivered from all sub-watersheds to Mina Lake was estimated to be 53,300 kg/year (59 tons/year). As a result, the North Crompton load to Mina Lake was 20 percent of the total phosphorus (highest over all). Based on the transport coefficients for phosphorus, North Crompton was rated sixth of eight for phosphorus reduction priority.

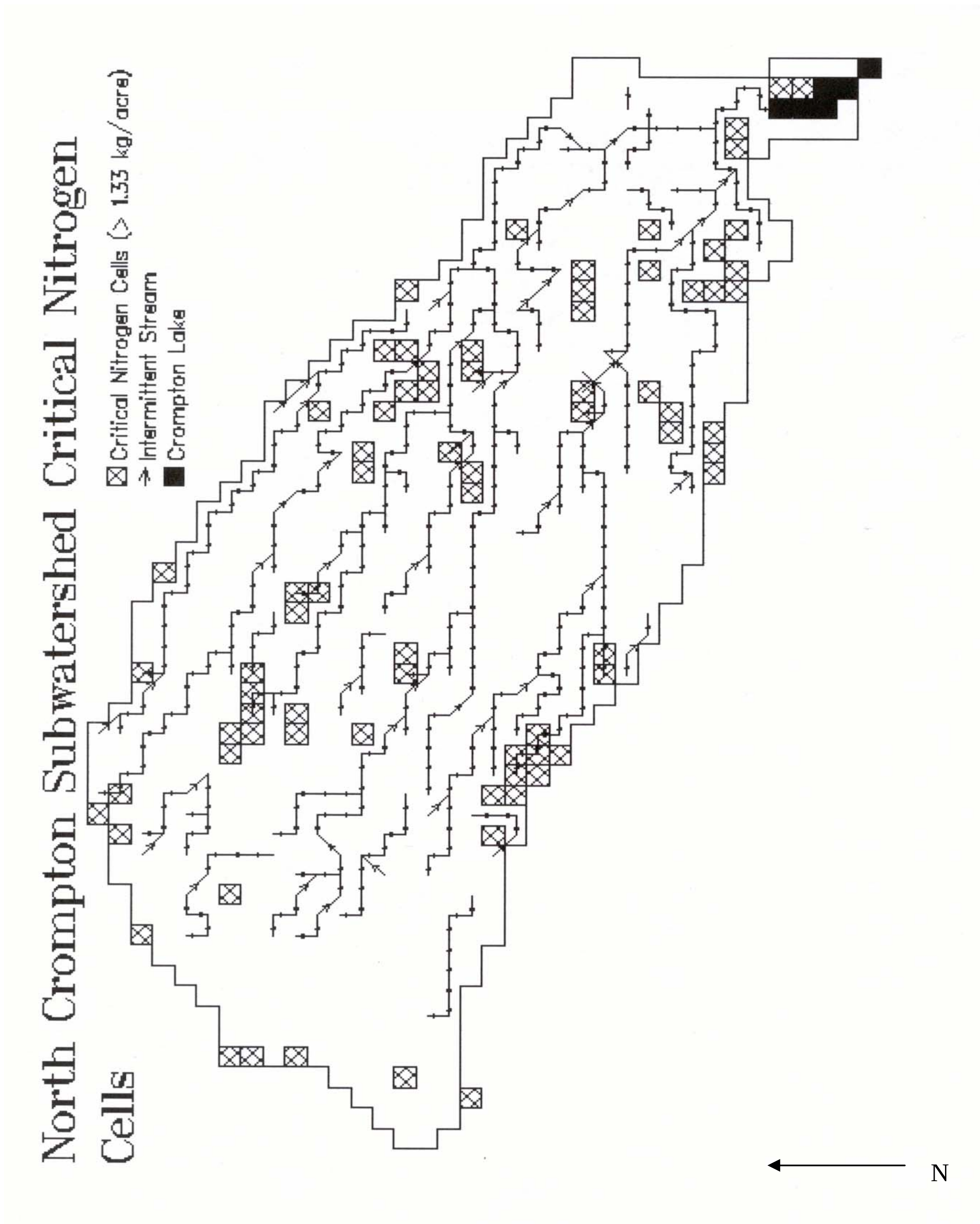


Figure C-83. Critical nitrogen cells for the North Crompton sub-watershed of Mina Lake.

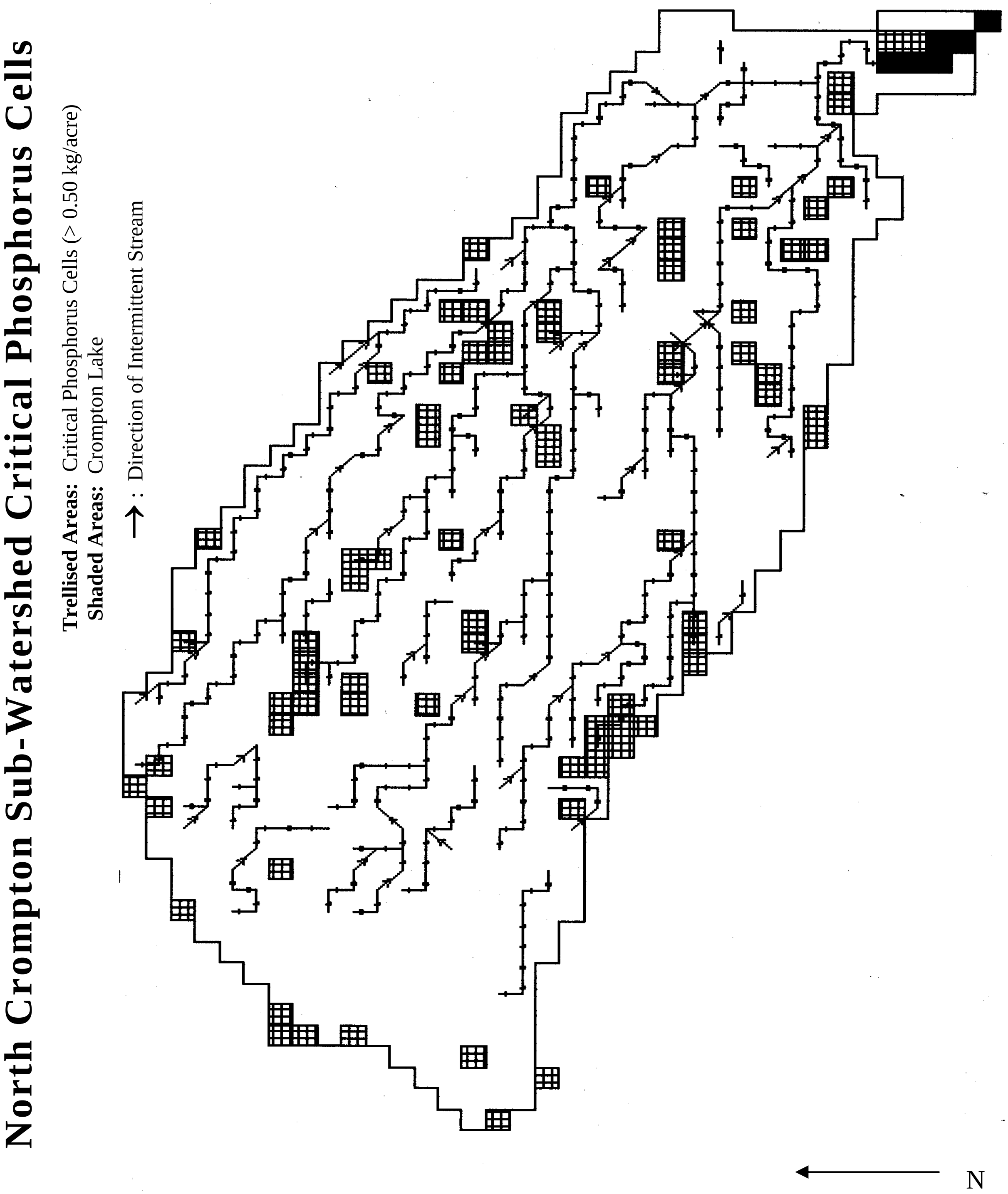


Figure C-84. Critical phosphorus cells for the North Crompton sub-watershed of Mina Lake.

Priority Ranking of Animal Feeding Areas for North Crompton Sub-watershed (25-Year Event)

A total of eight animal feeding areas were identified during the AGNPS data acquisition phase of the project. Table C-36 lists the AGNPS analysis of each feeding area. Of these, 2 were found to have an AGNPS ranking greater than 40. AGNPS ranks feeding areas from zero to 100 with a zero ranked feeding area having a smaller pollution potential and a 100 ranking having a large pollution potential. AGNPS estimates the total impact of having a feeding area or multiple feeding areas within a cell by combining and recalculating all values to arrive at nutrient and COD values to the cell. Critical feeding area locations are depicted in Figure C-15.

In order to determine the impact of the feeding areas, AGNPS outputs from nutrient and feeding area critical cell data were analyzed (Table C-34). A reduction efficiency coefficient was determined by calculating a ratio of the difference (per acre) between the overall amount of nutrients generated per cell (acres multiplied by transport coefficient) and feedlot-generated nutrient loads. The results were then used to estimate the cell capacity, or lack of capacity, to reduce nutrient levels under current conditions. Topographical gradient, size, location of buffering zones and proximity to surface conduits were possible conditions influencing reduction and diffusion of nutrients.

Table C-90. Critical Cell (CC) reduction efficiency ratio for the North Crompton sub-watershed.

Cell Number and Parameter	Feedlot Mass Generated (kg)	Transport Coefficient from (CC) Load Data **	Total Mass Transported (kg)	Difference (kg)	Reduction Efficiency Coefficient (kg/acre)	Rating (Table C- 35)
#411 Nitrogen	**46.7**	**0.69**	**27.6**	**19.1**	**0.48**	**MF**
#411 Phosphorus	**18.4**	**0.12**	**4.80**	**13.6**	**0.34**	**MF**
#602 Nitrogen *	**37.5**	**1.21**	**48.4**	**-10.9**	**-0.27**	**MU**
#602 Phosphorus *	**15.8**	**0.50**	**20.0**	**-4.20**	**-0.11**	**MU**
#675 Nitrogen	**26.8**	**0.64**	**25.6**	**1.20**	**0.03**	**N**
#675 Phosphorus	**7.46**	**0.08**	**3.20**	**4.26**	**0.11**	**MF**
#765 Nitrogen	**9.94**	**0.56**	**22.4**	**-12.5**	**-0.31**	**MU**
#765 Phosphorus	**4.57**	**0.07**	**2.80**	**1.77**	**0.04**	**N**
#831 Nitrogen *	**52.9**	**0.48**	**19.2**	**33.7**	**0.84**	**MF**
#831 Phosphorus *	**16.6**	**0.14**	**5.60**	**11.0**	**0.28**	**MF**
Average					0.14	MF

Shaded area indicates critical nutrient cells
* = Indicates critical feedlot cell
**** = Indicates threshold values for the North Crompton sub-watershed (nitrogen yields > 1.33 kg/acre or phosphorus yields > 0.51 kg/acre)**

Reduction efficiency coefficients range from positive to negative values and were interpreted using a sliding scale with values and ratings based on Table C-35. All feeding areas, critical or not, were analyzed for reduction potential to determine trends and ratings. These values may be used to estimate the sensitivity or resistance potential of the cell to perturbations within the feeding area(s) (increasing the number of animal units/area) or within the cell (changes in landscape/land-use, buffer reduction, tillage

practices, etc.) based on current conditions. BMP improvements in the feeding areas or the cells with favorable/marginally favorable ratings should respond/improve more rapidly than the cells with a neutral to unfavorable rating. Another use for this rating may be to prioritize/rank all critical feeding areas (feeding areas needing BMPs) within a watershed by reduction efficiency (improvement potential) to target/select feeding areas to realize maximum nutrient reduction in the watershed when implementation funds are limited.

Table C-91. Nutrient reduction efficiency rating scale for Mina Lake.

Rating	Criteria
Favorable (F)	**Greater than 2.0 kg/acre**
Marginally Favorable (MF)	**Between 0.1 and 2.0 kg/acre**
Neutral (N)	**Between -0.1 and 0.1 kg/acre**
Marginally Unfavorable (MU)	**Between –2 and –0.1 kg/acre**
Unfavorable (U)	**Less than –2.0 kg/acre**

None of the North Crompton feeding area cells exceeded overall nutrient threshold limits, but cells #602 and #831 exceeded critical feeding area nutrient threshold limits. The higher efficiency ratio of cell #831 might indicate that feeding area nutrients had greater impact on nutrient output than the cell, but were well buffered and cell supportable. Negative values for cell #602 might also indicate the feeding area activities had less impact on nutrient output than the cell and were also cell-supportable. Over all, North Crompton was found to have a marginally favorable efficiency ratio. Nutrient levels are cell-supportable based on Table C-35; however, cell outputs would be sensitive to elevated (increased) nutrient concentrations.

The animal feeding areas rated above 40 should be monitored for animal density or use-intensity. If use intensifies without modification of current conditions, the potential for sediment and nutrient yield will increase, especially in unfavorable to marginally unfavorable cells. Positive steps should be taken to identify and modify existing conditions within critical feeding areas. Careful study of feeding area size, animal density/intensity of use, and buffering capacity may be needed to reduce the AGNPS feedlot ratings and increase the reduction efficiencies (ratings).

Application of BMPs in feeding areas and cells with favorable to marginally favorable rating would be expected to show marked improvement. Sources of nutrient loads not modeled through this study were those from septic systems or livestock with direct access to the lake or adjacent streams.

Table C-92. AGNPS feedlot ratings and data for the North Crompton sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 411		Cell # 675	
Nitrogen concentration (ppm)	**39.8**	**Nitrogen concentration (ppm)**	**3.13**
Phosphorus concentration (ppm)	**15.4**	**Phosphorus concentration (ppm)**	**1.05**
COD concentration (ppm)	**961**	**COD concentration (ppm)**	**83.1**
Nitrogen mass (kg)	**36.8**	**Nitrogen mass (kg)**	**16.3**
Phosphorus mass (kg)	**14.3**	**Phosphorus mass (kg)**	**5.47**
COD mass (kg)	**889**	**COD mass (kg)**	**431**
Animal feedlot rating number	38	**Animal feedlot rating number**	29
Cell # 411		Cell # 675	
Nitrogen concentration (ppm)	**26.9**	**Nitrogen concentration (ppm)**	**7.40**
Phosphorus concentration (ppm)	**11.2**	**Phosphorus concentration (ppm)**	**1.39**
COD concentration (ppm)	**514**	**COD concentration (ppm)**	**49.3**
Nitrogen mass (kg)	**9.93**	**Nitrogen mass (kg)**	**10.6**
Phosphorus mass (kg)	**4.14**	**Phosphorus mass (kg)**	**1.99**
COD mass (kg)	**190**	**COD mass (kg)**	**70.4**
Animal feedlot rating number	17	**Animal feedlot rating number**	0
Cell # 411 TOTAL		Cell # 675 TOTAL	
Nitrogen concentration (ppm)		**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)		**Phosphorus concentration (ppm)**	
COD concentration (ppm)		**COD concentration (ppm)**	
Nitrogen mass (kg)	**46.7**	**Nitrogen mass (kg)**	**26.8**
Phosphorus mass (kg)	**18.4**	**Phosphorus mass (kg)**	**7.46**
COD mass (kg)	**1079**	**COD mass (kg)**	**502**
Animal feedlot rating number	-	**Animal feedlot rating number**	-
Cell # 602		Cell # 765	
Nitrogen concentration (ppm)	**19.5**	**Nitrogen concentration (ppm)**	**30.1**
Phosphorus concentration (ppm)	**8.42**	**Phosphorus concentration (ppm)**	**13.9**
COD concentration (ppm)	**796**	**COD concentration (ppm)**	**647**
Nitrogen mass (kg)	**37.5**	**Nitrogen mass (kg)**	**9.94**
Phosphorus mass (kg)	**15.8**	**Phosphorus mass (kg)**	**4.57**
COD mass (kg)	**1497**	**COD mass (kg)**	**214**

Animal feedlot rating number	46	**Animal feedlot rating number**	18

Table C-36 (Continued). AGNPS feedlot ratings and data for the North Crompton sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 831	
Nitrogen concentration (ppm)	**27.3**
Phosphorus concentration (ppm)	**10.0**
COD concentration (ppm)	**452**
Nitrogen mass (kg)	**17.6**
Phosphorus mass (kg)	**6.45**
COD mass (kg)	**291**
Animal feedlot rating number	23
Cell # 831	
Nitrogen concentration (ppm)	**26.7**
Phosphorus concentration (ppm)	**7.68**
COD concentration (ppm)	**775**
Nitrogen mass (kg)	**35.3**
Phosphorus mass (kg)	**10.2**
COD mass (kg)	**1027**
Animal feedlot rating number	41
Cell # 831 TOTAL	
Nitrogen concentration (ppm)	
Phosphorus concentration (ppm)	
COD concentration (ppm)	
Nitrogen mass (kg)	**52.9**
Phosphorus mass (kg)	**16.6**
COD mass (kg)	**1318**
Animal feedlot rating number	**-**

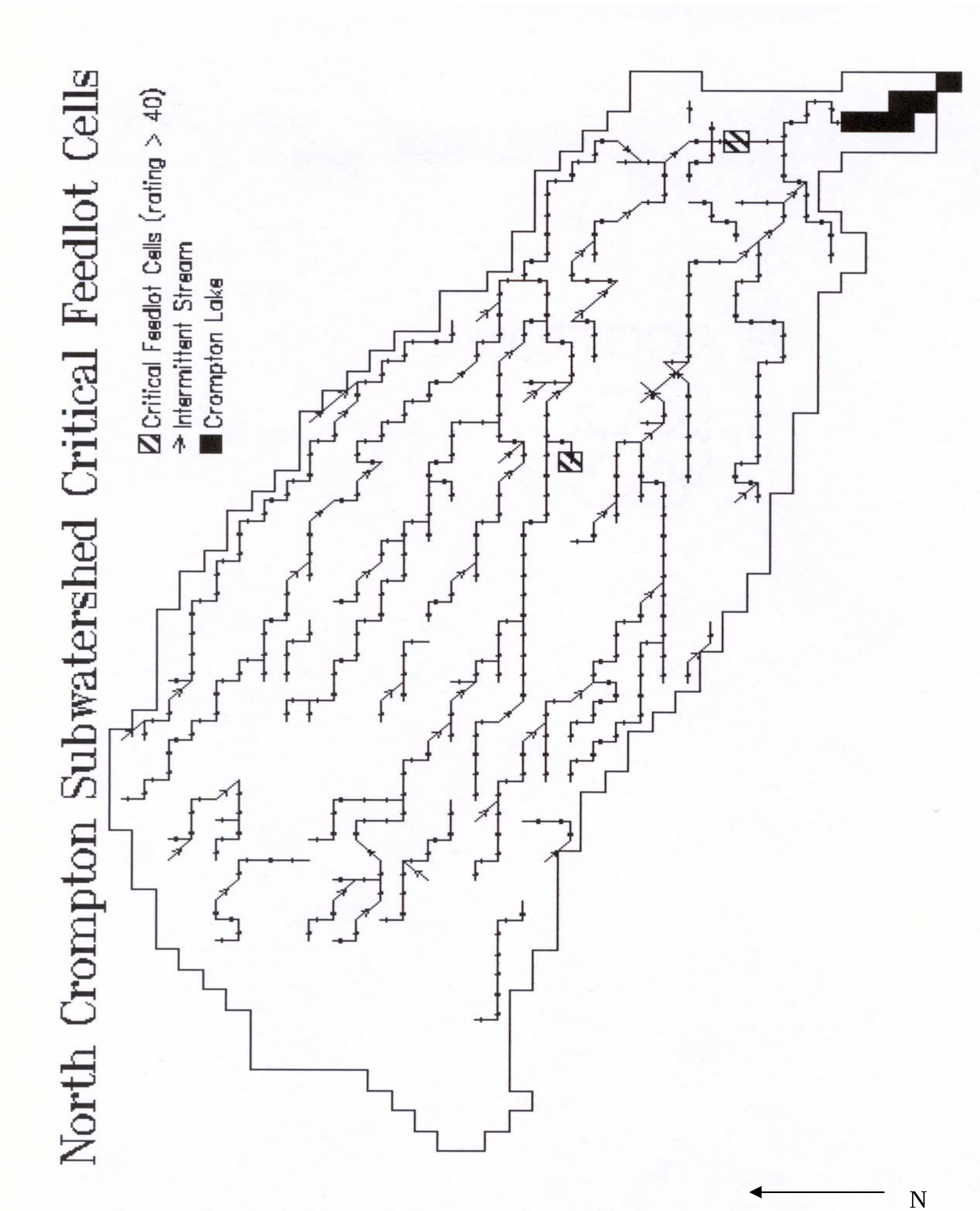


Figure C-85. Critical feedlot cells for the North Crompton sub-watershed of Mina Lake.

Modeled Sediment, Nitrogen and Phosphorus Reductions (North Crompton Sub-watershed)

Several Best Management Practices (BMP) were modeled using the AGNPS computer model. These included installation of Animal Waste Management Systems (AWMS), grassed waterways, reduction of fertilizer application levels, and conversion of conventional tillage practices to minimum or no-tillage methods.

Eight feeding areas within the North Crompton sub-watershed were identified. The AGNPS assessment of field feedlot data rated 2 feeding areas as critical (rated above 40 based on objective criteria). Efforts to improve feeding areas would result in a minimal reduction of nitrogen and phosphorus levels mainly because of the size of the watershed.

AGNPS compared fertilizer application rates using the current rate of application (approx. 45.4 kg or 100 lbs/acre nitrogen and 18.1 kg or 40 lbs/acre phosphorus) to a reduced rate (22.7 kg/acre or 50 lbs/acre nitrogen and 9.1 kg/acre or 20 lbs/acre phosphorus). The sub-watershed model indicated a reduction in the total nitrogen load from 33,384 kg/year (36.8 tons) to 30,813 kg/year (34.0 tons(or 7 percent) and a minimal reduction in total phosphorus.

The model estimated that modifying tilled acreage within critical erosion cells to conservation tillage practices would reduce the sediment load delivered by Snake Creek from 3,171,373 kg/year or 3,494.8 tons to 3,044,518 kg/year or 3,356.0 tons (4 percent). This practice will also reduce the total nitrogen yield from 33,384 kg/year or 36.8 tons to 29,962 kg or 33.0 tons (10 percent). The phosphorus yield would be reduced from 10,516 kg/year or 11.6 tons to 10,077 kg/year or 11.1 tons (4 percent). Based on AGNPS reduction estimates, conversion from conventional to minimum/no tillage will have the greatest impact on the watershed.

BMP recommendations should be implemented within sub-watershed priority critical cells (Table C-37). Field data for priority critical cells should be field verified prior to BMP planning and implementation. The AGNPS model did not simulate grass waterways, gully and streambank erosion; however, these BMPs should also be evaluated.

Table C-93. AGNPS modeling reductions for North Crompton sub-watershed BMPs[1].

		Percent Reduction		
BMP	Unit	Sediments	Nitrogen	Phosphorus
Feedlot	**North Crompton**	**0**	**0**	**0**
Fertilizer	**North Crompton**	**0**	**7**	**0**
Minimum Till	**North Crompton**	**4**	**10**	**4**
Sub-watershed Total		**4**	**17**	**4**

[1] = Reductions calculated 1999-2000 field data

Rosette Sub-watershed AGNPS Analysis (A Sub-watershed of Mina Lake)

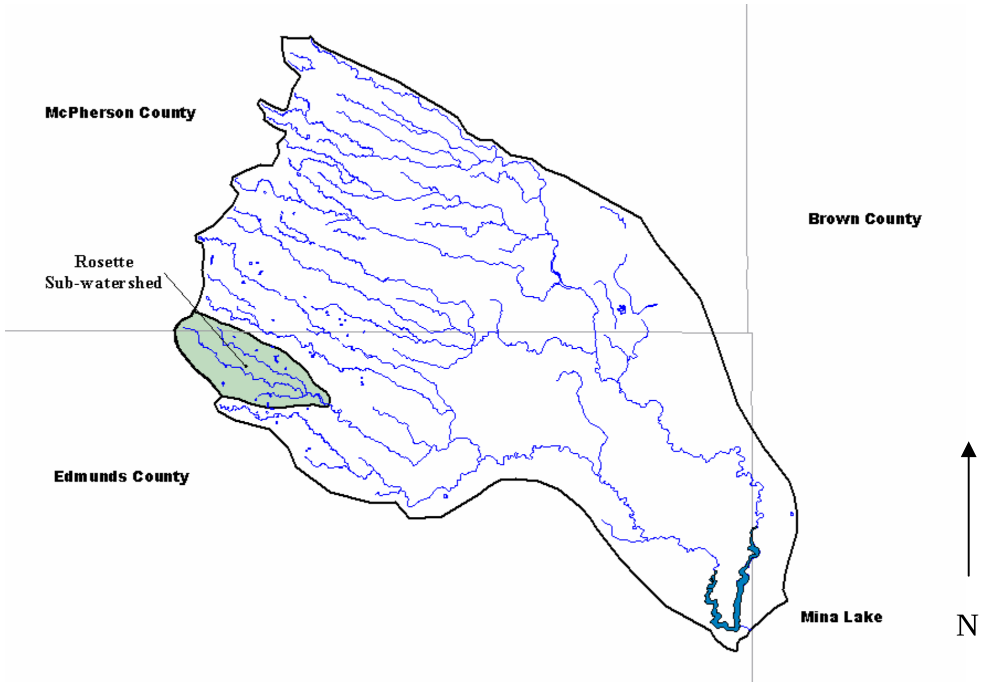


Figure C-86. The Rosette Sub-watershed within the Mina Lake watershed.

The Rosette sub-watershed is located in Edmunds County (with a minor portion in McPherson County), in northeastern South Dakota, and is a drainage for the western tributary of the Mina Lake watershed. The basin of the Rosette sub-watershed is the smallest in the Mina system (4 percent of total hydrologic input) and encompasses an approximate area 2,331 hectares (5,760 acres). The Rosette sub-watershed is a shallow basin that drops 72 meters (236 feet) over 9.2 kilometers (5.7 miles), and has the highest grade (0.8 percent) in the Mina system. Runoff from Rosette sub-watershed accumulates in Rosette Lake, which then discharges into the West Mina sub-watershed (Figure C-16).

The Rosette drainage is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. Five monitoring sites were set up at various locations along Snake Creek to collect water quantity data and measure selected water quality parameters within the creek. No sites are located within the Rosette sub-watershed.

Due to the lack of site-specific water quality data with each sub-watershed, a computer model was selected to assess the Non-point Source (NPS) loads throughout the Mina Lake watershed. The data was used to model current loading to Rosette Lake and Snake Creek and was used for comparisons to other sub-watersheds in the Mina Lake drainage.

Cropping practices, including tillage, fertilizer use and range management directly influence the intensity of sediment and nutrient runoff. None of the Rosette sub-

watershed is used for cropland; the acreage may instead be used as rangeland. Tillage, fertilizer, and feedlot Best Management Practices (BMPs) were modeled and analyzed to estimate the runoff reduction potential within the sub-watershed.

Evaluation/Quantification of Sub-watershed Non-Point Source Loading

Delineation and Location of Sub-watershed

The following AGNPS outlet cell numbers correlate to AGNPS sub-watershed and water quality monitoring sites used in the Mina Lake watershed assessment study during 1999 and 2000 (Table C-38):

Table C-94. AGNPS outlet cell number for the Rosette sub-watershed of Mina Lake.

Sub-watershed	AGNPS outlet cell number
Rosette	**144**

The following tables estimate the delivery coefficients, annual loading and critical values for priority cells for sediment (Table C-39), nitrogen (Table C-40), and phosphorus (Table C-41) in the Rosette sub-watershed:

Table C-95. Export coefficients (kg/acre) for the Rosette sub-watershed of Mina Lake♣.

				Export Coefficients					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area Acres	Percent of Watershed	Sediment kg/acre	Attached-N kg/acre	Dissolved-N kg/acre	Total Nitrogen kg/acre	Attached-P kg/acre	Dissolved-P kg/acre	Total Phosphorus kg/acre
Rosette	**5,760**	**4**	**3.67**	**0.02**	**0.29**	**0.32**	**0.01**	**0.04**	**0.05**

Table C-96. Annualized Loading (kg) for the Rosette sub-watershed of Mina Lake♣.

				Sub-watershed Loading					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area Acres	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
Rosette	**5,760**	**4**	**21,119**	**131**	**1,698**	**1,829**	**26**	**235**	**261**

Table C-97. Priority cell threshold values for the Rosette sub-watershed of Mina Lake.

	Critical Values (kg/acre)		
Parameter	Priority-1	Priority-2	Priority-3
Sediment	**4,183**	**3,014**	**1,845**
Nitrogen	**1.77**	**1.30**	**0.82**
Phosphorus	**0.55**	**0.40**	**0.26**

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulative rainfall events during an average year. This includes a 1-year, 24-hour event of 1.85 inches (EI = 17.5), 3 semiannual rainfall events of 1.23 inches (EI = 7.4) and a series of 10 small rainfall events of 0.8 inch (EI = 3.0) for a total "R" factor of 69.7.

Identification of Critical Non-Point Source Cells for Rosette Sub-watershed (25-Year Event)

Priority 1, 2, and 3 critical cell thresholds were established based upon 1, 2 and 3 standard deviations of the mean using NPS cell yield data, event rainfall amount of 4.1 inches, and Event Intensity (EI) of 104.5, as follows:

Sediment erosion rate >1,845 kg/acre or 2.03 ton/acre
Total nitrogen cell yields > 0.82 kg/acre or 1.81 lbs/acre
Total phosphorus cell yields > 0.26 kg/acre or 0.57 lbs/acre

The yields for each of these cells are listed in Table C-42 and Table C-43 and their general locations in the sub-watershed are documented for sediment (Figure C-17), nitrogen (Figure C-18), and phosphorus (Figure C-19). Priority 1 and 2 critical cells should be given high priority during BMP planning and implementation.

Analysis of the Mina Lake watershed data indicates that 7 of 144 Rosette cells, or 4.7 percent, have a sediment yield greater than 2.03 ton/acre. This is approximately 0.17 percent of the cells found within the entire watershed. The AGNPS model predicted that 73,101 kilograms (80.6 tons) of sediment would be generated during a single 25-year event from this sub-watershed.

The model estimated that 6 cells, or 4.2 percent, have a total nitrogen yield greater than 0.82 kg/acre. The AGNPS model predicted that 0.26 kilograms of nitrogen would be generated per acre, for a total of 1,515 kg (3,340 lbs) of nitrogen, during a single 25-year event.

The model also estimated that 7 cells, or 4.7 percent, have a total phosphorus yield greater than 0.26 kg/acre. The AGNPS model predicted that 0.05 kilograms of phosphorus would be generated per acre, for a total of 287 kg (633 lbs) of phosphorus, during a single 25-year event. A correlation between dissolved and sediment-bound nutrients was not determined.

Table C-98. Rosette sub-watershed priority-1 and 2 critical cells for sediment, nitrogen and phosphorus.

Rosette Priority-1 & 2 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
111	**9,825**	**91,290**	128	**0.17**	**4.84**	**5.02**	128	**0.09**	**1.23**	**1.32**
45	**6,595**	**63,548**	45	**1.91**	**0.79**	**2.70**	45	**0.96**	**0.15**	**1.11**
131	**5,761**	**330,524**	111	**1.06**	**0.34**	**1.40**	111	**0.53**	**0.05**	**0.59**
130	**4,990**	**166,677**	137	**0.37**	**0.79**	**1.17**	137	**0.19**	**0.15**	**0.34**
106	**2,948**	**24,839**	125	**0.53**	**0.39**	**0.92**	125	**0.27**	**0.06**	**0.33**
140	**2,849**	**79,252**					119	**0.26**	**0.06**	**0.32**
Critical Acres			Critical Acres				Critical Acres			
Priority 1		160	Priority 1			80	Priority 1			120
Priority 2		80	Priority 2			120	Priority 2			120

Shaded areas are Priority-1 cells

Table C-99. Rosette sub-watershed priority-3 critical cells for sediment, nitrogen and phosphorus.

Rosette Priority-3 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
129	**1,960**	**145,340**	119	**0.52**	**0.39**	**0.91**	46	**0.18**	**0.08**	**0.26**
102	**1,833**	**83,969**	46	**0.35**	**0.45**	**0.81**	108	**0.23**	**0.01**	**0.24**
119	**1,461**	**12,356**	134	**0.39**	**0.22**	**0.61**	134	**0.20**	**0.01**	**0.21**
46	**1,397**	**30,835**	135	**0.38**	**0.22**	**0.60**	135	**0.19**	**0.01**	**0.20**
112	**1,343**	**149,849**	140	**0.16**	**0.43**	**0.59**	59	**0.10**	**0.07**	**0.17**
143	**1,343**	**311,383**	141	**0.15**	**0.44**	**0.59**	140	**0.08**	**0.08**	**0.16**
120	**1,234**	**29,456**	59	**0.20**	**0.39**	**0.59**	141	**0.07**	**0.09**	**0.16**
108	**1,216**	**10,923**	108	**0.47**	**0.11**	**0.58**	142	**0.07**	**0.08**	**0.15**
101	**1,207**	**71,368**	142	**0.14**	**0.44**	**0.57**	139	**0.06**	**0.08**	**0.15**
			139	**0.12**	**0.42**	**0.54**	106	**0.12**	**0.02**	**0.14**
			106	**0.25**	**0.15**	**0.40**	32	**0.12**	**0.01**	**0.13**
			126	**0.15**	**0.24**	**0.39**	56	**0.12**	**0.01**	**0.13**
			127	**0.15**	**0.23**	**0.38**	5	**0.11**	**0.01**	**0.12**
			138	**0.13**	**0.25**	**0.38**	7	**0.11**	**0.01**	**0.12**
			32	**0.25**	**0.11**	**0.36**	28	**0.11**	**0.01**	**0.12**
			136	**0.16**	**0.20**	**0.36**	41	**0.11**	**0.01**	**0.12**
							87	**0.11**	**0.01**	**0.12**
Critical Acres			Critical Acres				Critical Acres			
Priority 3		360	Priority 3			640	Priority 3			680

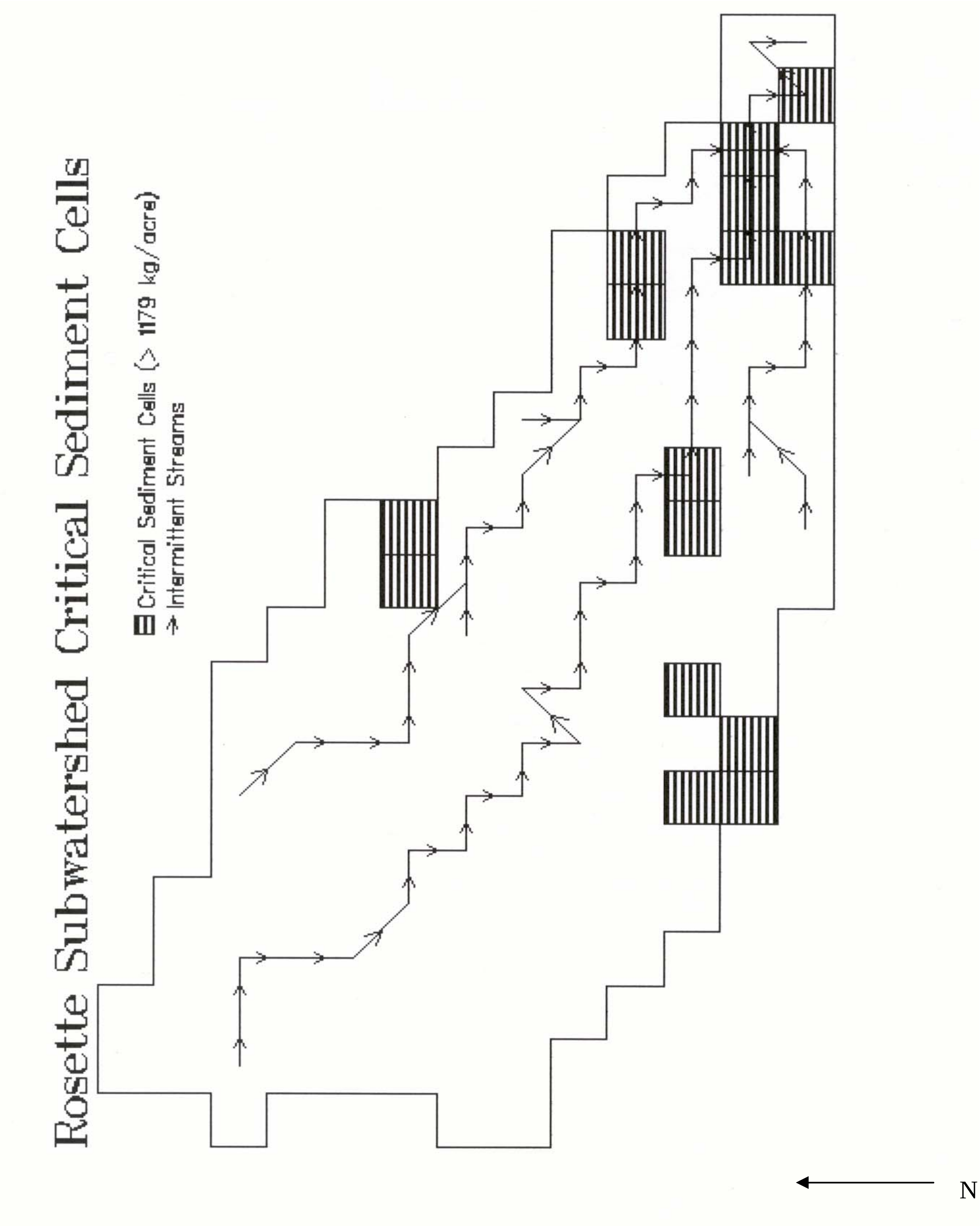


Figure C-87. Critical sediment cells for the Rosette sub-watershed of Mina Lake.

Sediment Analysis

The AGNPS model calculated that the sediment delivered from the sub-watershed is 3.7 kg/acre/year. As a result, 21,119 kg or 23 tons of sediment (lowest amount in the Mina system) would be generated annually from this sub-watershed. In summary, the Rosette sub-watershed was estimated to contribute 1 percent of the west tributary sediment load, and contributed 0.2 percent of the total sediment load to Mina Lake. The Rosette sub-watershed contains 2 percent of the critical erosion cells within 4 percent (smallest over all) of the watershed surface area. Based on the export coefficient, the sub-watershed is ranked eighth of eight on a list of priorities for sediment improvements.

The high sediment yield within the sub-watershed critical cells can be attributed to land use, land slope, and proximity to surface water conduits. Common critical cell characteristics for the Mina Lake system include croplands with a slope greater than 2 percent that are closer than 152 meters (500 feet) to a stream.

Total Nutrient Analysis

The AGNPS data indicates that the Rosette subwatershed had a total nitrogen (soluble + sediment-bound) transport rate of 0.32 kg/acre/year (equivalent to 1,829 kg or 4,032 lbs). Ninety-three percent (highest percentage in the Mina Lake system) of the transported nitrogen from this sub-watershed was estimated to be in dissolved form while 77 percent of the total nitrogen load to Mina Lake was estimated to be in dissolved form. The total nitrogen load delivered from the sub-watersheds to Mina Lake was estimated to be 211,203 kg or 233 tons/year. As a result, the Rosette load to Mina Lake is 1 percent of the total nitrogen. Based on the transport coefficients for nitrogen, Rosette was rated eighth of eight for nitrogen reduction priority.

This sub-watershed also had the eighth-highest total phosphorus (soluble + sediment bound) transport rate of 0.05 kg/acre/year (equivalent to 261 kg or 0.3 tons). Ninety percent (highest over all) of the transported phosphorus from this sub-watershed was estimated to be in dissolved form while 56 percent of the total phosphorus to Mina Lake was estimated to be in dissolved form. The total phosphorus load delivered from the sub-watersheds to Mina Lake was estimated to be 53,300 kg/year or 59 tons/year. As a result, the total phosphorus load from the Rosette sub-watershed load to Mina Lake was less than 1 percent. Based on the transport coefficients for phosphorus, Rosette was rated eighth of eight for phosphorus reduction priority.

Dissolved nitrogen and phosphorus nutrient levels from the Rosette sub-watershed were estimated to be 93 and 90 percent, respectively.

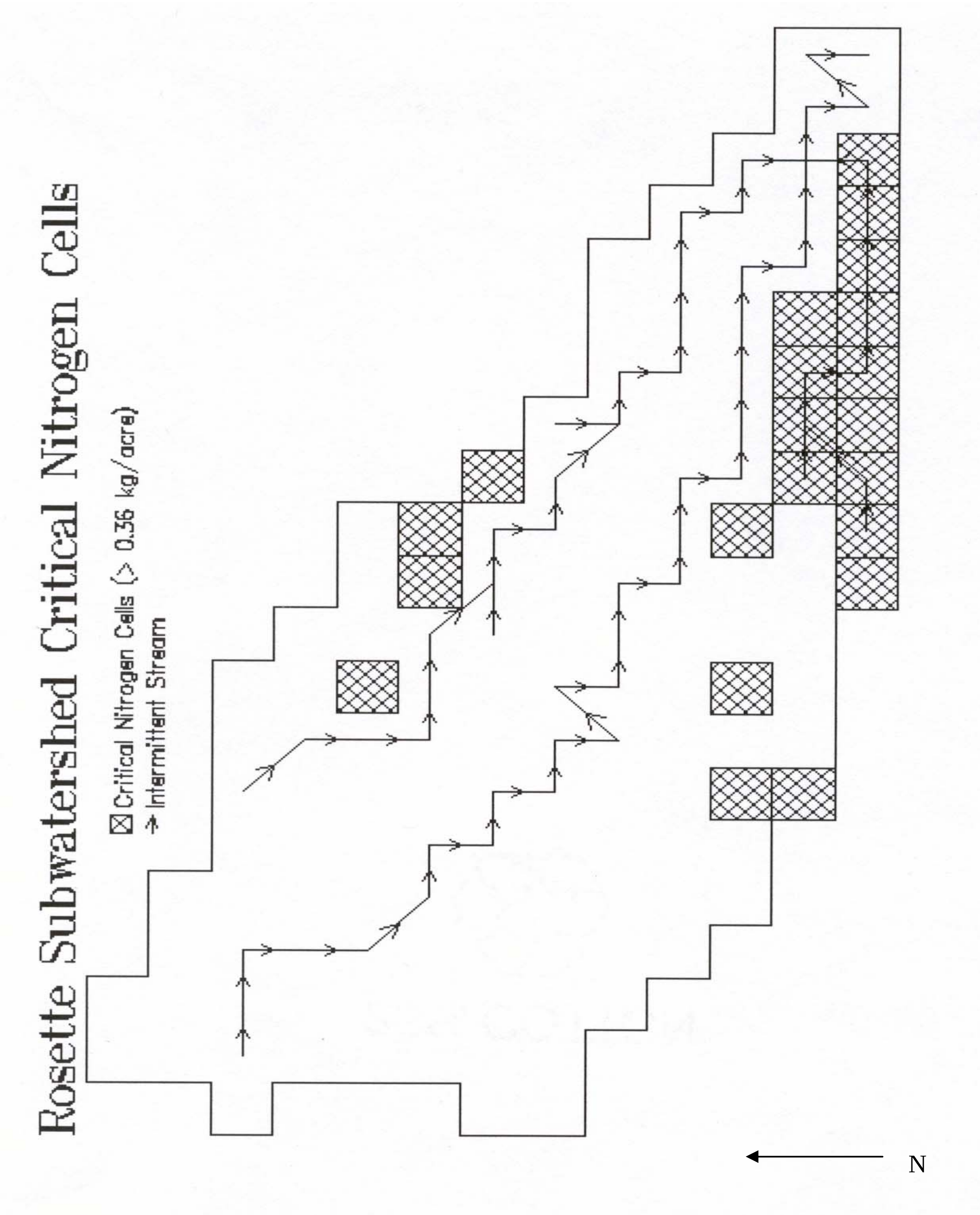


Figure C-88. Critical nitrogen cells for the Rosette sub-watershed of Mina Lake.

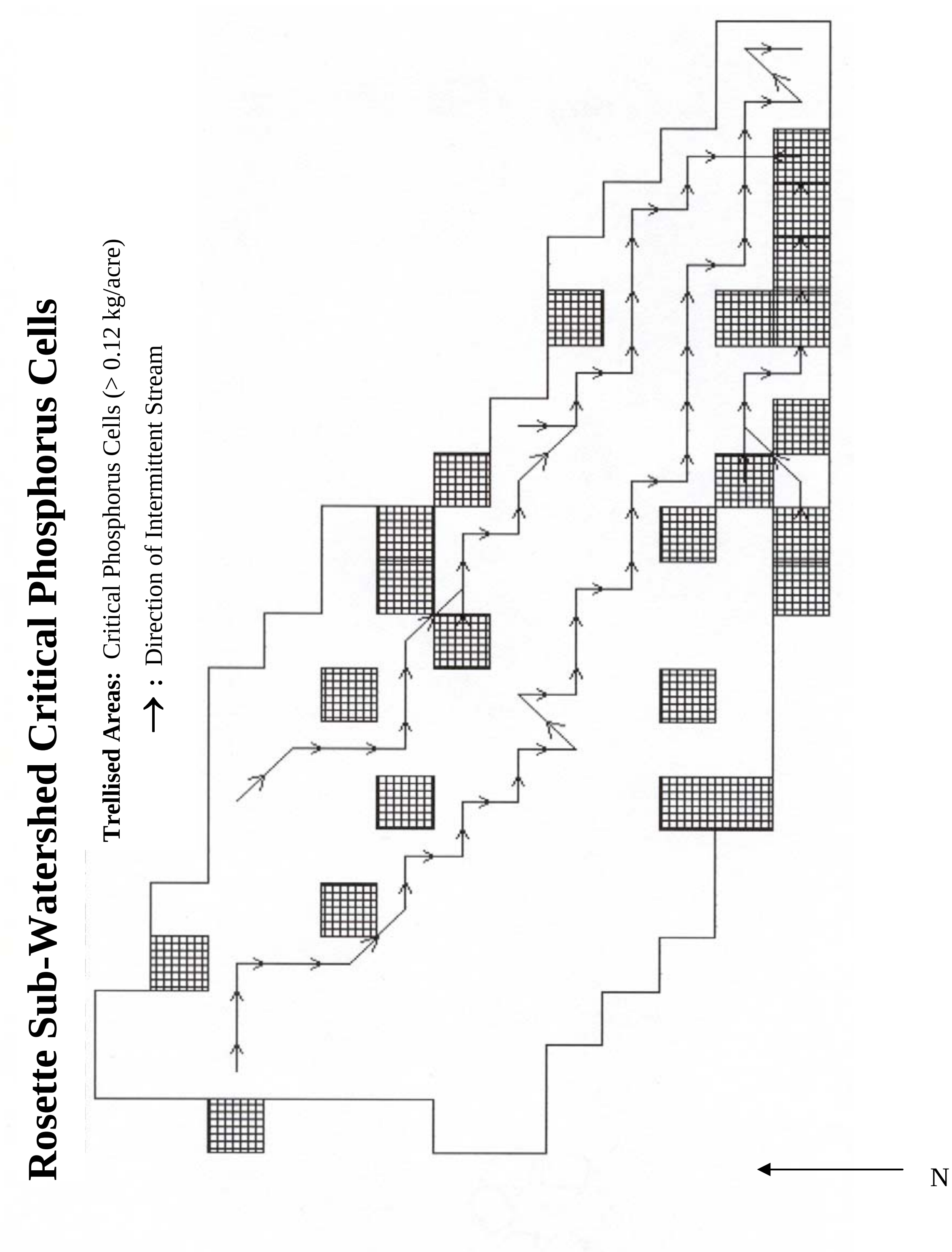


Figure C-89. Critical phosphorus cells for the Rosette sub-watershed of Mina Lake.

Priority Ranking of Animal Feeding Areas for Rosette Sub-watershed (25-Year Event)

Two animal feeding areas were identified during the AGNPS data acquisition phase of the project. Table C-46 lists the AGNPS analysis of each feeding area. Of these, one had an AGNPS ranking greater than 40. AGNPS ranks feeding areas from zero to 100 with a zero ranked feeding area having a smaller pollution potential and a 100 ranking having a large pollution potential. AGNPS estimates the total impact of having a feeding area or multiple feeding areas within a cell by combining and recalculating all values to arrive at nutrient and COD values to the cell. Critical feeding area locations are depicted in Figure C-20.

In order to determine the impact of the feeding areas, AGNPS outputs from nutrient and feeding area critical cell data were analyzed (Table C-44). A reduction efficiency coefficient was determined by calculating a ratio of the difference (per acre) between the overall amount of nutrients generated per cell (acres multiplied by transport coefficient) and feedlot-generated nutrient loads. The results were then used to estimate the cell capacity, or lack of capacity, to reduce nutrient levels under current conditions. Topographical gradient, size, location of buffering zones and proximity to surface conduits were possible influences on nutrient reduction and diffusion.

Reduction efficiency coefficients range from positive to negative values and were interpreted using a sliding scale with values and ratings based on Table C-45. All feeding areas, critical or not, were analyzed for reduction potential to determine trends and ratings. These values may be used to estimate the sensitivity or resistance potential of the cell to perturbations within the feeding area(s) (increasing the number of animal units/area) or within the cell (changes in landscape/landuse, buffer reduction, tillage practices, etc.) based on current conditions. BMP improvements in the feeding areas or the cell with favorable/marginally favorable ratings should respond/improve more rapidly than the cell with a neutral to unfavorable rating. Another use for this rating may be to prioritize/rank all critical feeding areas (feeding areas needing BMPs) within a watershed by reduction efficiency (improvement potential) to target/select feeding areas to realize maximum nutrient reduction in the watershed when implementation funds are limited.

Table C-100. Critical Cell (CC) reduction efficiency ratio for the Rosette sub-watershed

Cell Number and Parameter	Feedlot Mass Generated (kg)	Transport Coefficient from (CC) Load Data **	Total Mass Transported (kg)	Difference (kg)	Reduction Efficiency Coefficient (kg/acre)	Rating (Table C- 45)
#115 Nitrogen	**9.55**	**0.24**	**9.60**	**-0.05**	**0.00**	**N**
#115 Phosphorus	**3.24**	**0.07**	**2.80**	**0.44**	**0.01**	**N**
#128 Nitrogen *	**189**	**5.02**	**201**	**-11.8**	**-0.30**	**MU**
#128 Phosphorus *	**128**	**1.32**	**52.8**	**75.2**	**1.88**	**MF**
Average					0.40	N

Shaded area indicates critical nutrient cell

* = Indicates critical feedlot cell

** = Indicates threshold values for the Rosette sub-watershed (nitrogen yields > 0.82 kg/acre or phosphorus yields > 0.26 kg/acre)

Table C-101. Nutrient reduction efficiency rating scale for Mina Lake.

Rating	Criteria
Favorable (F)	**Greater than 2.0 kg/acre**
Marginally Favorable (MF)	**Between 0.1 and 2.0 kg/acre**
Neutral (N)	**Between -0.1 and 0.1 kg/acre**
Marginally Unfavorable (MU)	**Between –2 and –0.1 kg/acre**
Unfavorable (U)	**Less than –2.0 kg/acre**

Cell #128 exceeded critical nutrient threshold limits, and the reduction ratings were mixed. The cell data may indicate development of a decreased buffering capacity to the higher-than-average topographical relief (40 feet) of the cell and close proximity to an intermittent stream. As a result, both the feeding area and cell nutrient levels exceeded the cell buffering capacity. Cell #115's nutrient levels are cell-supportable; however, cell output would be sensitive to elevated (increased) nutrient concentrations. The average cell efficiency ratios were shown to be neutral for nutrient reduction.

The animal feeding areas rated above 40 should be monitored for animal density or use-intensity. If use intensifies without modification of current conditions, the potential for sediment and nutrient yield will increase, especially in unfavorable to marginally unfavorable cells. Positive steps should be taken to identify and modify existing conditions within critical feeding areas. Careful study of feeding area size, animal density/intensity of use, and buffering capacity may be needed to reduce the AGNPS feedlot ratings and increase the reduction efficiencies (ratings).

Improvements in feeding areas and cells with favorable to marginally favorable rating would be expected to show marked improvement. Sources of nutrient loads not modeled by this study were those from septic systems and livestock with direct access to the lake or adjacent streams.

Table C-102. AGNPS feedlot ratings and data for the Rosette sub-watershed of Mina Lake.

Feedlot Analysis			
Cell # 115		Cell # 128	
Nitrogen concentration (ppm)	**95.1**	**Nitrogen concentration (ppm)**	**84.5**
Phosphorus concentration (ppm)	**32.2**	**Phosphorus concentration (ppm)**	**21.9**
COD concentration (ppm)	**1,451**	**COD concentration (ppm)**	**1,545**
Nitrogen mass (kg)	**9.55**	**Nitrogen mass (kg)**	**189**
Phosphorus mass (kg)	**3.24**	**Phosphorus mass (kg)**	**49.2**
COD mass (kg)	**146**	**COD mass (kg)**	**3,460**
Animal feedlot rating number	13	**Animal feedlot rating number**	58

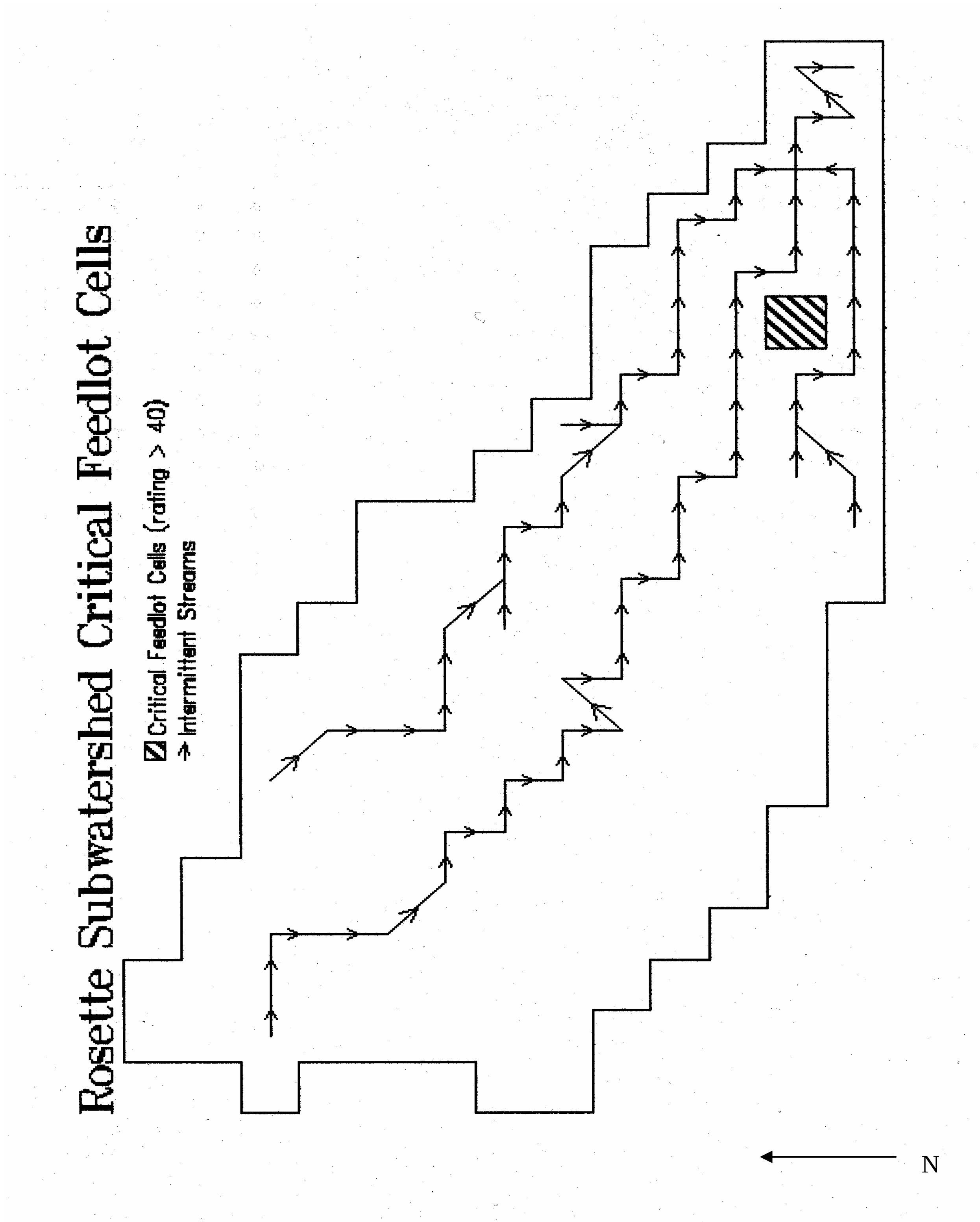


Figure C-90. Critical Feedlot Cells for the Rosette sub-watershed of Mina Lake.

Modeled Sediment, Nitrogen and Phosphorus Reductions (Rosette Sub-watershed)

Several Best Management Practices (BMP) were modeled using the AGNPS computer model. These included installation of Animal Waste Management Systems (AWMS), grassed waterways, reduction of fertilizer application levels, and conversion of conventional tillage practices to minimum or no-till methods.

Two feeding areas within the Rosette sub-watershed were identified. The AGNPS assessment of field feedlot data rated Cell #128 critical for feeding area and overall nutrient levels (rated above 40, based on objective criteria). Efforts to improve feeding areas would reduce total nitrogen from 1,829 kg/year or 2.0 tons to 1,601 kg/year or 1.8 tons (12 percent reduction) and from 261 kg/year or 575.4 lbs to 218 kg/year or 480.6 lbs (16 percent) for total phosphorus.

AGNPS compared fertilizer application rates using the current rate of application (approx. 45.4 kg or 100 lbs/acre nitrogen and 18.1 kg or 40 lbs/acre phosphorus) to a reduced rate (22.7 kg/acre or 50 lbs/acre nitrogen and 9.1 kg/acre or 20 lbs/acre phosphorus). The AGNPS sub-watershed model indicated a reduction in a total nitrogen load of 1,829 kg/year or 2.0 tons to 1,542 kg/year or 1.7 tons(15 percent). Total phosphorus reduction was estimated to fall from 261 kg/year or 575.4 lbs to 218 kg/year or 480.6 lbs (16 percent).

The model estimated that modifying tilled acreage within critical erosion cells to conservation tillage practices would reduce the sediment load delivered by Snake Creek from 21,119 kg/year to 17,964 kg/year (14 percent). The AGNPS sub-watershed model indicated a reduction in a total nitrogen load of 1,829 kg/year or 2.0 tons to 1,542 kg/year or 1.7 tons (15 percent). Total phosphorus reduction was estimated to fall from 261 kg/year or 575.4 lbs to 218 kg/year or 480.6 lbs (16 percent). Based on AGNPS reduction estimates, conversion from conventional to minimum/no tillage will have the greatest impact on the watershed.

BMP recommendations should be implemented within sub-watershed priority critical cells (Table C-47). Field data for priority critical cells should be field verified prior to BMP planning and implementation. The AGNPS model did not simulate grass waterways, gully and streambank erosion; however, these BMPs should also be evaluated.

Table C-103. AGNPS modeling reductions for Rosette sub-watershed BMPs[1].

		Percent Reduction		
BMP	Unit	Sediments	Nitrogen	Phosphorus
Feedlot	**Rosette**	**0**	**12**	**16**
Fertilizer	**Rosette**	**0**	**15**	**16**
Minimum Till	**Rosette**	**14**	**15**	**16**
Sub-watershed Total		**14**	**42**	**48**

[1] = Reductions calculated 1999-2000 field data

West Crompton Sub-watershed AGNPS Analysis (Sub-watershed of Mina Lake)

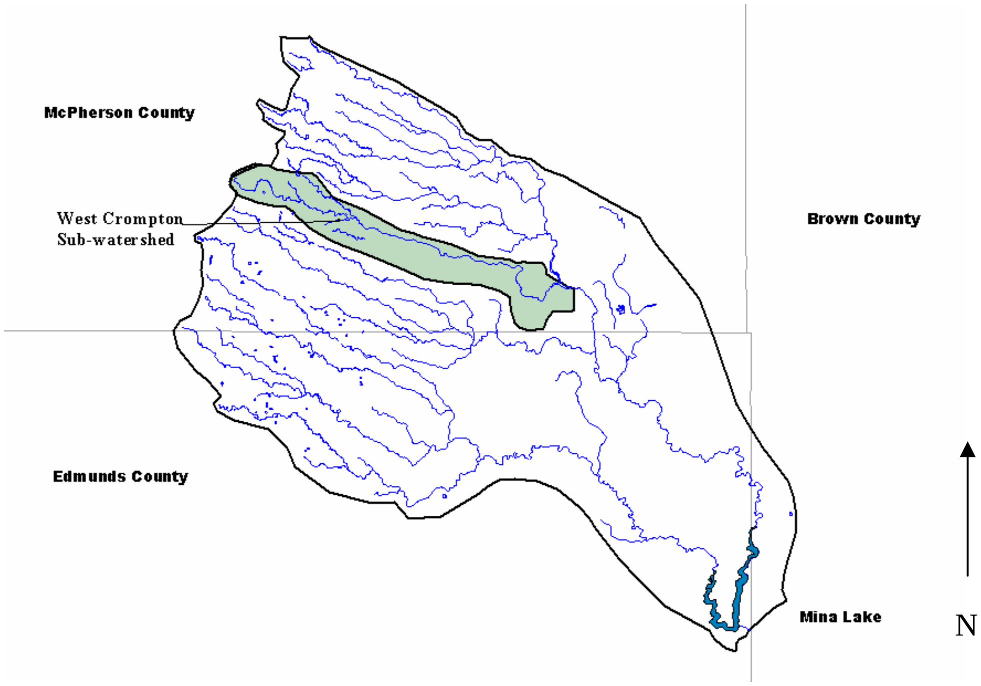


Figure C-91. The West Crompton Sub-watershed within the Mina Lake watershed.

The West Crompton sub-watershed is located in McPherson County, in northeastern South Dakota, and is the central drainage for the eastern tributary of the Mina Lake watershed. The basin of the West Crompton sub-watershed contributes 5 percent of total hydrologic input and encompasses an approximate area of 4,613 hectares (11,400 acres). The West Crompton sub-watershed is a shallow basin that drops 119 meters or 391 feet over 22 kilometers or 13.7 miles (0.5 percent grade). West Crompton, along with the North Crompton sub-watershed, drains into Crompton Lake (an impoundment on Snake Creek). Crompton Lake then discharges into the Snake Creek tributary, which flows through the East Mina and AGNPS Ungauged watersheds for approximately 24 kilometers (15 miles) before entering Mina Lake (Figure C-21).

The West Crompton watershed is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. Five monitoring sites were set up at various locations along Snake Creek to collect water quantity samples and measure selected water quality parameters within the creek. No water quality monitoring sites were located within the West Crompton sub-watershed.

Due to the lack of site-specific water quality data with each sub-watershed, a computer model was selected to assess the Non-point Source (NPS) loads throughout the Mina Lake watershed. Data was used to model current loading to Snake Creek and was used for comparisons with other sub-watersheds in the Mina Lake drainage.

Cropping practices, including tillage and fertilizer use, and range management directly influence the intensity of sediment and nutrient runoff. Nearly 100 acres, not quite 1 percent of the West Crompton sub-watershed, is used for cropland; the remaining acreage may be used as rangeland. Tillage, fertilizer, and feedlot Best Management Practices (BMPs) were modeled and analyzed to estimate the runoff reduction potential within the sub-watershed.

Evaluation/Quantification of Sub-watershed Non-Point Source Loading

Delineation and Location of Sub-watershed

The following AGNPS outlet cell numbers correlate to AGNPS sub-watershed and water quality monitoring sites used in the Mina Lake watershed assessment study during 1999 and 2000 (Table C-48):

Table C-104. AGNPS outlet cell number for the West Crompton sub-watershed of Mina Lake.

Sub-watershed	AGNPS outlet cell number
West Crompton	**249**

The following tables estimate the delivery coefficients, annual loading and critical values for priority cells for sediment (Table C-49), nitrogen (Table C-50), and phosphorus (Table C-51) in the West Crompton sub-watershed:

Table C-105. Export coefficients (kg/acre) for the West Crompton sub-watershed of Mina Lake♣.

				Export Coefficients					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area acres	Percent of Watershed	Sediment kg/acre	Attached-N kg/acre	Dissolved-N kg/acre	Total Nitrogen kg/acre	Attached-P kg/acre	Dissolved-P kg/acre	Total Phosphorus kg/acre
West Crompton	**11,400**	**7**	**108**	**0.51**	**0.65**	**1.16**	**0.26**	**0.11**	**0.38**

Table C-106. Annualized loading (kg) for the West Crompton sub-watershed of Mina Lake♣.

				Sub-watershed Loading					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area acres	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
West Crompton	**11,400**	**7**	**1,227,938**	**5,791**	**7,446**	**13,238**	**2,999**	**1,293**	**4,292**

Table C-107. Priority cell threshold values for the West Crompton sub-watershed of Mina Lake♣.

	Critical Values (kg/acre)		
Parameter	Priority-1	Priority-2	Priority-3
Sediment	**2,381**	**1,792**	**1,203**
Nitrogen	**2.69**	**2.05**	**1.40**
Phosphorus	**1.02**	**0.77**	**0.52**

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulative rainfall events during an average year. This includes a 1-year, 24-hour event of 1.85 inches (EI = 17.5), 3 semiannual rainfall events of 1.23 inches (EI = 7.4) and a series of 10 small rainfall events of 0.8 inch (EI = 3.0) for a total "R" factor of 69.7.

Identification of Critical Non-Point Source Cells for West Crompton Sub-watershed (25-Year Event)

Priority 1, 2, and 3 critical cell thresholds were established based upon 1, 2 and 3 standard deviations of the mean using NPS cell yield data, event rainfall amount of 4.1 inches, and Event Intensity (EI) of 104.0, as follows:

Sediment erosion rate > 1,203 kg/acre or 1.33 ton/acre
Total nitrogen cell yields > 1.40 kg/acre or 3.09 lbs/acre
Total phosphorus cell yields > 0.52 kg/acre or 1.15 lbs/acre

The yields for each of these cells are listed in Tables C-52 and Table C-53 and their general locations in the sub-watershed are documented for sediment (Figure C-22), nitrogen (Figure C-23), and phosphorus (Figure C-24). Priority 1 and 2 critical cells should be given high priority during BMP planning and implementation.

Analysis of the Mina Lake watershed data indicates that 37 of 285 West Crompton cells, or 13 percent, have a sediment yield greater than 1,203 kg/acre (1.33 tons/acre). This is approximately 0.9 percent of the cells found within the entire watershed. The AGNPS model predicted that 1,011,177 kilograms (1,115 tons) of sediment would be generated during a single 25-year event from this sub-watershed.

The model estimated 28 cells, or 9.8 percent, have a total nitrogen yield greater than 1.40 kg/acre (3.09 lbs/acre). The AGNPS model predicted that 0.63 kilograms of nitrogen would be generated per acre, for a total of 7,136 kg (7.87 tons) of nitrogen, during a single 25-year event.

The model also estimated 24 cells, or 8.4 percent, have a total phosphorus yield greater than 0.52 kg/acre (1.15 lbs/acre). The AGNPS model predicted that 0.186 kilograms of phosphorus would be generated per acre, for a total of 2,120 kg (4,674 lbs) of phosphorus, during a single 25-year event. A correlation between dissolved and sediment-bound nutrients was not determined.

Table C-108. West Crompton priority-1 and 2 critical cells for sediment, nitrogen and phosphorus.

West Crompton Priority-1 & 2 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
248	**3,547**	**1,016,239**	258	**3.24**	**2.73**	**5.96**	258	**1.62**	**0.60**	**2.22**
77	**3,338**	**80,105**	274	**3.30**	**1.32**	**4.62**	274	**1.65**	**0.27**	**1.92**
274	**3,239**	**86,165**	177	**1.56**	**2.73**	**4.29**	77	**1.56**	**0.15**	**1.71**
258	**3,121**	**84,241**	77	**3.11**	**0.81**	**3.92**	177	**0.78**	**0.60**	**1.38**
120	**2,876**	**196,841**	121	**1.76**	**1.12**	**2.88**	121	**0.88**	**0.23**	**1.10**
257	**2,395**	**948,000**	65	**1.22**	**1.19**	**2.41**	67	**1.05**	**0.01**	**1.06**
140	**2,377**	**607,542**	176	**0.92**	**1.46**	**2.38**	267	**0.76**	**0.14**	**0.90**
67	**2,341**	**48,906**	5	**1.31**	**0.98**	**2.30**	180	**0.88**	**0.01**	**0.88**
157	**2,186**	**794,604**	267	**1.52**	**0.75**	**2.27**	65	**0.61**	**0.24**	**0.85**
148	**2,150**	**695,168**	67	**2.10**	**0.17**	**2.27**	5	**0.65**	**0.20**	**0.85**
95	**2,050**	**364,861**	164	**1.26**	**0.98**	**2.24**	164	**0.63**	**0.20**	**0.83**
184	**2,023**	**835,627**								
149	**2,005**	**723,481**								
53	**1,823**	**133,592**								
Critical Acres			Critical Acres				Critical Acres			
Priority 1		240	Priority 1			200	Priority 1			240
Priority 2		320	Priority 2			240	Priority 2			200

Shaded areas are Priority-1 cells

Table C-109. West Crompton priority-3 critical cells for sediment, nitrogen and phosphorus.

West Crompton Priority-3 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
168	**1,678**	**84,513**	168	**0.89**	**1.04**	**1.93**	176	**0.46**	**0.30**	**0.76**
109	**1,669**	**140,088**	180	**1.76**	**0.17**	**1.93**	268	**0.57**	**0.11**	**0.68**
110	**1,669**	**153,859**	171	**0.88**	**1.03**	**1.91**	168	**0.45**	**0.21**	**0.66**
141	**1,633**	**634,758**	167	**0.85**	**1.05**	**1.90**	165	**0.46**	**0.20**	**0.65**
93	**1,606**	**299,108**	165	**0.91**	**0.98**	**1.90**	171	**0.44**	**0.21**	**0.65**
121	**1,533**	**39,181**	166	**0.85**	**1.03**	**1.88**	167	**0.43**	**0.21**	**0.64**
180	**1,533**	**39,181**	217	**0.51**	**1.36**	**1.87**	166	**0.43**	**0.20**	**0.63**
176	**1,424**	**34,736**	191	**0.33**	**1.47**	**1.80**	6	**0.60**	**0.01**	**0.61**
66	**1,406**	**77,038**	218	**0.61**	**1.16**	**1.77**	217	**0.25**	**0.34**	**0.59**
167	**1,388**	**63,186**	268	**1.13**	**0.63**	**1.76**	218	**0.31**	**0.28**	**0.59**
41	**1,370**	**238,118**	181	**0.98**	**0.51**	**1.49**	181	**0.49**	**0.09**	**0.57**
218	**1,352**	**63,068**	219	**0.46**	**1.02**	**1.48**	182	**0.41**	**0.11**	**0.53**
171	**1,343**	**49,360**	182	**0.83**	**0.63**	**1.46**	101	**0.51**	**0.01**	**0.52**
177	**1,343**	**33,892**	216	**0.54**	**0.91**	**1.45**				
170	**1,334**	**774,555**	200	**0.59**	**0.84**	**1.43**				
47	**1,297**	**57,543**	214	**0.70**	**0.70**	**1.41**				
16	**1,288**	**58,704**	215	**0.56**	**0.84**	**1.41**				
46	**1,288**	**62,433**								
64	**1,288**	**46,457**								
39	**1,270**	**80,150**								
200	**1,270**	**49,605**								
166	**1,243**	**47,772**								
169	**1,243**	**785,142**								
Critical Acres			Critical Acres				Critical Acres			
Priority 3		920	Priority 3			680	Priority 3			520

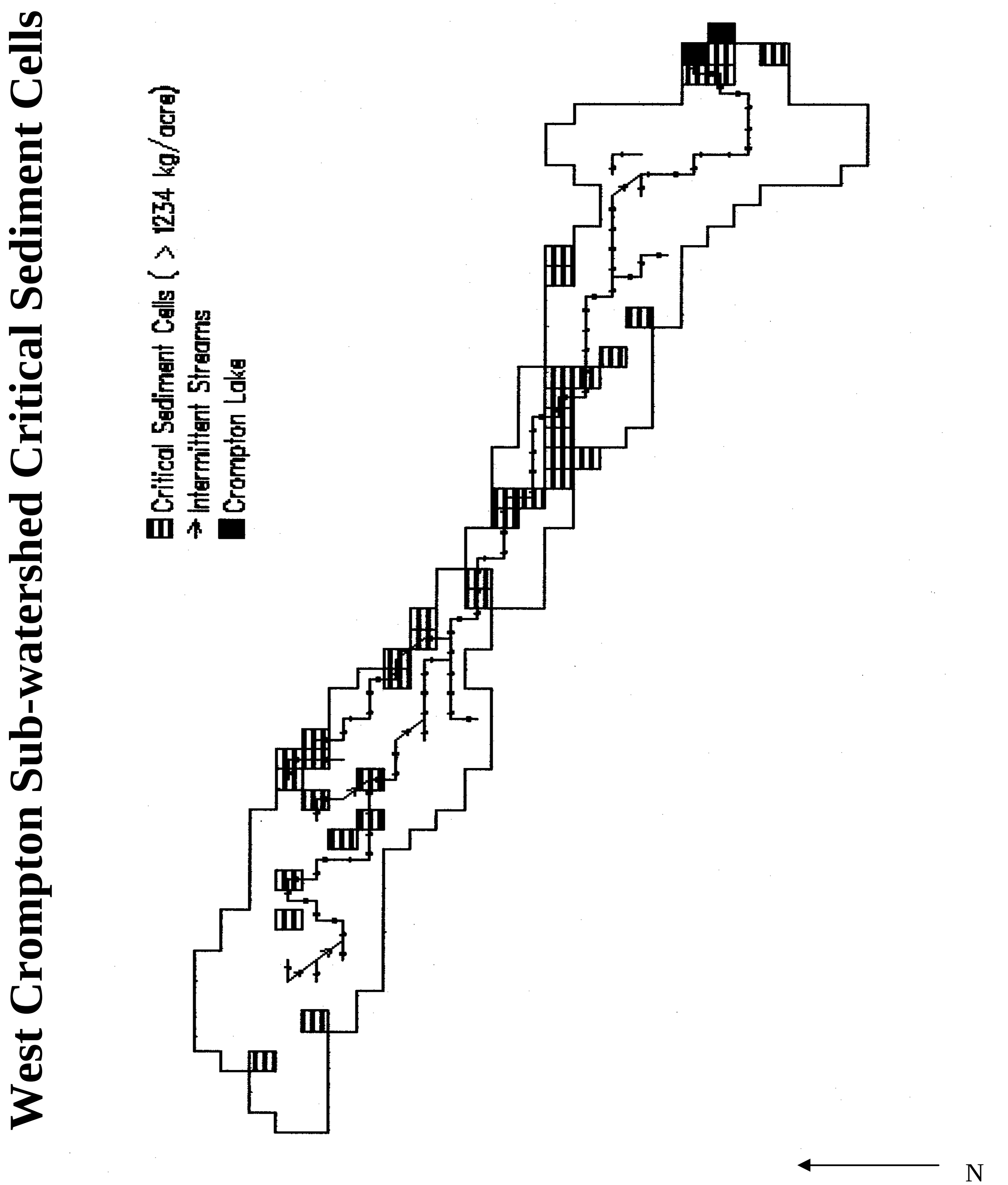


Figure C-92. Critical sediment cells for the West Crompton sub-watershed of Mina Lake.

Sediment Analysis

The AGNPS model calculated that the sediment delivered from the sub-watershed is 108 kg/acre/year for an estimated annual load. As a result, 1,227,938 kg or 1,354 tons of sediment would be generated annually from this sub-watershed. In summary, West Crompton was estimated to contribute 20 percent of the eastern tributary sediment load and 13 percent of the total sediment load to Mina Lake. West Crompton contains 8 percent of the critical erosion cells within 5 percent of the watershed surface area. Based on the export coefficients, the sub-watershed is ranked second of eight on a list of priorities for sediment improvements.

The high sediment yield within the sub-watershed critical cells can be attributed to land use, minimal buffer strips, land slope, and proximity to surface water conduits. Common critical cell characteristics for the Mina Lake system include croplands with a slope greater than 2 percent that are closer than 152 meters (500 feet) to a stream.

Total Nutrient Analysis

AGNPS data indicates that the West Crompton subwatershed had a total nitrogen (soluble + sediment-bound) transport rate of 1.16 kg/acre/year (equivalent to 13,238 kg or 15 tons). Fifty-six percent of the transported nitrogen from this sub-watershed was estimated to be in dissolved form while 77 percent of the total nitrogen was estimated to be in dissolved form. The total nitrogen load delivered from all sub-watersheds to Mina Lake was estimated to be 211,203 kg or 233 tons/year. As a result, the West Crompton load to Mina Lake was 6 percent of the total nitrogen. Based on the transport coefficients for nitrogen, West Crompton was rated fifth of eight for nitrogen reduction priority.

This sub-watershed tied sub-watershed Y for the fifth highest total phosphorus (soluble + sediment-bound) transport rate of 0.14 kg/acre/year (equivalent to 1,603 kg or 1.8 tons). Thirty percent (lowest for all sub-watersheds) of the phosphorus from this sub-watershed was estimated to be in dissolved form while 56 percent of the total phosphorus load to Mina Lake was estimated to be in dissolved form. The total phosphorus load delivered from all sub-watersheds to Mina Lake was estimated to be 53,300 kg/year (59 tons/year). As a result, the West Crompton load to Mina Lake was 8 percent of the total phosphorus (tied with AGNPS Ungauged sub-watershed). Based on the transport coefficients for phosphorus, West Crompton was rated fourth of eight for phosphorus reduction priority.

Dissolved nitrogen and phosphorus nutrient levels from West Crompton were estimated to be 56 percent and 30 percent, respectively.

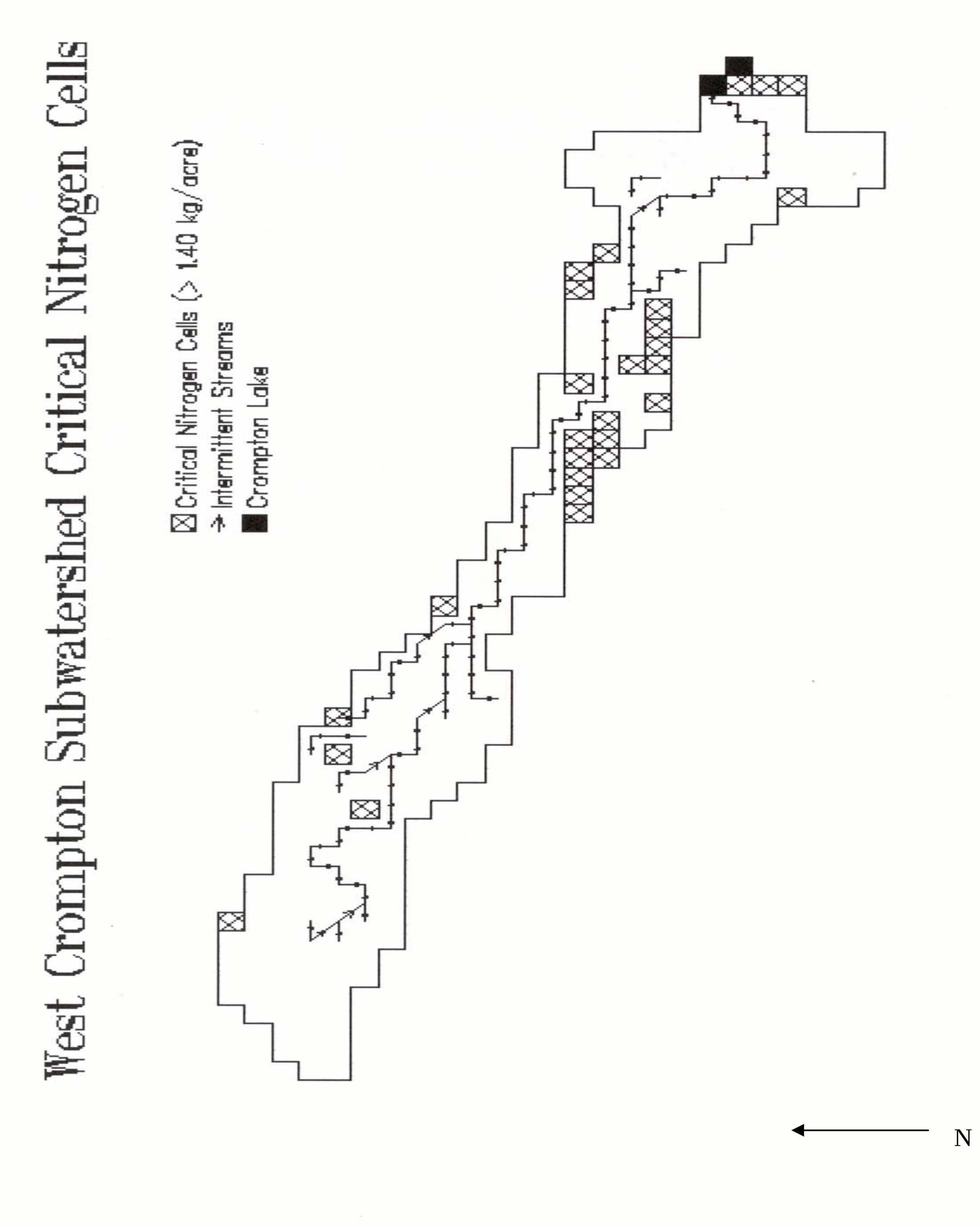


Figure C-93. Critical nitrogen cells for the West Crompton sub-watershed of Mina Lake.

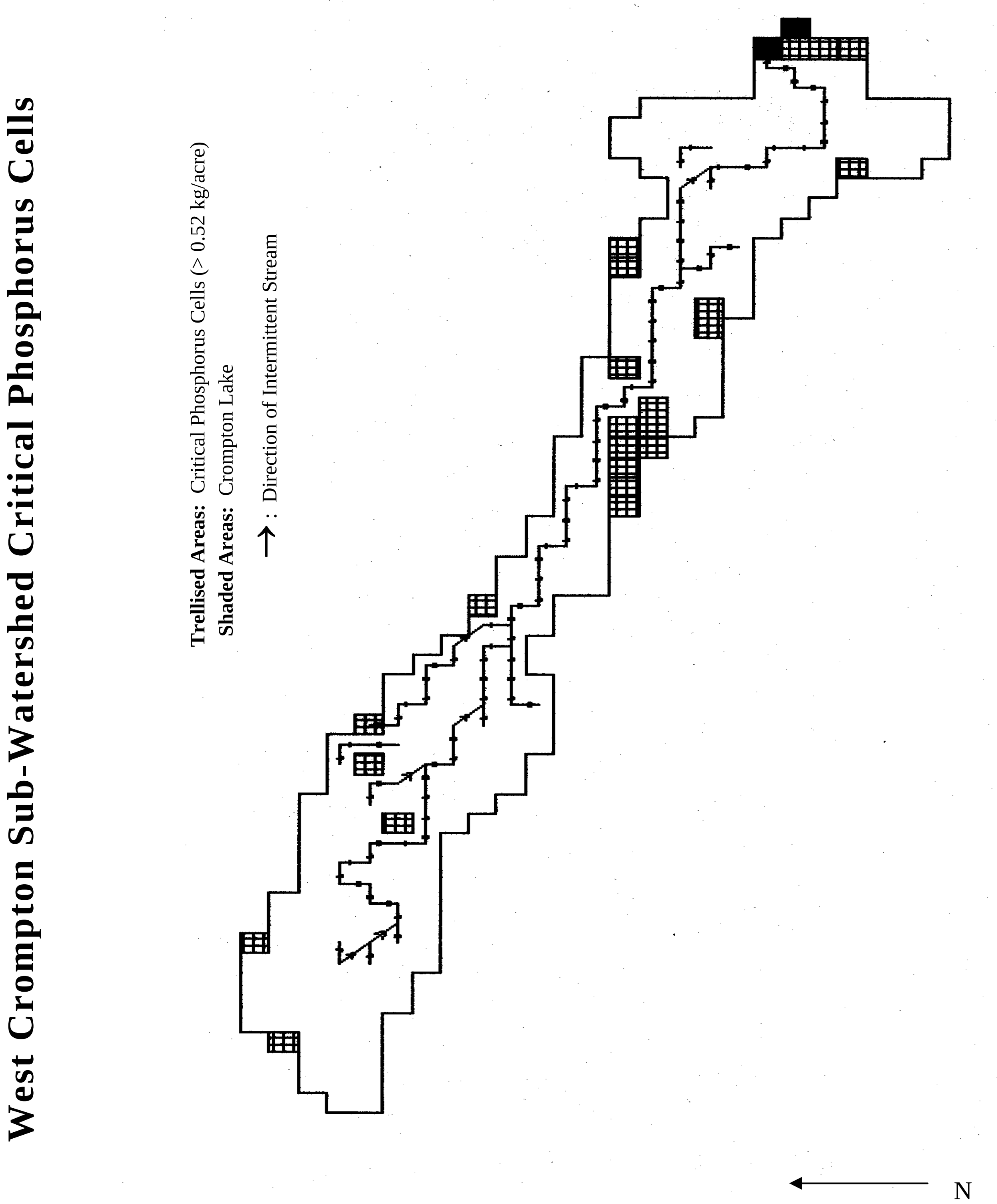


Figure C-94. Critical phosphorus cells for the West Crompton sub-watershed of Mina Lake.

Priority Ranking of Animal Feeding Areas in West Crompton Sub-watershed (25-Year Event)

A total of four animal feeding areas were identified during the AGNPS data acquisition phase of the project. Table C-56 lists the AGNPS analysis of each feeding area. Of these, two were found to have an AGNPS ranking greater than 40, and one had an AGNPS ranking of 62. AGNPS ranks feeding areas from zero to 100 with a zero ranked feeding area having a smaller pollution potential and a 100 ranking having a large pollution potential. AGNPS estimates the total impact of having a feeding area or multiple feeding areas within a cell by combining and recalculating all values to arrive at nutrient and COD values to the cell. Critical feeding area locations are depicted in Figure C-25.

In order to determine the impact of the feeding areas, AGNPS outputs from nutrient and feeding area critical cell data were analyzed (Table C-54). A reduction efficiency coefficient was determined by calculating a ratio of the difference (per acre) between the overall amount of nutrients generated per cell (acres multiplied by transport coefficient) and feedlot-generated nutrient loads. The results were then used to estimate the cell capacity, or lack of capacity, to reduce nutrient levels under current conditions. Topographical gradient, size, location of buffering zones and proximity to surface conduits were possible influences on nutrient reduction and diffusion.

Table C-110. Critical Cell (CC) reduction efficiency ratio for the West Crompton sub-watershed.

Cell Number and Parameter	Feedlot Mass Generated (kg)	Transport Coefficient from (CC) Load Data **	Total Mass Transported (kg)	Difference (kg)	Reduction Efficiency Coefficient (kg/acre)	Rating (Table C- 55)
#99 Nitrogen *	**123**	**0.75**	**30.0**	**93.0**	**2.33**	**F**
#99 Phosphorus *	**39.8**	**0.25**	**10.0**	**29.8**	**0.75**	**MF**
#217 Nitrogen	**81.0**	**1.87**	**74.8**	**6.20**	**0.16**	**MF**
#217 Phosphorus	**29.4**	**0.59**	**23.6**	**5.80**	**0.15**	**MF**
#264 Nitrogen	**10.1**	**0.58**	**23.2**	**-13.1**	**-0.33**	**MU**
#264 Phosphorus	**1.95**	**0.17**	**6.80**	**-4.85**	**-0.12**	**MU**
Average					0.49	MF

Shaded area indicates critical nutrient cells

* = Indicates critical feedlot cell

** = Indicates threshold values for the West Crompton sub-watershed (nitrogen yields > 1.40 kg/acre or phosphorus yields > 0.52 kg/acre)

Table C-111. Nutrient reduction efficiency rating scale for Mina Lake.

Rating	Criteria
Favorable (F)	**Greater than 2.0 kg/acre**
Marginally Favorable (MF)	**Between 0.1 and 2.0 kg/acre**
Neutral (N)	**Between -0.1 and 0.1 kg/acre**
Marginally Unfavorable (MU)	**Between –2 and –0.1 kg/acre**
Unfavorable (U)	**Less than –2.0 kg/acre**

Reduction efficiency coefficients range from positive to negative values and were interpreted using a sliding scale with values and ratings based on Table C-55. All feeding areas, critical or not, were analyzed for reduction potential to determine trends and ratings. These values may be used to estimate the sensitivity or resistance potential of the cell to perturbations within the feeding area(s) (increasing the number of animal units/area) or within the cell (changes in landscape/landuse, buffer reduction, tillage practices, etc.) based on current conditions. BMP improvements in the feeding areas or the cell with favorable/marginally favorable ratings should respond/improve more rapidly than the cell with a neutral to unfavorable rating. Another use for this rating may be to prioritize/rank all critical feeding areas (feeding areas needing BMPs) within a watershed by reduction efficiency (improvement potential) to target/select feeding areas to realize maximum nutrient reduction in the watershed when implementation funds are limited.

None of the West Crompton cells exceeded both overall nutrient and feeding area nutrient threshold values. Cell #217 exceeded overall nutrient output limits, but not feeding area nutrient limits. The AGNPS method used to develop feeding area critical values caused a highly rated feeding area to be ignored. Cell #99 exceeded the feeding area nutrient limits, but was not critical for overall nutrient output. The higher efficiency ratio of cell #99 may indicate that feeding area nutrients had a greater impact on nutrient output than the cell, but were well buffered and cell supportable. The sub-watershed, as a whole, was found to have a marginally favorable efficiency ratio; however, cell output would be sensitive to elevated (increased) nutrient concentrations.

The animal feeding areas rated above 40 should be monitored for animal density or use-intensity. If use intensifies without modification of current conditions, the potential for sediment and nutrient yield will increase, especially in unfavorable to marginally unfavorable cells. Positive steps should be taken to identify and modify existing conditions within critical feeding areas. Careful study of feeding area size, animal density/intensity of use, and buffering capacity may be needed to reduce the AGNPS feedlot ratings and increase the reduction efficiencies (ratings).

Improvements in feeding areas and cells with favorable to marginally favorable rating would be expected to show marked improvement. Sources of nutrient loads not modeled through this study were from septic systems and livestock with direct access to the lake or adjacent streams.

Table C-112. AGNPS feedlot ratings and data for the West Crompton sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 99		Cell # 264	
Nitrogen concentration (ppm)	**27.7**	**Nitrogen concentration (ppm)**	**0.24**
Phosphorus concentration (ppm)	**8.96**	**Phosphorus concentration (ppm)**	**0.05**
COD concentration (ppm)	**889**	**COD concentration (ppm)**	**2.96**
Nitrogen mass (kg)	**123**	**Nitrogen mass (kg)**	**10.1**
Phosphorus mass (kg)	**39.8**	**Phosphorus mass (kg)**	**1.95**
COD mass (kg)	**3949**	**COD mass (kg)**	**123**
Animal feedlot rating number	62	**Animal feedlot rating number**	4

Cell # 217	
Nitrogen concentration (ppm)	**25.03**
Phosphorus concentration (ppm)	**9.03**
COD concentration (ppm)	**892**
Nitrogen mass (kg)	**74.9**
Phosphorus mass (kg)	**27.0**
COD mass (kg)	**2,670**
Animal feedlot rating number	55

Cell # 217	
Nitrogen concentration (ppm)	**12.5**
Phosphorus concentration (ppm)	**4.89**
COD concentration (ppm)	**219**
Nitrogen mass (kg)	**6.05**
Phosphorus mass (kg)	**2.37**
COD mass (kg)	**106**
Animal feedlot rating number	9

Cell # 217 TOTAL	
Nitrogen concentration (ppm)	
Phosphorus concentration (ppm)	
COD concentration (ppm)	
Nitrogen mass (kg)	**81.0**
Phosphorus mass (kg)	**29.4**
COD mass (kg)	**2,776**

Animal feedlot rating number -

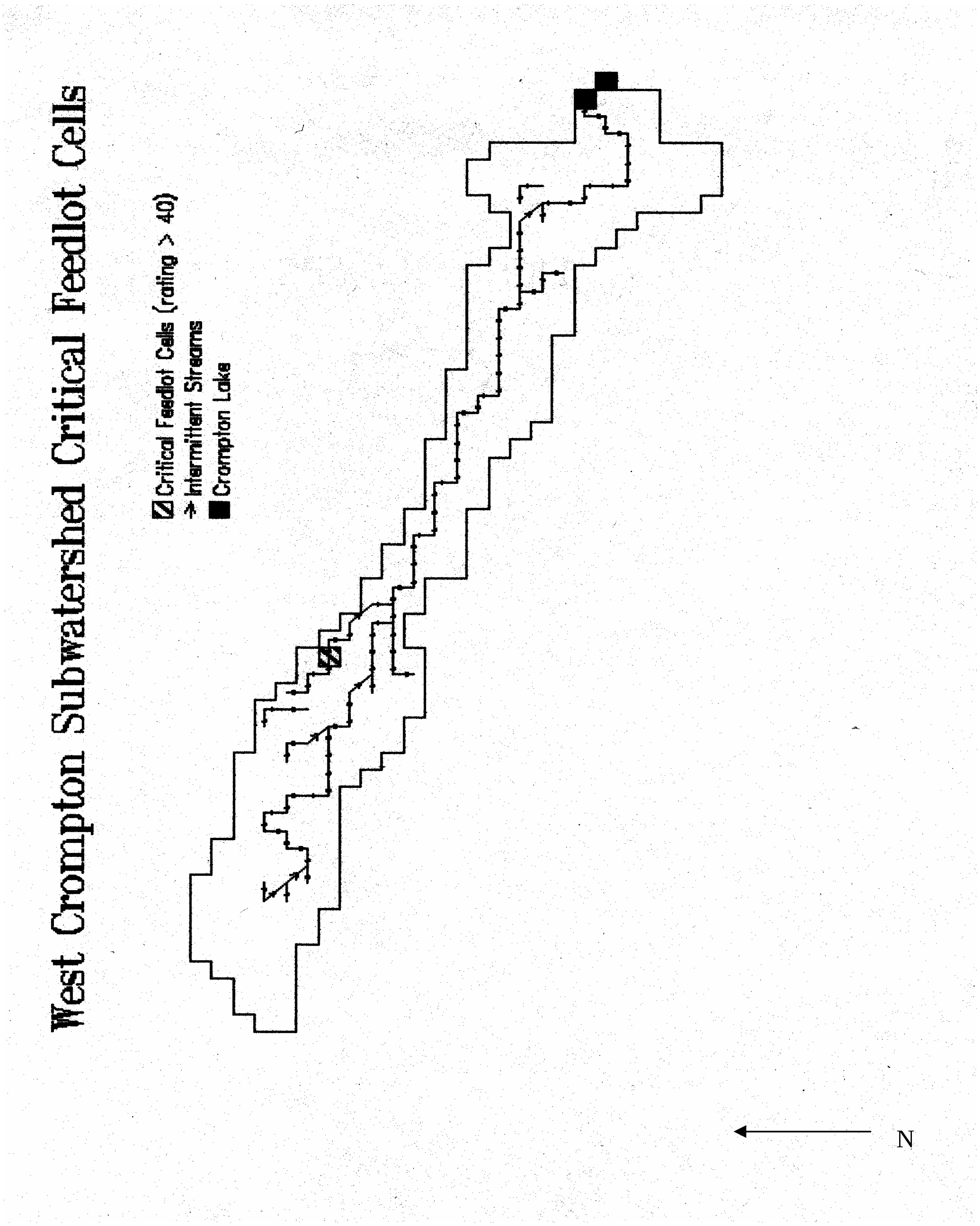


Figure C-95. Critical feedlot cells for the West Crompton sub-watershed of Mina Lake.

Modeled Sediment, Nitrogen and Phosphorus Reductions (West Crompton Sub-watershed)

Several Best Management Practices (BMP) were modeled using the AGNPS computer model. These included installation of Animal Waste Management Systems (AWMS), grassed waterways, reduction of crop ground fertilizer application levels, and conversion of conventional till practices to minimum or no-till methods.

Three feeding areas within the West Crompton sub-watershed were identified. The AGNPS assessment of field feedlot data rated one feeding area as critical (rated above 40, based on objective criteria). Efforts to improve feeding areas would reduce total nitrogen from 13,238 kg/year or 14.6 tons to 12,964 kg/year or 14.3 tons (2 percent reduction) and result in no reduction in total phosphorus loads.

AGNPS compared fertilizer application rates using the current rate of application (approx. 45.4 kg or 100 lbs/acre nitrogen and 18.1 kg or 40 lbs/acre phosphorus) to a reduced rate (22.7 kg/acre or 50 lbs/acre nitrogen and 9.1 kg/acre or 20 lbs/acre phosphorus). The sub-watershed model indicated a reduction in the total nitrogen load of 13,238 kg/year or 14.6 tons to 11,873 kg/year or 13.1 tons (10 percent) and reductions in total phosphorus loads from 4,292 kg/year or 4.7 tons to 4,034 kg/year or 4.4 tons (6 percent).

The model estimated that modifying tilled acreage within critical erosion cells to conservation tillage practices would reduce the sediment load delivered by Snake Creek from 1,227,938 kg/year or 1,353.6 tons to 1,170,338 kg/year or 1,290.1 tons (4 percent). The sub-watershed model indicated a reduction in the total nitrogen load of 13,238 kg/year or 14.6 tons to 12,008 kg/year or 13.2 tons (9 percent) and in the total phosphorus load from 4,292 kg/year or 4.7 tons to 4,034 kg/year or 4.4 tons (6 percent). Based on AGNPS reduction estimates, conversion from conventional to minimum/no tillage will have the greatest impact on the watershed.

BMP recommendations should be implemented within sub-watershed priority critical cells (Table C-57). Field data for priority critical cells should be field verified prior to BMP planning and implementation. The AGNPS model did not simulate grass waterways, gully and streambank erosion, however, these BMPs should also be evaluated.

Table C-113. AGNPS modeling reductions for West Crompton sub-watershed BMPs[1].

		Percent Reduction		
BMP	Unit	Sediments	Nitrogen	Phosphorus
Feedlot	**West Crompton**	**0**	**2**	**0**
Fertilizer	**West Crompton**	**0**	**10**	**6**
Minimum Till	**West Crompton**	**4**	**9**	**6**
Sub-watershed Total		**4**	**21**	**12**

[1] = Reductions calculated 1999-2000 field data

West Mina Sub-Watershed AGNPS Analysis (A Sub-watershed of Mina Lake)

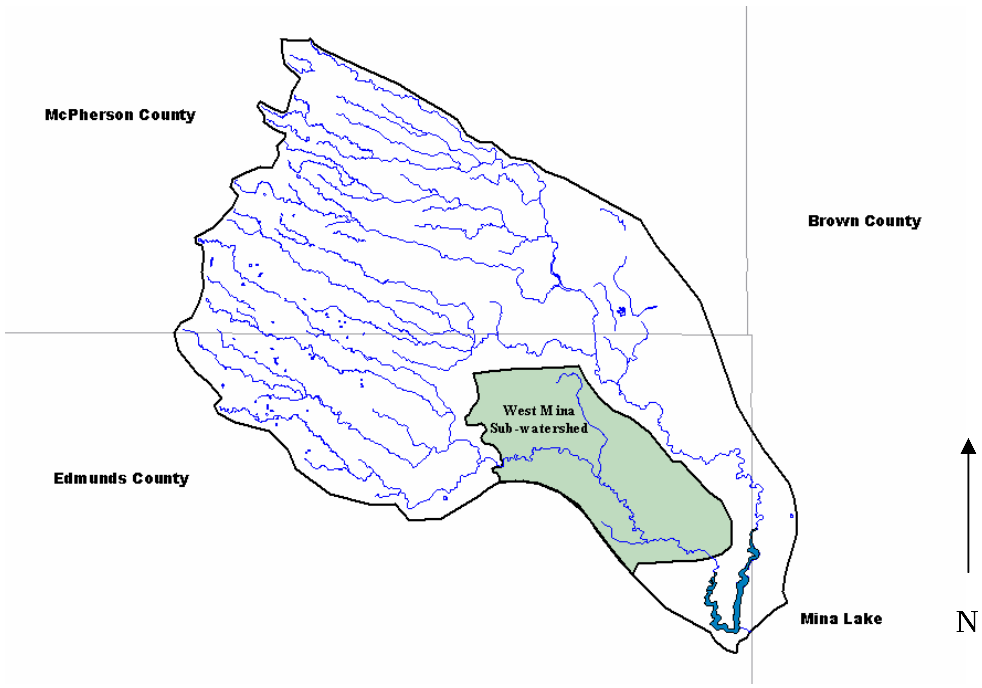


Figure C-96. The West Mina Sub-watershed within the Mina Lake watershed.

The West Mina sub-watershed is located within Edmunds County, in northeastern South Dakota, and is the main drainage for the western tributary of Snake Creek in the Mina Lake watershed. West Mina contributes 15 percent of total hydrologic input to the Mina system and encompasses an approximate area of 9,680 hectares (23,920 acres). The West Mina sub-watershed is a very shallow basin that drops 16.8 meters or 55 feet over 14.5 kilometers or 9 miles (0.1 percent grade) and serves as a discharge for the Rosette and Y sub-watersheds (Figure C-26).

The West Mina watershed is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. Five monitoring sites were set up at various locations along Snake Creek to collect water quantity samples and measure selected water quality parameters within the creek. Site SC-1 is located within the West Mina sub-watershed on an unnamed, intermittent stream (for this study, west tributary of Snake Creek), approximately 3 miles upstream from the western inlet to Mina Lake.

Due to the lack of site-specific water quality data, a computer model was selected to assess the Non-point Source (NPS) loads throughout the Mina Lake watershed. The West Mina watershed is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. The data was used to model current loading to Snake Creek and was used for comparisons to other sub-watersheds in the Mina Lake drainage.

Cropping practices, including tillage and fertilizer use, and range management directly influence the intensity of sediment and nutrient runoff. Over 1,600 acres, or 7 percent, of

the West Mina sub-watershed is used for cropland; the remaining acreage may be used as rangeland and pasture. Tillage, fertilizer, and feedlot Best Management Practices (BMPs) were modeled and analyzed to estimate the runoff reduction potential within the sub-watershed.

Evaluation/Quantification of Sub-watershed Non-Point Source Loading

Delineation and Location of Sub-watershed

The following AGNPS outlet cell numbers correlate to AGNPS sub-watershed and water quality monitoring sites used in the Mina Lake watershed assessment study during 1999 and 2000 (Table C-58):

Table C-114. AGNPS outlet cell number for the West Mina and Snake Creek 1 (SC-1) sub-watersheds of Mina Lake.

Sub-watershed/Site	AGNPS outlet cell number
West Mina	**605**
SC-1	**548**

The following tables estimate the delivery coefficients, annual loading and critical values for priority cells for sediment (Table C-59), nitrogen (Table C-60), and phosphorus (Table C-61) in the West Mina sub-watershed:

Table C-115. Export coefficients (kg/acre) for the West Mina and Snake Creek 1 (SC-1) sub-watersheds of Mina Lake♣.

				Export Coefficients					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area acres	Percent of Watershed	Sediment kg/acre	Attached-N kg/acre	Dissolved-N kg/acre	Total Nitrogen kg/acre	Attached-P kg/acre	Dissolved-P kg/acre	Total Phosphorus kg/acre
West Mina	**23,920**	**15**	**42.4**	**0.21**	**1.55**	**1.76**	**0.11**	**0.29**	**0.40**
Snake Creek 1 (SC-1)	**50,400**	**32**	**36.3**	**0.20**	**1.20**	**1.39**	**0.09**	**0.21**	**0.31**

Table C-116. Annualized loading (kg) for the West Mina and Snake Creek 1 (SC-1) sub-watersheds of Mina Lake♣.

				Sub-watershed Loading					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area acres	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
West Mina	**23,920**	**15**	**1,013,480**	**5,099**	**37,107**	**42,206**	**2,712**	**6,944**	**9,656**
Snake Creek 1 (SC-1)	**50,400**	**32**	**1,831,470**	**9,917**	**60,263**	**70,180**	**4,776**	**10,713**	**15,489**

Table C-117. Priority cell threshold values for the West Mina and Snake Creek 1 (SC-1) sub-watersheds of Mina Lake♣.

	Critical Values (kg/acre)		
Parameter	Priority-1	Priority-2	Priority-3
Sediment	**2,821**	**2,100**	**1,379**
Nitrogen	**4.34**	**3.28**	**2.23**
Phosphorus	**1.55**	**1.16**	**0.78**

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulative rainfall events during a average year. This includes a 1-year, 24-hour event of 1.85 inches (EI = 17.5), 3 semiannual rainfall events of 1.23 inches (EI = 7.4) and a series of 10 small rainfall events of 0.8 inch (EI = 3.0) for a total "R" factor of 69.7.

Identification of Critical Non-Point Source Cells for the West Mina Sub-watershed (25-Year Event)

Priority 1, 2, and 3 critical cell thresholds were established based upon 1, 2 and 3 standard deviations of the mean using NPS cell yield data, event rainfall amount of 4.1 inches, and Event Intensity (EI) of 104.0, as follows:

Sediment erosion rate >1,379 kg/acre or 1.52 ton/acre
Total nitrogen cell yields > 2.23 kg/acre or 4.92 lbs/acre
Total phosphorus cell yields > 0.78 kg/acre or 1.72 lbs/acre

The yields for each of these cells are listed in Table C-62 and Table C-63 and their general locations in the sub-watershed are documented for sediment (Figure C-27), nitrogen (Figure C-28), and phosphorus (Figure C-29). Priority 1 and 2 critical cells should be given high priority during BMP planning and implementation.

Analysis of the Mina Lake watershed data indicates that 79 of 736 West Mina cells, or 10.7 percent, have a sediment yield greater than 1,379 kg/acre (1.52 tons/acre). This is approximately 2 percent of the cells found within the Mina Lake watershed. The AGNPS model predicted that 2,273,063 kilograms (2,505.6 tons) of sediment would be generated during a single 25-year event from this sub-watershed.

The model estimated that 88 cells, or 12 percent, have a total nitrogen yield greater than 2.23 kg/acre (4.92 lbs/acre). The AGNPS model predicted that 0.93 kilograms of nitrogen would be generated per acre, for a total of 22,134 kg (24.4 tons) of nitrogen, during a single 25-year event.

The model also estimated that 82 cells, or 11 percent, have a total phosphorus yield greater than 0.78 kg/acre (1.72 lbs/acre). The AGNPS model predicted that 0.26 kilograms of phosphorus would be generated per acre, for a total of 6,184 kg (6.82 tons) of phosphorus, during a single 25-year event. A correlation between dissolved and sediment-bound nutrients was not determined.

Table C-118. West Mina priority-1 and 2 critical cells for sediment, nitrogen and phosphorus.

West Mina Priority-1 & 2 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
23	**10,142**	**278,307**	23	**8.42**	**1.05**	**9.48**	23	**4.21**	**0.21**	**4.42**
474	**5,162**	**162,795**	10	**4.08**	**2.55**	**6.63**	10	**2.04**	**0.56**	**2.60**
10	**4,091**	**112,509**	248	**4.03**	**2.37**	**6.40**	248	**2.02**	**0.52**	**2.54**
247	**4,064**	**996,027**	439	**1.04**	**5.09**	**6.13**	188	**1.46**	**0.60**	**2.06**
248	**4,064**	**110,913**	730	**2.50**	**3.27**	**5.77**	270	**1.53**	**0.52**	**2.05**
166	**3,792**	**174,225**	188	**2.92**	**2.73**	**5.65**	730	**1.25**	**0.73**	**1.98**
654	**3,520**	**554,209**	270	**3.06**	**2.37**	**5.43**	253	**1.35**	**0.60**	**1.95**
249	**3,121**	**89,376**	253	**2.70**	**2.73**	**5.42**	92	**1.30**	**0.52**	**1.82**
26	**3,075**	**691,793**	92	**2.61**	**2.37**	**4.98**	298	**1.25**	**0.52**	**1.77**
188	**2,785**	**74,045**	298	**2.50**	**2.37**	**4.87**	439	**0.52**	**1.15**	**1.67**
293	**2,703**	**96,670**	11	**2.23**	**2.55**	**4.78**	11	**1.11**	**0.56**	**1.67**
270	**2,585**	**78,363**	293	**1.31**	**3.45**	**4.76**	474	**1.57**	**0.07**	**1.64**
661	**2,585**	**95,880**	37	**2.15**	**2.55**	**4.70**	37	**1.08**	**0.56**	**1.64**
253	**2,558**	**67,095**	38	**2.15**	**2.55**	**4.70**	38	**1.08**	**0.56**	**1.64**
92	**2,449**	**64,274**	290	**1.89**	**2.73**	**4.62**	223	**1.25**	**0.30**	**1.56**
543	**2,422**	**268,881**	131	**1.80**	**2.73**	**4.52**	290	**0.95**	**0.60**	**1.55**
539	**2,413**	**55,901**	88	**1.80**	**2.55**	**4.35**	131	**0.90**	**0.60**	**1.50**
200	**2,295**	**468,435**	105	**1.80**	**2.55**	**4.35**	707	**1.17**	**0.30**	**1.47**
223	**2,295**	**61,008**	201	**1.75**	**2.55**	**4.30**	226	**0.95**	**0.52**	**1.47**
298	**2,295**	**61,008**	226	**1.89**	**2.37**	**4.26**	88	**0.90**	**0.56**	**1.46**
632	**2,295**	**113,979**	108	**1.63**	**2.55**	**4.18**	105	**0.90**	**0.56**	**1.46**
730	**2,295**	**61,008**	71	**1.60**	**2.55**	**4.15**	201	**0.88**	**0.56**	**1.43**
269	**2,195**	**72,421**	570	**1.38**	**2.73**	**4.11**	293	**0.65**	**0.77**	**1.42**
707	**2,105**	**56,119**	70	**1.27**	**2.80**	**4.07**	255	**0.91**	**0.47**	**1.38**
			58	**1.69**	**2.37**	**4.06**	108	**0.81**	**0.56**	**1.37**
			255	**1.82**	**2.19**	**4.01**	58	**0.85**	**0.52**	**1.37**
			528	**1.28**	**2.73**	**4.01**	71	**0.80**	**0.56**	**1.36**
			223	**2.50**	**1.48**	**3.98**	433	**0.26**	**1.05**	**1.31**
			225	**1.51**	**2.37**	**3.88**	570	**0.69**	**0.60**	**1.29**
			707	**2.34**	**1.48**	**3.82**	225	**0.75**	**0.52**	**1.27**
			292	**1.16**	**2.64**	**3.79**	70	**0.64**	**0.61**	**1.24**
			155	**1.38**	**2.37**	**3.76**	528	**0.64**	**0.60**	**1.24**
			650	**0.88**	**2.84**	**3.72**	238	**0.95**	**0.26**	**1.21**
			123	**1.33**	**2.37**	**3.70**	155	**0.69**	**0.52**	**1.21**
			146	**1.31**	**2.37**	**3.68**	123	**0.67**	**0.52**	**1.18**
			474	**3.15**	**0.44**	**3.59**	539	**1.17**	**0.01**	**1.17**
			178	**1.03**	**2.55**	**3.58**	661	**0.74**	**0.43**	**1.17**
			59	**1.19**	**2.37**	**3.57**	146	**0.65**	**0.52**	**1.17**
			284	**1.21**	**2.33**	**3.54**				
			12	**1.04**	**2.46**	**3.50**				
			661	**1.49**	**2.01**	**3.50**				
			60	**0.94**	**2.37**	**3.31**				
			13	**0.88**	**2.43**	**3.31**				
Critical Acres			Critical Acres				Critical Acres			
Priority 1		400	Priority 1			720	Priority 1			640
Priority 2		560	Priority 2			1,000	Priority 2			880

Shaded areas are Priority-1 cells

Table C-119. West Mina priority-3 critical cells for sediment, nitrogen and phosphorus.

West Mina Priority-3 Cells											
Sediment			Nitrogen				Phosphorus				
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
323	**2,014**	**85,148**	238	**1.89**	**1.30**	**3.19**	87	**0.95**	**0.21**	**1.16**
633	**2,014**	**194,328**	460	**0.51**	**2.62**	**3.13**	292	**0.58**	**0.58**	**1.16**
660	**2,014**	**52,018**	79	**0.78**	**2.33**	**3.11**	59	**0.59**	**0.52**	**1.11**
8	**1,978**	**109,280**	286	**0.78**	**2.33**	**3.11**	77	**0.85**	**0.26**	**1.11**
11	**1,960**	**52,735**	96	**0.76**	**2.33**	**3.09**	284	**0.61**	**0.50**	**1.11**
37	**1,923**	**50,657**	221	**1.59**	**1.48**	**3.07**	221	**0.79**	**0.30**	**1.10**
38	**1,923**	**50,657**	365	**1.26**	**1.75**	**3.00**	204	**0.88**	**0.20**	**1.08**
676	**1,923**	**82,917**	77	**1.69**	**1.30**	**2.99**	178	**0.52**	**0.56**	**1.08**
320	**1,869**	**857,962**	312	**0.64**	**2.33**	**2.98**	492	**1.03**	**0.04**	**1.07**
44	**1,860**	**695,050**	87	**1.91**	**1.05**	**2.96**	650	**0.44**	**0.63**	**1.07**
470	**1,823**	**41,658**	433	**0.53**	**2.39**	**2.92**	131	**0.90**	**0.60**	**1.50**
507	**1,823**	**88,677**	94	**1.59**	**1.30**	**2.88**	707	**1.17**	**0.30**	**1.47**
545	**1,805**	**2,138,691**	109	**0.97**	**1.91**	**2.88**	226	**0.95**	**0.52**	**1.47**
551	**1,796**	**52,381**	42	**1.50**	**1.30**	**2.79**	88	**0.90**	**0.56**	**1.46**
492	**1,769**	**191,108**	203	**1.09**	**1.68**	**2.77**	105	**0.90**	**0.56**	**1.46**
54	**1,751**	**177,010**	204	**1.77**	**0.98**	**2.75**	201	**0.88**	**0.56**	**1.43**
199	**1,751**	**419,592**	649	**1.20**	**1.54**	**2.74**	293	**0.65**	**0.77**	**1.42**
557	**1,751**	**45,223**	179	**0.83**	**1.85**	**2.69**	255	**0.91**	**0.47**	**1.38**
649	**1,751**	**48,798**	57	**1.67**	**0.98**	**2.65**	108	**0.81**	**0.56**	**1.37**
636	**1,742**	**43,808**	264	**0.48**	**2.17**	**2.65**	58	**0.85**	**0.52**	**1.37**
108	**1,733**	**71,259**	660	**1.27**	**1.38**	**2.65**	71	**0.80**	**0.56**	**1.36**
292	**1,724**	**55,366**	51	**1.21**	**1.37**	**2.58**	433	**0.26**	**1.05**	**1.31**
87	**1,669**	**43,427**	28	**0.69**	**1.88**	**2.57**	570	**0.69**	**0.60**	**1.29**
130	**1,669**	**300,832**	240	**1.27**	**1.30**	**2.56**	225	**0.75**	**0.52**	**1.27**
540	**1,669**	**43,327**	540	**1.09**	**1.46**	**2.55**	70	**0.64**	**0.61**	**1.24**
653	**1,660**	**163,629**	239	**1.22**	**1.30**	**2.52**	528	**0.64**	**0.60**	**1.24**
40	**1,615**	**562,927**	539	**2.33**	**0.19**	**2.52**	238	**0.95**	**0.26**	**1.21**
226	**1,615**	**43,082**	557	**1.13**	**1.38**	**2.51**	155	**0.69**	**0.52**	**1.21**
238	**1,615**	**43,082**	731	**0.76**	**1.74**	**2.50**	123	**0.67**	**0.52**	**1.18**
261	**1,615**	**50,694**	262	**0.54**	**1.95**	**2.49**	539	**1.17**	**0.01**	**1.17**
290	**1,615**	**43,082**	157	**1.16**	**1.28**	**2.44**	661	**0.74**	**0.43**	**1.17**
157	**1,579**	**46,775**	291	**0.68**	**1.76**	**2.44**	146	**0.65**	**0.52**	**1.17**
255	**1,579**	**41,105**	311	**1.14**	**1.30**	**2.44**	87	**0.95**	**0.21**	**1.16**
204	**1,533**	**39,562**	412	**0.61**	**1.83**	**2.44**	292	**0.58**	**0.58**	**1.16**
25	**1,524**	**657,510**	527	**0.58**	**1.85**	**2.43**	59	**0.59**	**0.52**	**1.11**
88	**1,524**	**40,288**	156	**0.92**	**1.50**	**2.42**	77	**0.85**	**0.26**	**1.11**
105	**1,524**	**40,288**	263	**0.46**	**1.95**	**2.41**	284	**0.61**	**0.50**	**1.11**
129	**1,524**	**274,106**	269	**1.65**	**0.74**	**2.39**	221	**0.79**	**0.30**	**1.10**
131	**1,524**	**40,288**	492	**2.05**	**0.32**	**2.38**	204	**0.88**	**0.20**	**1.08**
278	**1,524**	**157,342**	47	**1.28**	**1.08**	**2.35**	178	**0.52**	**0.56**	**1.08**
154	**1,506**	**342,789**	39	**0.69**	**1.65**	**2.35**	492	**1.03**	**0.04**	**1.07**
176	**1,506**	**364,934**	261	**0.89**	**1.44**	**2.33**	650	**0.44**	**0.63**	**1.07**
201	**1,506**	**39,063**	276	**0.86**	**1.47**	**2.33**				
63	**1,433**	**36,895**	195	**1.23**	**1.08**	**2.31**				
483	**1,433**	**38,165**	196	**1.23**	**1.08**	**2.31**				
56	**1,415**	**189,928**								

Table C-63 (Continued). West Mina priority-3 critical cells for sediment, nitrogen and phosphorus.

West Mina Priority-3 Cells (Continued)										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
58	**1,415**	**37,467**								
76	**1,415**	**42,601**								
77	**1,415**	**37,467**								
146	**1,415**	**54,213**								
315	**1,415**	**43,119**								
501	**1,415**	**51,737**								
637	**1,415**	**58,087**								
57	**1,406**	**36,814**								
266	**1,388**	**12,664**								
Critical Acres			Critical Acres				Critical Acres			
Priority 3		2,200	Priority 3			1,800	Priority 3			1,680

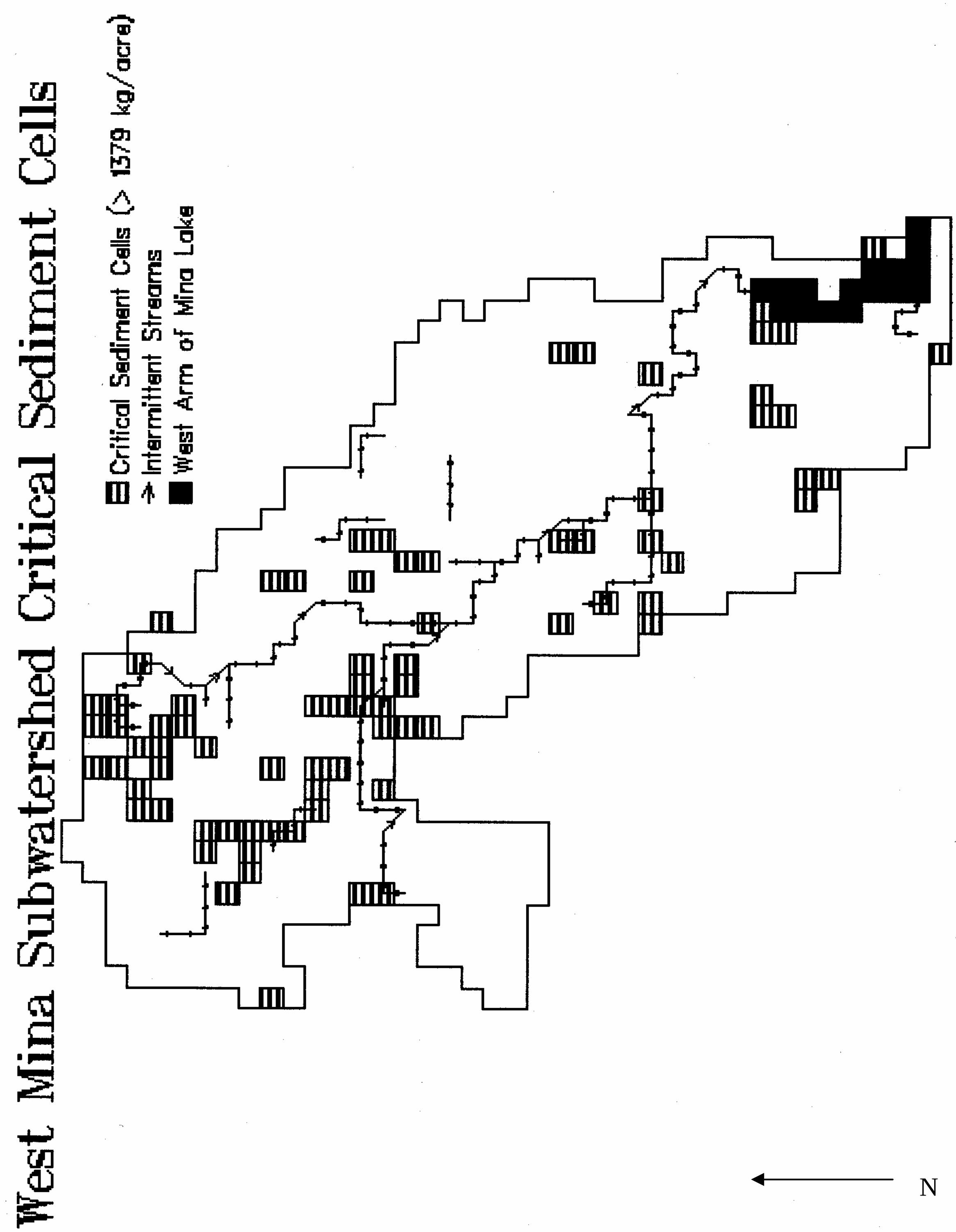


Figure C-97. Critical sediment cells for the West Mina sub-watershed of Mina Lake.

Sediment Analysis

The AGNPS model calculated that the sediment delivered from the sub-watershed is 42.4 kg/acre/year. As a result, 1,013,480 kg (1,117 tons) of sediment would be generated annually from this sub-watershed. In summary, West Mina was estimated to contribute 43 percent of the west tributary sediment load and 10 percent of the total sediment load to Mina Lake. West Mina contains 16 percent of the critical erosion cells and comprises 15 percent of the watershed surface area. Based on the export coefficient, the West Mina sub-watershed is ranked fourth of eight on a list of priorities for sediment improvements.

The high sediment yield within the sub-watershed critical cells can be attributed to land use, minimal buffers, land slope, and proximity to surface water conduits. Common critical cell characteristics for the Mina Lake system include croplands with a slope greater than 2 percent that are closer than 152 meters (500 feet) to a stream.

Total Nutrient Analysis

The AGNPS data indicated that the West Mina subwatershed had the highest total nitrogen (soluble + sediment-bound) transport rate of 1.76 kg/acre/year (equivalent to 42,206 kg or 47 tons). Eight-eight percent of the transported nitrogen from this sub-watershed was estimated to be in dissolved form while 77 percent of the total nitrogen load to Mina Lake was estimated to be in dissolved form. The total nitrogen load delivered from the sub-watersheds to Mina Lake was estimated to be 211,203 kg or 233 tons/year. As a result, the West Mina load to Mina Lake was 20 percent (highest over all) of the total nitrogen. Based on the transport coefficients for nitrogen, West Mina was rated third of eight for nitrogen reduction priority.

This sub-watershed had a total phosphorus (soluble + sediment-bound) transport rate of 0.40 kg/acre/year (equivalent to 9,656 kg or 10.6 tons). Seventy-two percent of the transported phosphorus from this sub-watershed was estimated to be in dissolved form while 56 percent of the total phosphorus load was estimated to be in dissolved form. The total phosphorus load delivered from all sub-watersheds to Mina Lake was estimated to be 53,300 kg/year (59 tons/year). As a result, the West Mina load of total phosphorus to Mina Lake was 18 percent. Based on the transport coefficients for phosphorus, West Mina was rated third of eight for phosphorus reduction priority.

Dissolved nitrogen and phosphorus nutrient levels from West Mina were estimated to be 88 percent and 72 percent, respectively.

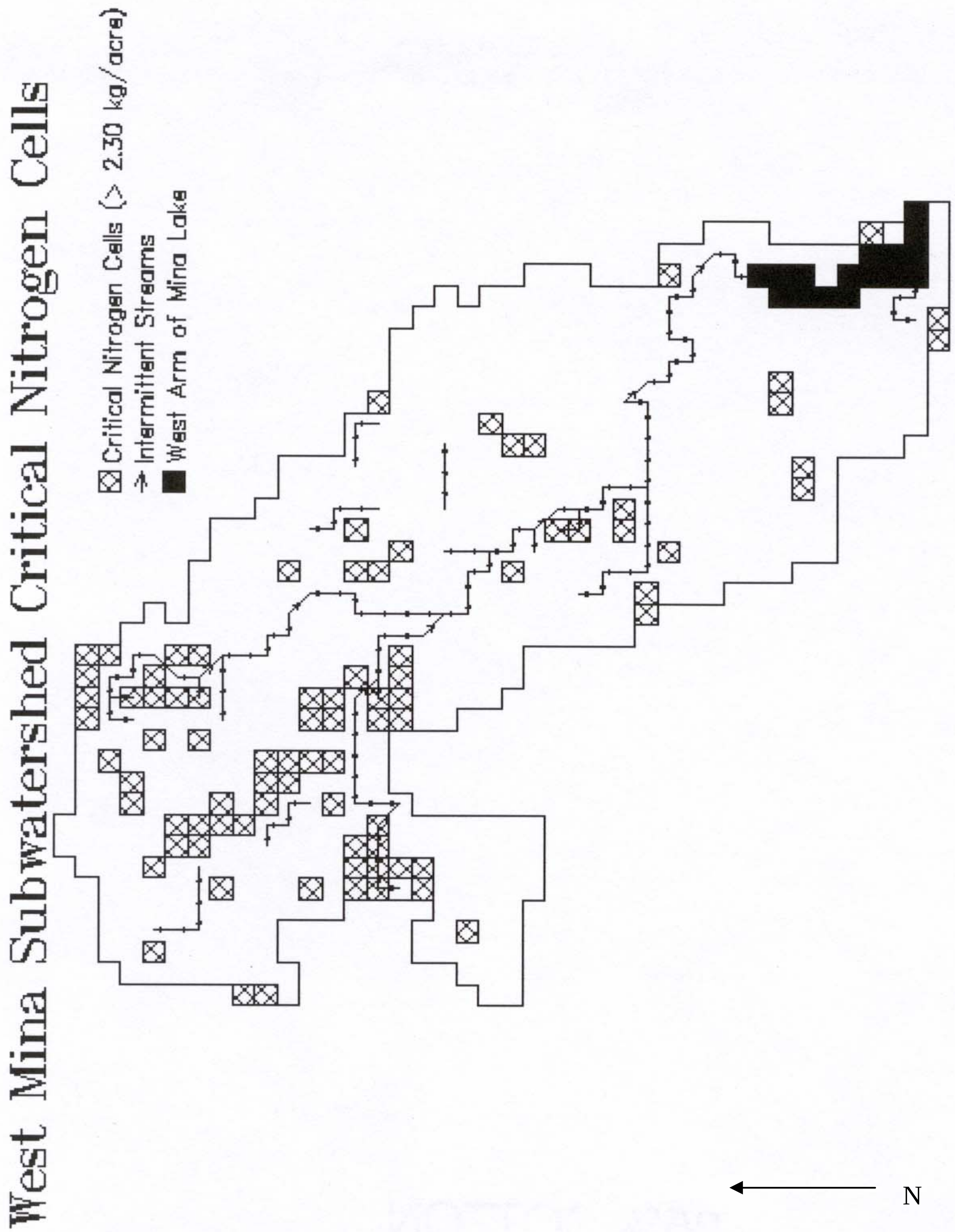


Figure C-98. Critical nitrogen cells for the West Mina sub-watershed of Mina Lake.

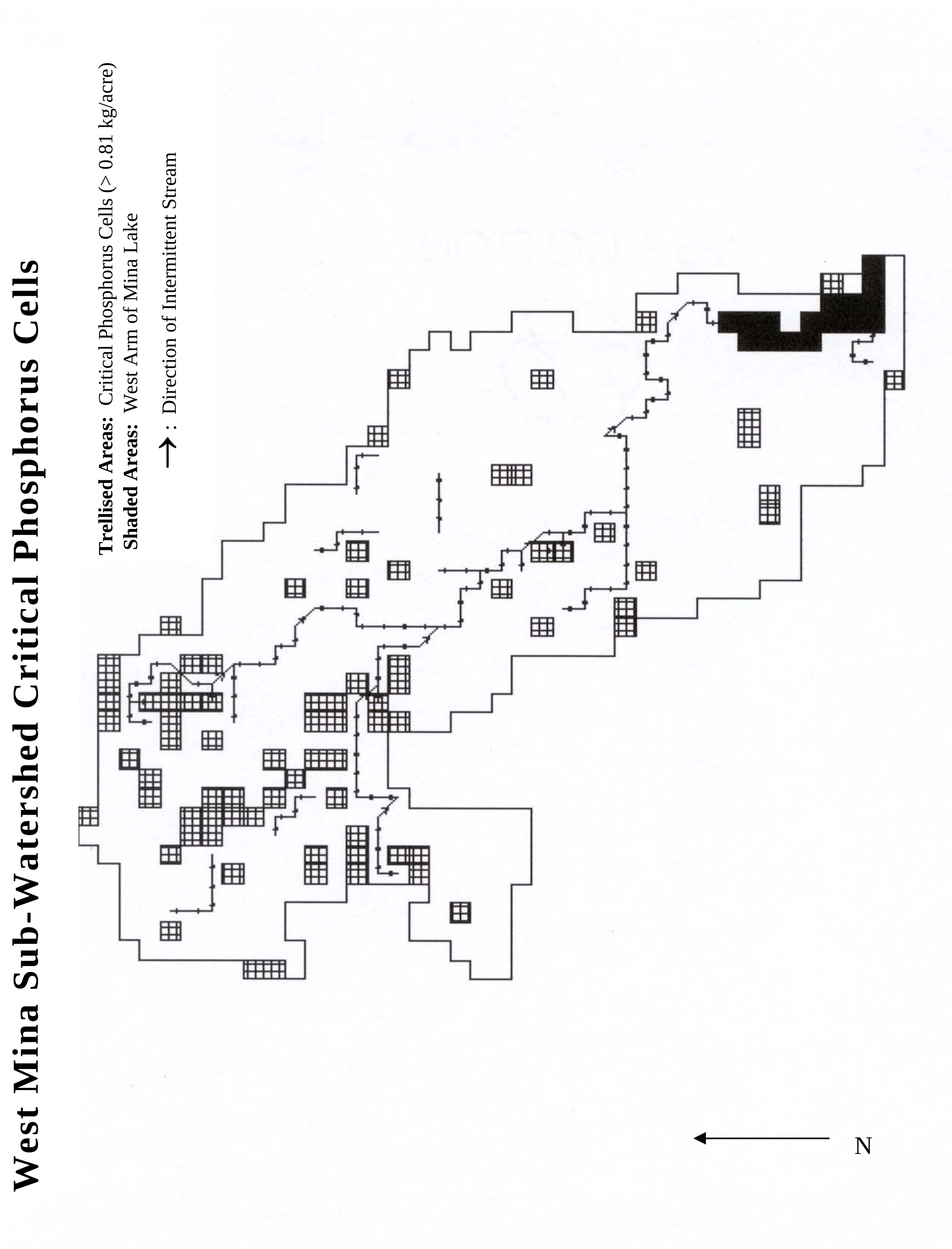


Figure C-99. Critical phosphorus cells for the West Mina sub-watershed of Mina Lake.

Priority Ranking of Animal Feeding Areas of West Mina Sub-watershed (25-Year Event)

A total of 26 animal feeding areas were identified during the AGNPS data acquisition phase of the project. Table C-66 lists the AGNPS analysis of each feeding area. Of these, four were found to have an AGNPS ranking greater than 40. One cell had an AGNPS ranking of 62. AGNPS ranks feeding areas from 0 to 100 with a 0 ranked feeding area having a smaller pollution potential and a 100 ranking having a large pollution potential. AGNPS estimates the total impact of having a feeding area or multiple feeding areas within a cell by combining and recalculating all values to arrive at nutrient and COD values to the cell. Critical feeding area locations are depicted in Figure C-30.

In order to determine the impact of the feeding areas, AGNPS outputs from nutrient and feeding area critical cell data were analyzed (Table C-64). A reduction efficiency coefficient was determined by calculating a ratio of the difference (per acre) between the overall amount of nutrients generated per cell (acres multiplied by transport coefficient) and feedlot-generated nutrient loads. The results were then used to estimate the cell capacity, or lack of capacity, to reduce nutrient levels under current conditions. Topographical gradient, size, location of buffering zones and proximity to surface conduits were possible influences on nutrient reduction and diffusion.

Reduction efficiency coefficients range from positive to negative values and were interpreted using a sliding scale with values and ratings based on Table C-65. All feeding areas, critical or not, were analyzed for reduction potential to determine trends and ratings. These values may be used to estimate the sensitivity or resistance potential of the cell to perturbations within the feeding area(s) (increasing the number of animal units/area) or within the cell (changes in landscape/landuse, buffer reduction, tillage practices, etc.) based on current conditions. BMP improvements in the feeding areas or the cell with favorable/marginally favorable ratings will respond/improve more rapidly than the cell with a neutral to unfavorable rating. Another use for this rating may be to prioritize/rank all critical feeding areas (feeding areas needing BMPs) within a watershed by reduction efficiency (improvement potential) to target/select feeding areas to realize maximum nutrient reduction in the watershed when implementation funds are limited.

Cell #433 exceeded both critical nutrient and feedlot threshold limits; the data indicated a marginally unfavorable reduction capacity. The proximity of both the cell and feedlot to Snake Creek likely influenced buffering capacity and made nutrient levels non-cell supportable. Cells #435 and #682 exceeded critical feedlot nutrient threshold limits. The higher efficiency ratio may indicate that the feeding area nutrients had a greater impact on nutrient output than the cell, but appeared to be well-buffered and cell-supportable. Cell #236 did not exceed feeding area nutrient limits, because the AGNPS method used to develop feeding area critical values caused a highly rated feeding area not to be ranked. The sub-watershed as a whole was found to have a marginally unfavorable efficiency ratio when the very high values from cell 682 were ignored. Over all, nutrient levels are cell-supportable; however, cell output would be sensitive to elevated (increased) nutrient concentrations.

Table C-120. Critical Cell (CC) reduction efficiency ratios for the West Mina sub-watershed.

Cell Number and Parameter	Feedlot Mass Generated (kg)	Transport Coefficient from (CC) Load Data **	Total Mass Transported (kg)	Difference (kg)	Reduction Efficiency Coefficient (kg/acre)	Rating (Table C- 65)
#98 Nitrogen	**0.00**	**0.86**	**34.4**	**-34.4**	**-0.86**	**MU**
#98 Phosphorus	**2.28**	**0.41**	**16.4**	**-14.1**	**-0.35**	**MU**
#111 Nitrogen	**16.7**	**1.56**	**62.4**	**-45.7**	**-1.14**	**MU**
#111 Phosphorus	**7.66**	**0.49**	**19.6**	**-11.9**	**-0.30**	**MU**
#236 Nitrogen	**102**	**0.90**	**36.0**	**66.0**	**1.65**	**MF**
#236 Phosphorus	**27.7**	**0.25**	**10.0**	**17.7**	**0.44**	**MF**
#314 Nitrogen	**0.25**	**0.48**	**19.2**	**-19.0**	**-0.47**	**MU**
#314 Phosphorus	**5.15**	**0.13**	**5.20**	**-0.05**	**0.00**	**N**
#427 Nitrogen	**38.6**	**1.76**	**70.4**	**-31.8**	**-0.80**	**MU**
#427 Phosphorus	**15.5**	**0.70**	**28.0**	**-12.5**	**-0.31**	**MU**
#430 Nitrogen	**2.51**	**0.81**	**32.4**	**-29.9**	**-0.75**	**MU**
#430 Phosphorus	**0.42**	**0.31**	**12.4**	**-12.0**	**-0.30**	**MU**
#433 Nitrogen *	**88.3**	**2.92**	**116.8**	**-28.5**	**-0.71**	**MU**
#433 Phosphorus *	**41.5**	**1.31**	**52.4**	**-10.9**	**-0.27**	**MU**
#434 Nitrogen	**16.0**	**1.08**	**43.2**	**-27.2**	**-0.68**	**MU**
#434 Phosphorus	**4.70**	**0.29**	**11.6**	**-6.90**	**-0.17**	**MU**
#435 Nitrogen *	**95.5**	**1.04**	**41.6**	**53.9**	**1.35**	**MF**
#435 Phosphorus *	**32.2**	**0.28**	**11.2**	**21.0**	**0.53**	**MF**
#445 Nitrogen	**4.24**	**1.09**	**43.6**	**-39.4**	**-0.98**	**MU**
#445 Phosphorus	**1.96**	**0.45**	**18.0**	**-16.0**	**-0.40**	**MU**
#453 Nitrogen	**8.85**	**0.47**	**18.8**	**-9.95**	**-0.25**	**MU**
#453 Phosphorus	**5.86**	**0.15**	**6.00**	**-0.14**	**0.00**	**N**
#525 Nitrogen	**16.2**	**0.58**	**23.2**	**-7.00**	**-0.18**	**MU**
#525 Phosphorus	**10.6**	**0.21**	**8.40**	**2.20**	**0.06**	**N**
#682 Nitrogen *	**385**	**1.24**	**49.6**	**335**	**8.39**	**F**
#682 Phosphorus *	**141**	**0.40**	**16.0**	**125**	**3.13**	**F**
Average with #682 value					0.25	MF
Average w/o #682 value					-0.20	MU

Shaded area indicates critical nutrient cell

* = Indicates critical feedlot cell

**** = Indicates threshold values for the West Mina sub-watershed (nitrogen yields > 2.23 kg/acre or phosphorus yields > 0.78 kg/acre)**

The animal feeding areas rated above 40 should be monitored for animal density or use-intensity. If use intensifies without modification of current conditions, the potential for sediment and nutrient yield will increase, especially in unfavorable to marginally unfavorable cells. Positive steps should be taken to identify and modify existing conditions within critical feeding areas. Careful study of feeding area size, animal density/intensity of use, and buffering capacity may be needed to reduce the AGNPS feedlot ratings and increase the reduction efficiencies (ratings).

Table C-121. Nutrient reduction efficiency rating scale for Mina Lake.

Rating	Criteria
Favorable (F)	**Greater than 2.0 kg/acre**
Marginally Favorable (MF)	**Between 0.1 and 2.0 kg/acre**
Neutral (N)	**Between -0.1 and 0.1 kg/acre**
Marginally Unfavorable (MU)	**Between –2 and –0.1 kg/acre**
Unfavorable (U)	**Less than –2.0 kg/acre**

Improvements in feeding areas and cells with favorable to marginally favorable rating would be expected to show marked improvement. Sources of nutrient loads not modeled through this study were those from septic systems and livestock with direct access to the lake or adjacent streams.

Table C-122. AGNPS feedlot ratings and data for the West Mina sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 98

Nitrogen concentration (ppm)	**0**
Phosphorus concentration (ppm)	**0.65**
COD concentration (ppm)	**80.9**
Nitrogen mass (kg)	**0**
Phosphorus mass (kg)	**2.28**
COD mass (kg)	**283**
Animal feedlot rating number	25

Cell # 111

Nitrogen concentration (ppm)	**6.52**
Phosphorus concentration (ppm)	**2.99**
COD concentration (ppm)	**274**
Nitrogen mass (kg)	**16.7**
Phosphorus mass (kg)	**7.66**
COD mass (kg)	**701**
Animal feedlot rating number	36

Cell # 236

Nitrogen concentration (ppm)	**0.98**
Phosphorus concentration (ppm)	**0.16**
COD concentration (ppm)	**4.90**
Nitrogen mass (kg)	**0.49**
Phosphorus mass (kg)	**0.08**
COD mass (kg)	**2.46**
Animal feedlot rating number	0

Cell # 236

Nitrogen concentration (ppm)	**18.8**
Phosphorus concentration (ppm)	**5.78**
COD concentration (ppm)	**572**
Nitrogen mass (kg)	**68.2**
Phosphorus mass (kg)	**20.9**
COD mass (kg)	**2,072**
Animal feedlot rating number	52

Cell # 236

Nitrogen concentration (ppm)	**39.2**
Phosphorus concentration (ppm)	**7.91**
COD concentration (ppm)	**892**
Nitrogen mass (kg)	**32.9**
Phosphorus mass (kg)	**6.64**
COD mass (kg)	**749**
Animal feedlot rating number	36

Cell # 236 TOTAL

Nitrogen concentration (ppm)	
Phosphorus concentration (ppm)	
COD concentration (ppm)	
Nitrogen mass (kg)	**102**
Phosphorus mass (kg)	**27.7**
COD mass (kg)	**2,823**

Animal feedlot rating number -

Table C-66 (Continued). AGNPS feedlot ratings and data for the West Mina sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 314		Cell # 430	
Nitrogen concentration (ppm)	**0.11**	**Nitrogen concentration (ppm)**	**1.56**
Phosphorus concentration (ppm)	**5.80**	**Phosphorus concentration (ppm)**	**0.26**
COD concentration (ppm)	**381**	**COD concentration (ppm)**	**7.82**
Nitrogen mass (kg)	**0.08**	**Nitrogen mass (kg)**	**1.65**
Phosphorus mass (kg)	**4.38**	**Phosphorus mass (kg)**	**0.27**
COD mass (kg)	**288**	**COD mass (kg)**	**8.24**
Animal feedlot rating number	23	**Animal feedlot rating number**	0
Cell # 314		Cell # 430	
Nitrogen concentration (ppm)	**0.56**	**Nitrogen concentration (ppm)**	**0.56**
Phosphorus concentration (ppm)	**2.56**	**Phosphorus concentration (ppm)**	**0.09**
COD concentration (ppm)	**153**	**COD concentration (ppm)**	**12.7**
Nitrogen mass (kg)	**0.17**	**Nitrogen mass (kg)**	**0.87**
Phosphorus mass (kg)	**0.77**	**Phosphorus mass (kg)**	**0.14**
COD mass (kg)	**46.3**	**COD mass (kg)**	**19.6**
Animal feedlot rating number	0	**Animal feedlot rating number**	0
Cell # 314 TOTAL		Cell # 430 TOTAL	
Nitrogen concentration (ppm)		**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)		**Phosphorus concentration (ppm)**	
COD concentration (ppm)		**COD concentration (ppm)**	
Nitrogen mass (kg)	**0.25**	**Nitrogen mass (kg)**	**2.51**
Phosphorus mass (kg)	**5.15**	**Phosphorus mass (kg)**	**0.42**
COD mass (kg)	**334**	**COD mass (kg)**	**27.8**
Animal feedlot rating number	**-**	**Animal feedlot rating number**	**-**

Table C-66 (Continued). AGNPS feedlot ratings and data for the West Mina sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 427		Cell # 427 TOTAL	
Nitrogen concentration (ppm)	**3.43**	**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)	**0.57**	**Phosphorus concentration (ppm)**	
COD concentration (ppm)	**17.2**	**COD concentration (ppm)**	
Nitrogen mass (kg)	**6.72**	**Nitrogen mass (kg)**	**38.6**
Phosphorus mass (kg)	**1.12**	**Phosphorus mass (kg)**	**15.5**
COD mass (kg)	**33.6**	**COD mass (kg)**	**1,098**
Animal feedlot rating number	0	**Animal feedlot rating number**	-
Cell # 427		Cell # 433	
Nitrogen concentration (ppm)	**7.78**	**Nitrogen concentration (ppm)**	**1.02**
Phosphorus concentration (ppm)	**4.48**	**Phosphorus concentration (ppm)**	**1.67**
COD concentration (ppm)	**209**	**COD concentration (ppm)**	**174**
Nitrogen mass (kg)	**0.99**	**Nitrogen mass (kg)**	**2.41**
Phosphorus mass (kg)	**0.57**	**Phosphorus mass (kg)**	**3.96**
COD mass (kg)	**26.7**	**COD mass (kg)**	**413**
Animal feedlot rating number	0	**Animal feedlot rating number**	29
Cell # 427		Cell # 433	
Nitrogen concentration (ppm)	**21.0**	**Nitrogen concentration (ppm)**	**74.4**
Phosphorus concentration (ppm)	**12.4**	**Phosphorus concentration (ppm)**	**32.5**
COD concentration (ppm)	**592**	**COD concentration (ppm)**	**1,512**
Nitrogen mass (kg)	**11.0**	**Nitrogen mass (kg)**	**85.9**
Phosphorus mass (kg)	**6.47**	**Phosphorus mass (kg)**	**37.5**
COD mass (kg)	**310**	**COD mass (kg)**	**1,745**
Animal feedlot rating number	24	**Animal feedlot rating number**	47
Cell # 427		Cell # 433 TOTAL	
Nitrogen concentration (ppm)	**14.8**	**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)	**5.45**	**Phosphorus concentration (ppm)**	
COD concentration (ppm)	**544**	**COD concentration (ppm)**	
Nitrogen mass (kg)	**19.8**	**Nitrogen mass (kg)**	**88.3**
Phosphorus mass (kg)	**7.29**	**Phosphorus mass (kg)**	**41.5**
COD mass (kg)	**728**	**COD mass (kg)**	**2,158**

Animal feedlot rating number	36	**Animal feedlot rating number**	**-**

Table C-66 (Continued). AGNPS feedlot ratings and data for the West Mina sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 445		Cell # 434	
Nitrogen concentration (ppm)	**4.21**	**Nitrogen concentration (ppm)**	**41.2**
Phosphorus concentration (ppm)	**2.40**	**Phosphorus concentration (ppm)**	**12.1**
COD concentration (ppm)	**146**	**COD concentration (ppm)**	**1,190**
Nitrogen mass (kg)	**1.9**	**Nitrogen mass (kg)**	**16.0**
Phosphorus mass (kg)	**1.08**	**Phosphorus mass (kg)**	**4.7**
COD mass (kg)	**65.9**	**COD mass (kg)**	**461**
Animal feedlot rating number	2	**Animal feedlot rating number**	28
Cell # 445		Cell # 525	
Nitrogen concentration (ppm)	**4.97**	**Nitrogen concentration (ppm)**	**19.3**
Phosphorus concentration (ppm)	**1.86**	**Phosphorus concentration (ppm)**	**10.0**
COD concentration (ppm)	**81.4**	**COD concentration (ppm)**	**471**
Nitrogen mass (kg)	**2.33**	**Nitrogen mass (kg)**	**12.9**
Phosphorus mass (kg)	**0.87**	**Phosphorus mass (kg)**	**6.69**
COD mass (kg)	**38.2**	**COD mass (kg)**	**315**
Animal feedlot rating number	0	**Animal feedlot rating number**	24
Cell # 445 TOTAL		Cell # 525	
Nitrogen concentration (ppm)		**Nitrogen concentration (ppm)**	**8.21**
Phosphorus concentration (ppm)		**Phosphorus concentration (ppm)**	**10**
COD concentration (ppm)		**COD concentration (ppm)**	**500**
Nitrogen mass (kg)	**4.24**	**Nitrogen mass (kg)**	**3.24**
Phosphorus mass (kg)	**1.96**	**Phosphorus mass (kg)**	**3.95**
COD mass (kg)	**104**	**COD mass (kg)**	**198**
Animal feedlot rating number	**-**	**Animal feedlot rating number**	18
		Cell # 525 TOTAL	
		Nitrogen concentration (ppm)	
		Phosphorus concentration (ppm)	
		COD concentration (ppm)	
		Nitrogen mass (kg)	**16.2**
		Phosphorus mass (kg)	**10.6**
		COD mass (kg)	**513**

	Animal feedlot rating number	-

Table C-66 (Continued). AGNPS feedlot ratings and data for the West Mina sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 453		Cell # 435	
Nitrogen concentration (ppm)	**1.26**	**Nitrogen concentration (ppm)**	**67.3**
Phosphorus concentration (ppm)	**1.50**	**Phosphorus concentration (ppm)**	**22.7**
COD concentration (ppm)	**160**	**COD concentration (ppm)**	**1,420**
Nitrogen mass (kg)	**1.99**	**Nitrogen mass (kg)**	**95.5**
Phosphorus mass (kg)	**2.36**	**Phosphorus mass (kg)**	**32.2**
COD mass (kg)	**251**	**COD mass (kg)**	**2,014**
Animal feedlot rating number	22	**Animal feedlot rating number**	50

Cell # 453		Cell # 682	
Nitrogen concentration (ppm)	**4.99**	**Nitrogen concentration (ppm)**	**2.85**
Phosphorus concentration (ppm)	**4.48**	**Phosphorus concentration (ppm)**	**0.98**
COD concentration (ppm)	**224**	**COD concentration (ppm)**	**34.0**
Nitrogen mass (kg)	**3.09**	**Nitrogen mass (kg)**	**359**
Phosphorus mass (kg)	**2.77**	**Phosphorus mass (kg)**	**124**
COD mass (kg)	**139**	**COD mass (kg)**	**4,273**
Animal feedlot rating number	12	**Animal feedlot rating number**	62

Cell # 453		Cell # 682	
Nitrogen concentration (ppm)	**3.78**	**Nitrogen concentration (ppm)**	**9.87**
Phosphorus concentration (ppm)	**0.73**	**Phosphorus concentration (ppm)**	**6.87**
COD concentration (ppm)	**49.6**	**COD concentration (ppm)**	**333**
Nitrogen mass (kg)	**3.78**	**Nitrogen mass (kg)**	**25.6**
Phosphorus mass (kg)	**0.73**	**Phosphorus mass (kg)**	**17.8**
COD mass (kg)	**49.6**	**COD mass (kg)**	**864**
Animal feedlot rating number	0	**Animal feedlot rating number**	40

Cell # 453 TOTAL		Cell # 682 TOTAL	
Nitrogen concentration (ppm)		**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)		**Phosphorus concentration (ppm)**	
COD concentration (ppm)		**COD concentration (ppm)**	
Nitrogen mass (kg)	**8.85**	**Nitrogen mass (kg)**	**385**
Phosphorus mass (kg)	**5.86**	**Phosphorus mass (kg)**	**141**
COD mass (kg)	**440**	**COD mass (kg)**	**5,138**

Animal feedlot rating number	-	Animal feedlot rating number	-

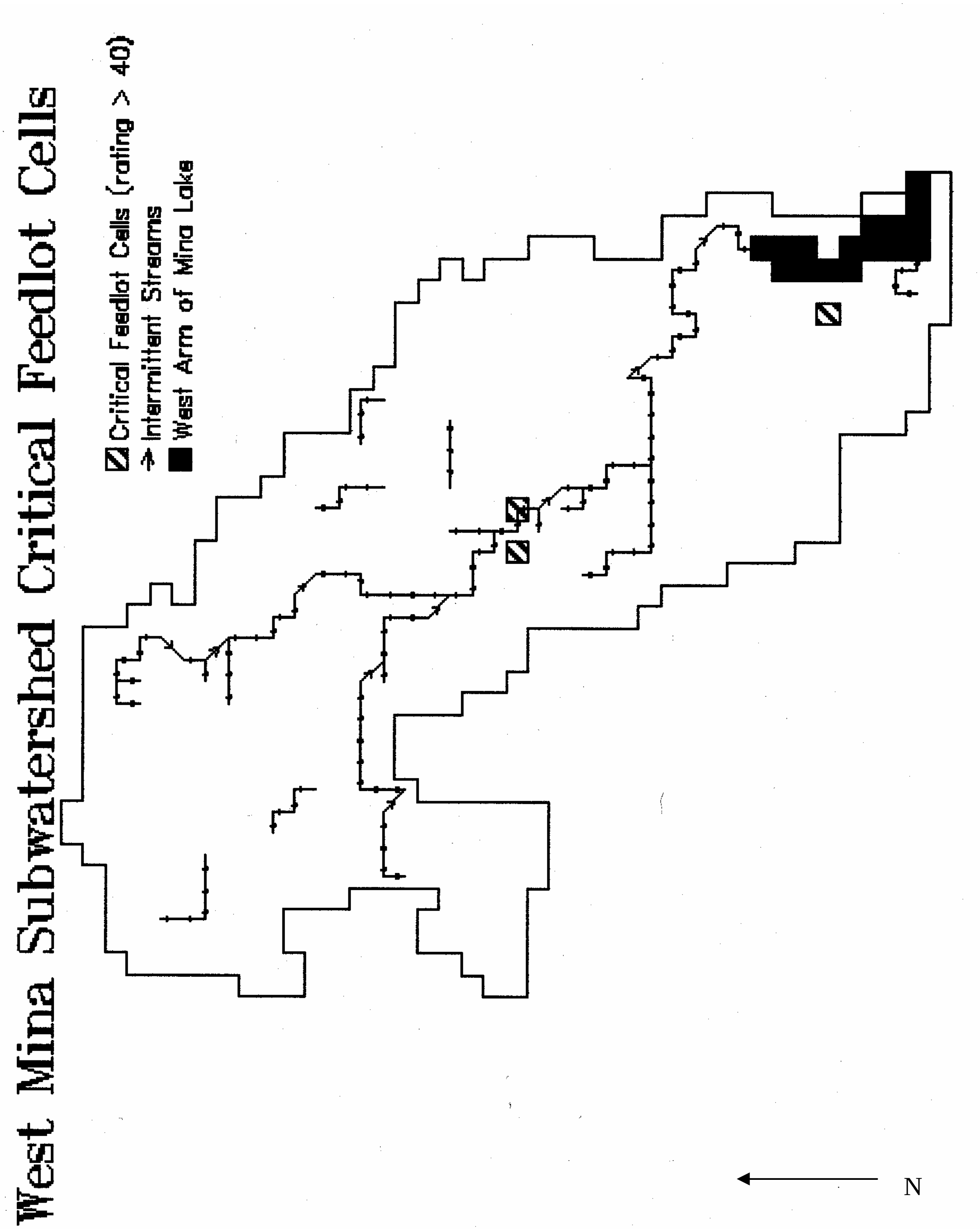


Figure C-100. Critical feedlot cells for the West Mina sub-watershed of Mina Lake.

Modeled Sediment, Nitrogen and Phosphorus Reductions (West Mina Sub-watershed)

Several Best Management Practices (BMP) were modeled using the AGNPS computer model. These included installation of Animal Waste Management Systems (AWMS), grassed waterways, reduction of crop ground fertilizer application levels, and conversion of conventional till practices to minimum or no-till methods.

Twenty-six feeding areas within the West Mina sub-watershed were identified. The AGNPS assessment of field feedlot data rated three feeding areas as critical (rated above 40 based on objective criteria). Efforts to improve feeding areas would result in minimal reduction in total nitrogen and in total phosphorus from 9,656 kg/year or 10.6 tons/year to 9,381 kg/year or 10.3 tons/year (2 percent).

AGNPS compared fertilizer application rates using the current rate of application (approx. 45.4 kg or 100 lbs/acre nitrogen and 18.1 kg or 40 lbs/acre phosphorus) to a reduced rate (22.7 kg/acre or 50 lbs/acre nitrogen and 9.1 kg/acre or 20 lbs/acre phosphorus). The sub-watershed model indicated a reduction in the total nitrogen load from 42,206 kg/year or 46.5 tons/year to 34,562 kg/year or 38.1 tons/year (16 percent) and for total phosphorus from 9,656 kg/year (10.6 tons/year) to 8,242 kg/year or 9.1 tons/year (14 percent).

The model estimated that modifying tilled acreage within critical erosion cells to conservation tillage practices would reduce the sediment load delivered by Snake Creek from 1,013,480 kg/year or 1,117.2 tons/year to 901,997 kg/year or 994.3 tons/year (11 percent). Total nitrogen load may be reduced from 42,206 kg/year or 46.5 tons/year to 34,562 kg/year or 38.1 tons/year (16 percent). This practice will also reduce the total phosphorus yield from 9,656 kg/year or 10.6 tons/year to 8,014 kg/year or 8.8 tons/year (17 percent). Based on AGNPS reduction estimates, conversion from conventional to minimum/no tillage will have the greatest impact on the watershed.

BMP recommendations should be implemented within sub-watershed and site priority critical cells (Table C-67 and Table C-68). Field data for priority critical cells should be field verified prior to BMP planning and implementation. The AGNPS model did not simulate grass waterways or gully and streambank erosion, however, and these BMPs should also be evaluated.

Table C-123. AGNPS modeling reductions for West Mina sub-watershed BMPs[1].

BMP	Unit	Percent Reduction		
		Sediments	Nitrogen	Phosphorus
Feedlot	**West Mina**	**0**	**0**	**2**
Fertilizer	**West Mina**	**0**	**16**	**14**
Minimum Till	**West Mina**	**11**	**16**	**17**
Sub-watershed Total		**11**	**32**	**33**

[1] = Reductions calculated 1999-2000 field data

Table C-124. AGNPS modeling reductions for Snake Creek 1 sub-watershed BMPs[1].

BMP	Unit	Percent		
		Sediments	Nitrogen	Phosphorus
Feedlot	**SC-1**	**0**	**0**	**0**
Fertilizer	**SC-1**	**0**	**11**	**8**
Minimum Till	**SC-1**	**6**	**11**	**5**
Site Total		**6**	**22**	**13**

[1] = Reductions calculated 1999-2000 field data

Y Sub-Watershed AGNPS Analysis (A Sub-watershed of Mina Lake)

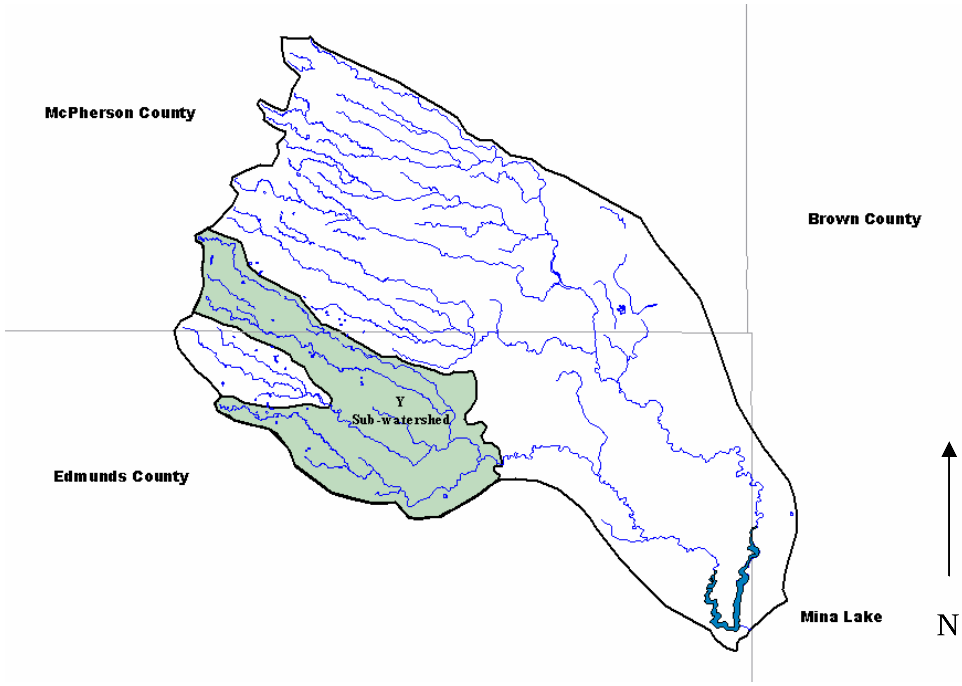


Figure C-101. The Y Sub-watershed within the Mina Lake Watershed.

The Y sub-watershed is located primarily within Edmunds County, with approximately one-fourth in McPherson County, in northeastern South Dakota, and is the largest drainage for the western tributary of the Mina Lake watershed. The second-largest sub-watershed in the Mina system, Y (20 percent of total hydrologic input) encompasses an approximate area of 12,804 hectares (31,640 acres). The Y sub-watershed is a shallow basin that drops 118 meters or 388 feet over 21.7 kilometers or 13.5 miles (0.5 percent grade). Y also serves as a discharge for Rosette Lake.

The Y watershed is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. Five monitoring sites were set up at various locations along Snake Creek to collect water quantity and quality parameters within the creek. Site SC-6 is located within the Y sub-watershed, approximately 2 miles downstream from the Plainview Colony.

Due to the lack of site-specific water quality data, a computer model was selected to assess the Non-point Source (NPS) loadings throughout the Mina Lake watershed. The Y watershed is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. The data was used to model current loading to Snake Creek and was used for comparisons with other sub-watersheds in the Mina Lake drainage.

Cropping practices, including tillage and fertilizer use, and range management directly influence the intensity of sediment and nutrient runoff. More than 5,360 acres, or 7 percent, of the West Mina sub-watershed is used for cropland; the remaining acreage

may be used as rangeland and pasture. Tillage, fertilizer, and feedlot Best Management Practices (BMPs) were modeled and analyzed to estimate the runoff reduction potential within the sub-watershed.

Evaluation/Quantification of Sub-watershed Non-Point Source Loading

Delineation and Location of Sub-watershed

The following AGNPS outlet cell numbers correlate to AGNPS sub-watershed and water quality monitoring sites used in the Mina Lake watershed assessment study during 1999 and 2000 (Table C-69):

Table C-125. AGNPS outlet cell number for the Y and Snake Creek 6 (SC-6) sub-watershed of Mina Lake.

Sub-watershed/Site	AGNPS outlet cell number
Y	**682**
SC-6	**300**

The following tables estimate the delivery coefficients, annual loading and critical values for priority cells for sediment (Table C-70), nitrogen (Table C-71), and phosphorus (Table C-72) in the Y sub-watershed:

Table C-126. Export coefficients (kg/acre) for the Y and Snake Creek 6 (SC-6) sub-watersheds of Mina Lake♣.

				Export Coefficients					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area Acres	Percent of Watershed	Sediment kg/acre	Attached-N kg/acre	Dissolved-N kg/acre	Total Nitrogen kg/acre	Attached-P kg/acre	Dissolved-P kg/acre	Total Phosphorus kg/acre
Y	**31,640**	**20**	**41.0**	**0.24**	**0.81**	**1.04**	**0.12**	**0.14**	**0.25**
Snake Creek 6 (SC-6)	**8,080**	**5**	**45.7**	**0.24**	**0.30**	**0.55**	**0.12**	**0.04**	**0.16**

Table C-127. Annualized loading (kg) for the Y and Snake Creek 6 (SC-6) sub-watersheds of Mina Lake♣.

				Sub-watershed Loading					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area Acres	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
Y	**31,640**	**20**	**1,296,058**	**7,463**	**25,546**	**33,099**	**3,731**	**4,305**	**8,037**
Snake Creek 6 (SC-6)	**8,080**	**5**	**369,324**	**1,979**	**2,456**	**4,435**	**990**	**330**	**1,319**

Table C-128. Priority cell threshold values for the Y and Snake Creek 6 (SC-6) sub-watersheds of Mina Lake♣.

	Critical Values (kg/acre)		
Parameter	Priority-1	Priority-2	Priority-3
Sediment	**4,227**	**3,155**	**2,083**
Nitrogen	**3.44**	**2.63**	**1.82**
Phosphorus	**1.45**	**1.10**	**0.75**

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulative rainfall events during an average year. This includes a 1-year, 24-hour event of 1.85 inches (EI = 17.5), 3 semiannual rainfall events of 1.23 inches (EI = 7.4) and a series of 10 small rainfall events of 0.8 inch (EI = 3.0) for a total "R" factor of 69.7.

Identification of Critical Non-Point Source Cells for the Y Sub-watershed (25-Year Event)

Priority 1, 2, and 3 critical cell thresholds were established based upon 1, 2 and 3 standard deviations of the mean using NPS cell yield data, event rainfall amount of 4.1 inches, and Event Intensity (EI) of 104.0, as follows:

Sediment erosion rate > 2,083 kg/acre or 2.30 tons/acre
Total nitrogen cell yields > 1.82 kg/acre or 4.01 lbs/acre
Total phosphorus cell yields > 0.75 kg/acre or 1.65 lbs/acre

The yields for each of these cells are listed in Table C-73 and Table C-74 and their locations in the sub-watershed are documented for sediment (Figure C-32), nitrogen (Figure C-33), and phosphorus (Figure C-34). Priority 1 and 2 critical cells should be given high priority during BMP planning and implementation.

Analysis of the Mina Lake watershed data indicates that 73 of 791 Y cells, or 9.2 percent, have a sediment yield greater than 2,083 kg/acre or 2.30 tons/acre. This is approximately 1.8 percent of the cells found within the Mina Lake watershed. The AGNPS model predicted that 4,064,130 kilograms (4,480 tons) of sediment would be generated during a single 25-year event from this sub-watershed.

The model estimated 77 cells, or 9.7 percent, have a total nitrogen yield greater than 1.82 kg/acre or 4.01 lbs/acre. The AGNPS model predicted that 0.77 kilograms of nitrogen would be generated per acre, for a total of 24,254 kg (26.7 tons) of nitrogen, during a single 25-year event.

The model also estimated 76 cells, or 9.6 percent, have a total phosphorus yield greater than 0.75 kg/acre or 1.65 lbs/acre. The AGNPS model predicted that 0.24 kilograms of phosphorus would be generated per acre, for a total of 7,750 kg (8.54 tons) of phosphorus, during a single 25-year event. A correlation between dissolved and sediment-bound nutrients was not determined.

Table C-129. Y sub-watershed priority-1 and 2 critical cells for sediment, nitrogen and phosphorus.

Y Priority-1 & 2 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
72	**8,682**	**309,087**	78	**6.89**	**0.24**	**7.12**	394	**3.50**	**0.01**	**3.51**
394	**8,410**	**220,764**	394	**7.00**	**0.11**	**7.11**	78	**3.44**	**0.01**	**3.46**
254	**8,065**	**764,068**	373	**4.76**	**0.92**	**5.67**	373	**2.38**	**0.18**	**2.56**
479	**7,838**	**472,671**	181	**4.60**	**0.98**	**5.58**	106	**2.46**	**0.09**	**2.55**
78	**7,375**	**216,291**	106	**4.93**	**0.51**	**5.44**	181	**2.30**	**0.20**	**2.49**
239	**7,103**	**579,565**	107	**4.49**	**0.51**	**5.00**	107	**2.24**	**0.09**	**2.33**
477	**6,895**	**186,980**	750	**0.89**	**4.06**	**4.95**	149	**1.87**	**0.20**	**2.07**
509	**6,895**	**657,937**	149	**3.74**	**0.98**	**4.73**	395	**1.85**	**0.01**	**1.86**
91	**6,777**	**610,309**	647	**2.45**	**2.01**	**4.46**	681	**1.52**	**0.24**	**1.77**
80	**6,632**	**300,152**	681	**3.05**	**1.21**	**4.26**	150	**1.64**	**0.11**	**1.75**
373	**5,017**	**136,341**	751	**1.94**	**2.30**	**4.24**	647	**1.22**	**0.43**	**1.66**
181	**4,853**	**130,671**	150	**3.27**	**0.61**	**3.88**	240	**1.52**	**0.01**	**1.53**
107	**4,663**	**126,634**	395	**3.70**	**0.11**	**3.81**	430	**1.49**	**0.01**	**1.50**
478	**4,518**	**364,380**	615	**2.45**	**1.21**	**3.66**	751	**0.97**	**0.50**	**1.47**
106	**4,318**	**142,392**	710	**2.45**	**1.21**	**3.66**	615	**1.22**	**0.24**	**1.47**
163	**4,246**	**139,371**	646	**1.86**	**1.61**	**3.47**	710	**1.22**	**0.24**	**1.47**
573	**4,218**	**605,764**	182	**2.42**	**0.98**	**3.40**	93	**1.35**	**0.10**	**1.45**
246	**4,173**	**1,326,614**	495	**2.10**	**1.30**	**3.40**	243	**1.33**	**0.11**	**1.44**
436	**4,173**	**159,057**	648	**1.38**	**2.01**	**3.40**	92	**1.32**	**0.10**	**1.42**
167	**4,001**	**738,150**	243	**2.67**	**0.61**	**3.28**	370	**1.42**	**0.01**	**1.42**
272	**3,946**	**861,863**	93	**2.69**	**0.58**	**3.27**	182	**1.21**	**0.20**	**1.40**
350	**3,946**	**95,354**	92	**2.64**	**0.58**	**3.23**	750	**0.44**	**0.91**	**1.35**
410	**3,946**	**212,853**	240	**3.05**	**0.17**	**3.22**	495	**1.05**	**0.26**	**1.31**
149	**3,810**	**101,015**	493	**0.83**	**2.33**	**3.16**	646	**0.93**	**0.34**	**1.27**
230	**3,475**	**1,370,078**	430	**2.98**	**0.11**	**3.09**	223	**1.10**	**0.16**	**1.26**
445	**3,475**	**238,771**	223	**2.20**	**0.85**	**3.04**	151	**1.09**	**0.11**	**1.20**
147	**3,320**	**519,473**	550	**1.03**	**2.01**	**3.04**	222	**1.03**	**0.16**	**1.19**
164	**3,320**	**184,513**	370	**2.83**	**0.13**	**2.96**	125	**1.17**	**0.01**	**1.17**
73	**3,230**	**107,964**	222	**2.05**	**0.85**	**2.90**	454	**1.01**	**0.16**	**1.17**
85	**3,230**	**405,095**	454	**2.03**	**0.85**	**2.88**	84	**1.14**	**0.01**	**1.15**
143	**3,230**	**226,443**	241	**1.94**	**0.92**	**2.86**	241	**0.97**	**0.18**	**1.15**
150	**3,221**	**85,384**	775	**1.45**	**1.39**	**2.84**	350	**1.03**	**0.12**	**1.15**
			349	**1.77**	**1.05**	**2.82**				
			151	**2.18**	**0.61**	**2.79**				
			693	**1.75**	**0.98**	**2.74**				
			350	**2.05**	**0.66**	**2.72**				
			557	**1.80**	**0.92**	**2.71**				
			463	**1.38**	**1.30**	**2.68**				
Critical Acres			Critical Acres				Critical Acres			
Priority 1		680	Priority 1			640	Priority 1			680
Priority 2		600	Priority 2			880	Priority 2			600

Shaded areas are Priority-1 cells

Table C-130. Y sub-watershed priority-3 critical cells for sediment, nitrogen and phosphorus.

Y Priority-3 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
75	**3,094**	**43,500**	743	**1.64**	**0.98**	**2.63**	648	**0.69**	**0.43**	**1.12**
370	**3,048**	**71,114**	678	**1.30**	**1.28**	**2.58**	349	**0.88**	**0.21**	**1.09**
510	**3,048**	**584,436**	263	**1.54**	**0.98**	**2.53**	557	**0.90**	**0.18**	**1.08**
694	**2,994**	**191,543**	403	**1.95**	**0.54**	**2.49**	403	**0.98**	**0.10**	**1.07**
148	**2,976**	**531,520**	125	**2.33**	**0.11**	**2.44**	693	**0.88**	**0.20**	**1.07**
240	**2,976**	**78,181**	285	**1.97**	**0.47**	**2.44**	285	**0.98**	**0.08**	**1.07**
245	**2,867**	**1,296,632**	644	**0.54**	**1.87**	**2.41**	431	**1.03**	**0.01**	**1.04**
681	**2,858**	**78,118**	84	**2.28**	**0.11**	**2.39**	743	**0.82**	**0.20**	**1.02**
751	**2,858**	**88,904**	704	**1.17**	**1.21**	**2.38**	775	**0.73**	**0.29**	**1.01**
77	**2,839**	**195,916**	732	**1.09**	**1.21**	**2.30**	399	**0.97**	**0.01**	**0.98**
89	**2,839**	**280,565**	277	**1.43**	**0.85**	**2.28**	464	**0.96**	**0.01**	**0.97**
290	**2,812**	**871,534**	231	**1.69**	**0.58**	**2.27**	263	**0.77**	**0.20**	**0.97**
255	**2,803**	**847,484**	425	**1.14**	**1.12**	**2.26**	463	**0.69**	**0.26**	**0.96**
71	**2,794**	**108,763**	402	**1.69**	**0.54**	**2.24**	231	**0.84**	**0.10**	**0.95**
165	**2,758**	**530,704**	525	**1.09**	**1.12**	**2.21**	402	**0.85**	**0.10**	**0.94**
471	**2,749**	**449,928**	431	**2.07**	**0.11**	**2.18**	550	**0.51**	**0.43**	**0.94**
221	**2,731**	**91,589**	399	**1.93**	**0.24**	**2.16**	123	**0.92**	**0.01**	**0.93**
166	**2,513**	**616,660**	464	**1.91**	**0.24**	**2.15**	493	**0.42**	**0.50**	**0.92**
293	**2,513**	**830,937**	556	**1.07**	**1.02**	**2.09**	678	**0.65**	**0.26**	**0.91**
92	**2,504**	**65,417**	562	**1.64**	**0.44**	**2.08**	562	**0.82**	**0.08**	**0.89**
93	**2,504**	**66,887**	566	**1.61**	**0.44**	**2.05**	79	**0.88**	**0.01**	**0.89**
94	**2,504**	**400,994**	731	**0.80**	**1.21**	**2.01**	164	**0.83**	**0.05**	**0.88**
33	**2,440**	**138,464**	123	**1.83**	**0.17**	**2.00**	566	**0.81**	**0.08**	**0.88**
508	**2,422**	**69,001**	195	**1.41**	**0.58**	**1.99**	72	**0.87**	**0.01**	**0.88**
125	**2,377**	**55,901**	79	**1.75**	**0.24**	**1.99**	277	**0.71**	**0.16**	**0.88**
395	**2,377**	**198,828**	164	**1.67**	**0.31**	**1.99**	80	**0.77**	**0.07**	**0.84**
63	**2,368**	**22,235**	621	**1.45**	**0.54**	**1.99**	704	**0.59**	**0.24**	**0.83**
231	**2,368**	**74,807**	677	**0.80**	**1.18**	**1.98**	195	**0.71**	**0.10**	**0.81**
182	**2,322**	**116,945**	696	**1.05**	**0.92**	**1.97**	621	**0.72**	**0.09**	**0.81**
651	**2,322**	**3,953,117**	80	**1.54**	**0.42**	**1.96**	163	**0.80**	**0.01**	**0.81**
68	**2,268**	**118,841**	699	**0.38**	**1.58**	**1.96**	692	**0.79**	**0.01**	**0.80**
664	**2,204**	**115,820**	744	**0.96**	**0.98**	**1.95**	66	**0.78**	**0.01**	**0.80**
585	**2,195**	**3,152,798**	670	**0.34**	**1.58**	**1.91**	425	**0.57**	**0.22**	**0.79**
615	**2,195**	**59,384**	769	**0.65**	**1.26**	**1.91**	732	**0.54**	**0.24**	**0.79**
646	**2,195**	**84,259**	727	**0.34**	**1.55**	**1.89**	218	**0.76**	**0.01**	**0.77**
647	**2,195**	**59,384**	617	**1.32**	**0.54**	**1.87**	662	**0.76**	**0.01**	**0.77**
710	**2,195**	**59,384**	72	**1.74**	**0.12**	**1.86**	525	**0.54**	**0.22**	**0.77**
114	**2,132**	**395,896**	390	**0.47**	**1.38**	**1.86**	537	**0.70**	**0.06**	**0.76**
291	**2,114**	**841,406**	643	**0.59**	**1.24**	**1.83**	617	**0.66**	**0.10**	**0.76**
563	**2,114**	**51,120**					124	**0.74**	**0.01**	**0.75**
223	**2,087**	**51,873**					410	**0.72**	**0.04**	**0.75**
							436	**0.74**	**0.01**	**0.75**
							477	**0.73**	**0.02**	**0.75**
							190	**0.74**	**0.01**	**0.75**
Critical Acres			Critical Acres				Critical Acres			
Priority 3		1,640	Priority 3			1,560	Priority 3			1,760

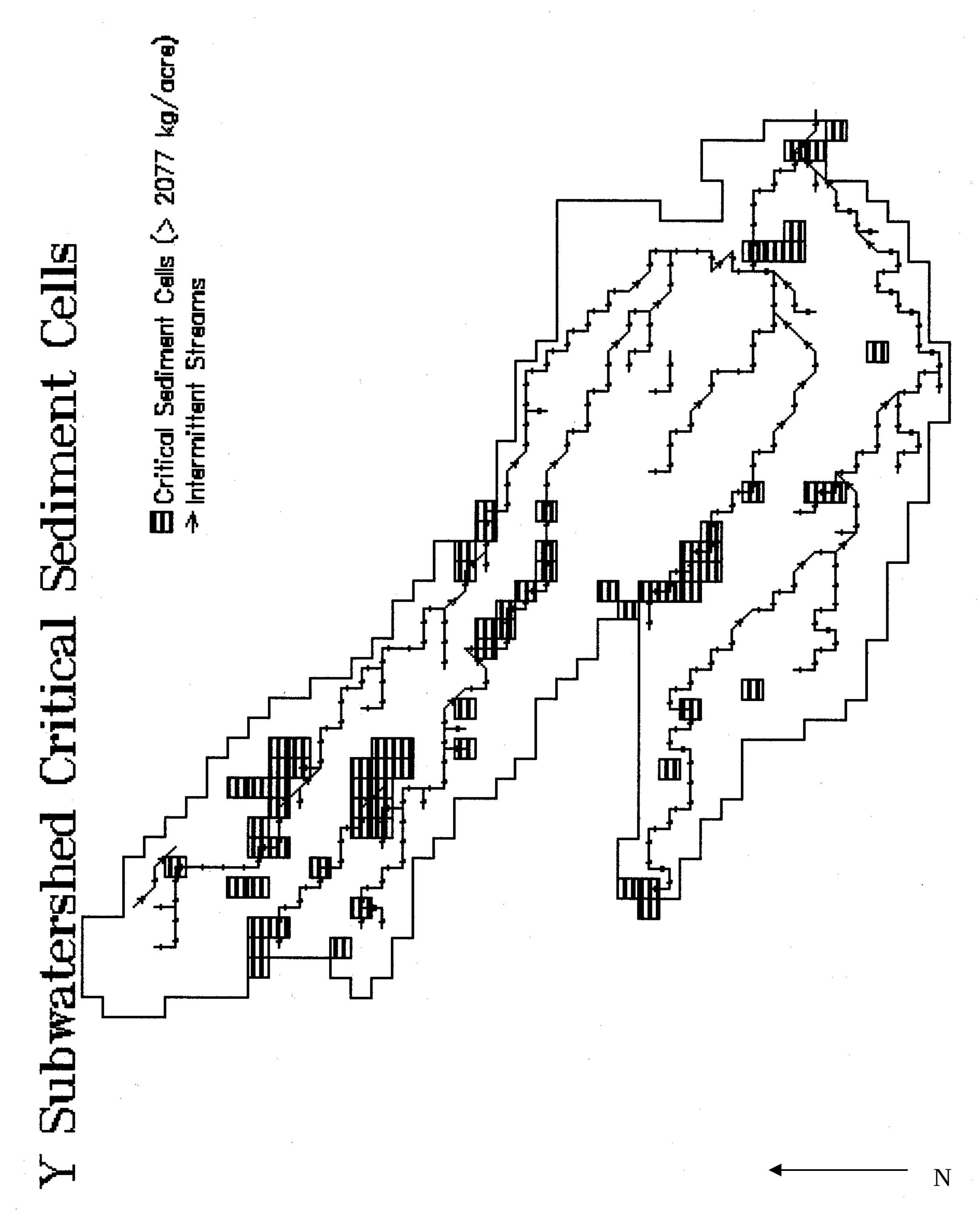


Figure C-102. Critical sediment cells for the Y sub-watershed of Mina Lake.

Sediment Analysis

The AGNPS model calculated that the sediment delivered from the sub-watershed is 41 kg/acre/year for an estimated annual load. As a result, 1,296,058 kg or 1,429 tons of sediment would be generated annually from this sub-watershed. In summary, the Y sub-watershed was estimated to contribute 56 percent of the west tributary sediment load, 13 percent of the total sediment load to Mina Lake. The Y sub-watershed contains 15 percent of the critical erosion cells within 20 percent of the watershed surface area. Based on the export coefficient, the sub-watershed is ranked fifth of eight on a list of priorities for sediment improvements.

The high sediment yield within the sub-watershed critical cells can be attributed to land use, minimal buffers, land slope, and proximity to surface water conduits. Common critical cell characteristics for the Mina Lake system include croplands with a slope greater than 2 percent that are closer than 152 meters (500 feet) to a stream.

Total Nutrient Analysis

The AGNPS data indicated that the Y subwatershed had a total nitrogen (soluble + sediment-bound) transport rate of 1.04 kg/acre/year (equivalent to 33,099 kg or 36 tons per year). Seventy-seven percent of the transported nitrogen from this sub-watershed was estimated to be in dissolved form while 77 percent of the total nitrogen load to Mina Lake was estimated to be in dissolved form. The total nitrogen load delivered from all sub-watersheds to Mina Lake was also estimated to be 211,203 kg or 233 tons/year. As a result, the Y sub-watershed load to Mina Lake was 16 percent of the total nitrogen load (tied with North Crompton). Based on the export coefficients for nitrogen, the Y sub-watershed was rated sixth of eight for nitrogen reduction priority.

This sub-watershed had a total phosphorus (soluble + sediment-bound) transport rate of 0.25 kg/acre/year (equivalent to a total 8,037 kg or 9.0 tons per year). Fifty-four percent of the transported phosphorus from this sub-watershed was estimated to be in dissolved form while 56 percent of the total phosphorus load to Mina Lake was estimated to be in dissolved form. The total phosphorus load delivered from all sub-watersheds to Mina Lake was estimated to be 53,300 kg/year (59 tons/year). As a result, the Y load to Mina Lake was 15 percent of the total phosphorus load. Based on the transport coefficient for phosphorus, the Y sub-watershed was rated seventh of eight for phosphorus reduction priority.

Dissolved nitrogen and phosphorus nutrient levels from Y sub-watershed were estimated to be 77 and 54 percent, respectively.

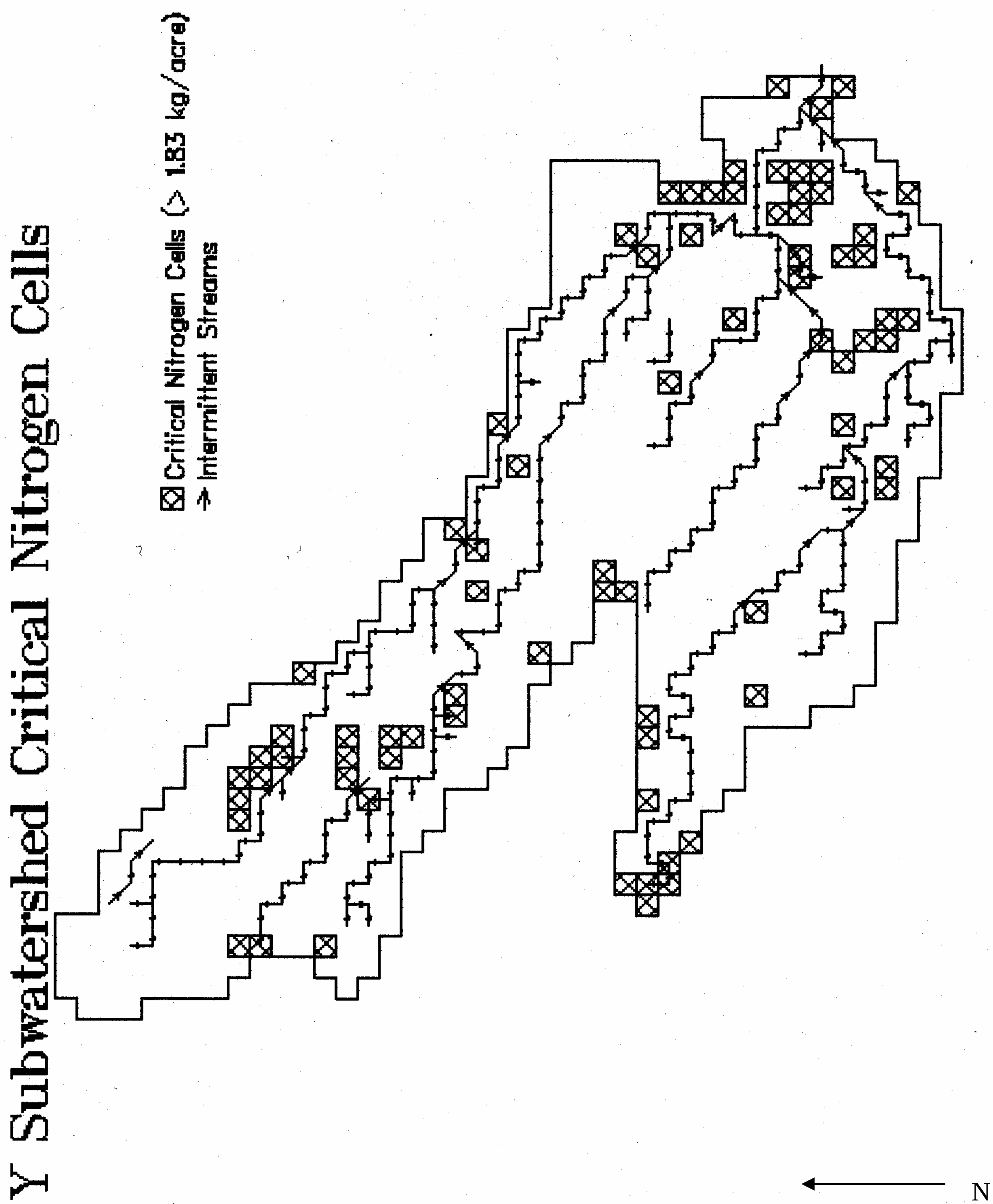


Figure C-103. Critical nitrogen cells of the Y sub-watershed of Mina Lake.

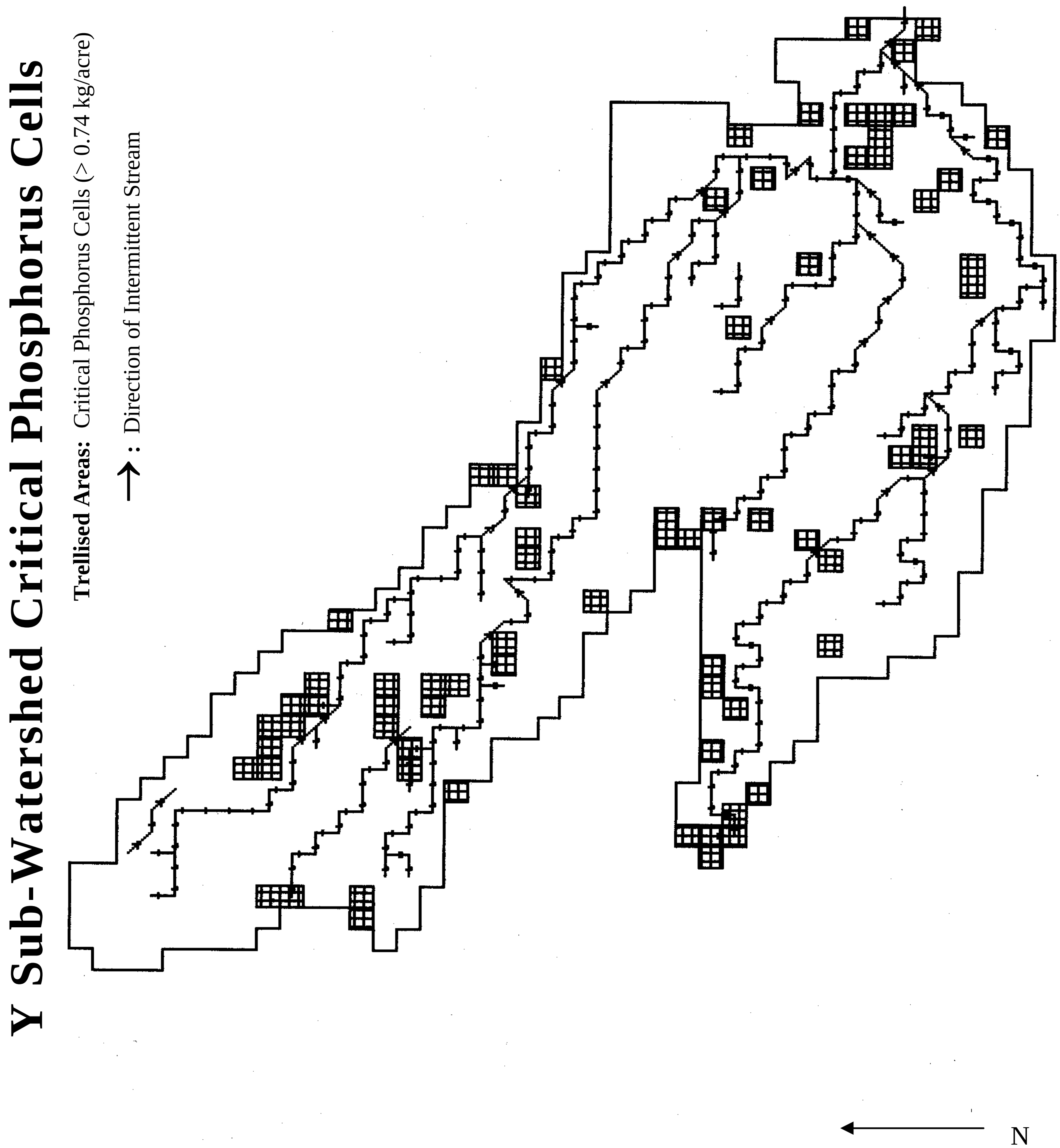


Figure C-104. Critical phosphorus cells for the Y sub-watershed of Mina Lake.

Priority Ranking of Animal Feeding Areas for the Y Sub-watershed (25-Year Event)

A total of 17 animal feeding areas were identified during the AGNPS data acquisition phase of the project. Table C-77 lists the AGNPS analysis of each feeding area. Of these, three had an AGNPS ranking greater than 40. AGNPS ranks feeding areas from zero to 100 with a zero ranked feeding area having a smaller pollution potential and a 100 ranking having a large pollution potential. AGNPS estimates the total impact of having a feeding area or multiple feeding areas within a cell by combining and recalculating all values to arrive at nutrient and COD values to the cell. Critical feeding area locations are depicted in Figure C-28.

Table C-131. Critical Cell (CC) reduction efficiency ratio for the Y sub-watershed

Cell Number and Parameter	Feedlot Mass Generated (kg)	Transport Coefficient from (CC) Load Data **	Total Mass Transported (kg)	Difference (kg)	Reduction Efficiency Coefficient (kg/acre)	Rating (Table C- 76)
#224 Nitrogen	**3.94**	**0.65**	**26.0**	**-22.1**	**-0.55**	**MU**
#224 Phosphorus	**0.66**	**0.25**	**10.0**	**-9.34**	**-0.23**	**MU**
#225 Nitrogen	**2.63**	**1.15**	**46.0**	**-43.4**	**-1.08**	**MU**
#225 Phosphorus	**0.44**	**0.49**	**19.6**	**-19.2**	**-0.48**	**MU**
#303 Nitrogen	**20.2**	**1.59**	**63.6**	**-43.4**	**-1.09**	**MU**
#303 Phosphorus	**3.37**	**0.57**	**22.8**	**-19.4**	**-0.49**	**MU**
#318 Nitrogen*	**166**	**0.65**	**26.0**	**140**	**3.50**	**F**
#318 Phosphorus *	**64.2**	**0.24**	**9.60**	**54.6**	**1.37**	**MF**
#577 Nitrogen	**103**	**1.62**	**64.8**	**38.2**	**0.96**	**MF**
#577 Phosphorus	**39.0**	**0.60**	**24.0**	**15.0**	**0.38**	**MF**
#590 Nitrogen	**10.3**	**0.55**	**22.0**	**-11.7**	**-0.29**	**MU**
#590 Phosphorus	**2.89**	**0.19**	**7.60**	**-4.71**	**-0.12**	**MU**
Average					0.16	MF

Shaded area indicates critical nutrient cells
* = Indicates critical feedlot cell
** = Indicates threshold values for the Y sub-watershed (nitrogen yields > 1.82 kg/acre or phosphorus yields > 0.75 kg/acre)

Table C-132. Nutrient reduction efficiency rating scale for Mina Lake.

Rating	Criteria
Favorable (F)	**Greater than 2.0 kg/acre**
Marginally Favorable (MF)	**Between 0.1 and 2.0 kg/acre**
Neutral (N)	**Between -0.1 and 0.1 kg/acre**
Marginally Unfavorable (MU)	**Between –2 and –0.1 kg/acre**
Unfavorable (U)	**Less than –2.0 kg/acre**

In order to determine the impact of the feeding areas, AGNPS outputs from nutrient and feeding area critical cell data were analyzed (Table C-75). A reduction efficiency coefficient was determined by calculating a ratio of the difference (per acre) between the

overall amount of nutrients generated per cell (acres multiplied by transport coefficient) and feedlot-generated nutrient loads. The results were then used to estimate the cell capacity, or lack of capacity, to reduce nutrient levels under current conditions. Topographical gradient, size, location of buffering zones and proximity to surface conduits were possible influences upon nutrient reduction and diffusion.

Reduction efficiency coefficients range from positive to negative values and were interpreted using a sliding scale with values and ratings based on Table C-76. All feeding areas critical or not were analyzed for reduction potential to determine trends and ratings. These values may be used to estimate the sensitivity or resistance potential of the cell to perturbations within the feeding area(s) (increasing the number of animal units/area) or within the cell (changes in landscape/landuse, buffer reduction, tillage practices, etc.) based on current conditions. BMP improvements in the feeding areas or the cell with favorable/marginally favorable ratings will respond/improve more rapidly than the cell with a neutral to unfavorable rating. Another use for this rating may be to prioritize/rank all critical feeding areas (feeding areas needing BMPs) within a watershed by reduction efficiency (improvement potential) to target/select feeding areas to realize maximum nutrient reduction in the watershed when implementation funds are limited.

None of the cells with feedlot areas exceeded critical nutrient threshold limits; however, cell #318 exceeded critical feedlot nutrient limits for two feedlots. The higher efficiency ratio may indicate that the feeding area nutrients had a greater impact on nutrient output than the cell, but were well buffered and cell supportable. Cell #577 did not exceed feeding area nutrient limits, because the AGNPS method used to develop feeding area critical values caused a feeding area to be ignored. Most of the other cells were shown to be marginally unfavorable, which indicated that non-feedlot activities might have a greater impact on nutrient production levels, but are fully cell-supportable. The sub-watershed, as a whole, was found to have a marginally unfavorable efficiency ratio when the high positive values from cell #318 were ignored. The overall nutrient levels are cell-supportable; however, cell output would be sensitive to elevated (increased) nutrient concentrations.

The animal feeding areas rated above 40 should be monitored for animal density or use-intensity. If use intensifies without modification of current conditions, the potential for sediment and nutrient yield will increase, especially in unfavorable to marginally unfavorable cells. Positive steps should be taken to identify and modify existing conditions within critical feeding areas. Careful study of feeding area size, animal density/intensity of use, and buffering capacity may be needed to reduce the AGNPS feedlot ratings and increase the reduction efficiencies (ratings).

Improvements in feeding areas and cells with favorable to marginally favorable rating would be expected to show marked improvement. Sources of nutrient loads not modeled through this study were those from septic systems and livestock with direct access to the lake or adjacent streams.

Table C-133. AGNPS feedlot ratings and data for the Y sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 303		Cell # 303 TOTAL	
Nitrogen concentration (ppm)	**4.56**	**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)	**0.76**	**Phosphorus concentration (ppm)**	
COD concentration (ppm)	**22.8**	**COD concentration (ppm)**	
Nitrogen mass (kg)	**6.78**	**Nitrogen mass (kg)**	**20.2**
Phosphorus mass (kg)	**1.13**	**Phosphorus mass (kg)**	**3.37**
COD mass (kg)	**33.9**	**COD mass (kg)**	**101**
Animal feedlot rating number	0	**Animal feedlot rating number**	**-**

Cell # 303		Cell # 224	
Nitrogen concentration (ppm)	**4.61**	**Nitrogen concentration (ppm)**	**2.22**
Phosphorus concentration (ppm)	**0.77**	**Phosphorus concentration (ppm)**	**0.37**
COD concentration (ppm)	**23.1**	**COD concentration (ppm)**	**11.1**
Nitrogen mass (kg)	**3.15**	**Nitrogen mass (kg)**	**2.63**
Phosphorus mass (kg)	**0.53**	**Phosphorus mass (kg)**	**0.44**
COD mass (kg)	**15.8**	**COD mass (kg)**	**13.1**
Animal feedlot rating number	0	**Animal feedlot rating number**	0

Cell # 303	
Nitrogen concentration (ppm)	**2.26**
Phosphorus concentration (ppm)	**0.38**
COD concentration (ppm)	**11.3**
Nitrogen mass (kg)	**2.88**
Phosphorus mass (kg)	**0.48**
COD mass (kg)	**14.4**
Animal feedlot rating number	0

Cell # 303	
Nitrogen concentration (ppm)	**7.63**
Phosphorus concentration (ppm)	**1.27**
COD concentration (ppm)	**38.2**
Nitrogen mass (kg)	**7.39**
Phosphorus mass (kg)	**1.23**
COD mass (kg)	**37.0**

Animal feedlot rating number 0

Table C-77 (Continued). AGNPS feedlot ratings and data for the Y sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 577		Cell # 225	
Nitrogen concentration (ppm)	**25.8**	**Nitrogen concentration (ppm)**	**0.89**
Phosphorus concentration (ppm)	**9.16**	**Phosphorus concentration (ppm)**	**0.15**
COD concentration (ppm)	**918**	**COD concentration (ppm)**	**4.43**
Nitrogen mass (kg)	**48.4**	**Nitrogen mass (kg)**	**1.20**
Phosphorus mass (kg)	**17.2**	**Phosphorus mass (kg)**	**0.2**
COD mass (kg)	**1,723**	**COD mass (kg)**	**6.00**
Animal feedlot rating number	48	**Animal feedlot rating number**	0

Cell # 577		Cell # 225	
Nitrogen concentration (ppm)	**28.3**	**Nitrogen concentration (ppm)**	**0.77**
Phosphorus concentration (ppm)	**11.0**	**Phosphorus concentration (ppm)**	**0.13**
COD concentration (ppm)	**516**	**COD concentration (ppm)**	**3.85**
Nitrogen mass (kg)	**45.1**	**Nitrogen mass (kg)**	**1.05**
Phosphorus mass (kg)	**17.6**	**Phosphorus mass (kg)**	**0.18**
COD mass (kg)	**823**	**COD mass (kg)**	**5.26**
Animal feedlot rating number	38	**Animal feedlot rating number**	0

Cell # 577		Cell # 225	
Nitrogen concentration (ppm)	**48.6**	**Nitrogen concentration (ppm)**	**1.98**
Phosphorus concentration (ppm)	**22.3**	**Phosphorus concentration (ppm)**	**0.33**
COD concentration (ppm)	**1,045**	**COD concentration (ppm)**	**9.90**
Nitrogen mass (kg)	**9.13**	**Nitrogen mass (kg)**	**1.69**
Phosphorus mass (kg)	**4.20**	**Phosphorus mass (kg)**	**0.28**
COD mass (kg)	**196**	**COD mass (kg)**	**8.46**
Animal feedlot rating number	17	**Animal feedlot rating number**	0

Cell # 577 TOTAL		Cell # 225 TOTAL	
Nitrogen concentration (ppm)		**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)		**Phosphorus concentration (ppm)**	
COD concentration (ppm)		**COD concentration (ppm)**	
Nitrogen mass (kg)	**103**	**Nitrogen mass (kg)**	**3.94**
Phosphorus mass (kg)	**39.0**	**Phosphorus mass (kg)**	**0.66**
COD mass (kg)	**2,743**	**COD mass (kg)**	**19.7**

Animal feedlot rating number	-	Animal feedlot rating number	-

Table C-77 (Continued). AGNPS feedlot ratings and data for the Y sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 318		Cell # 318 TOTAL	
Nitrogen concentration (ppm)	**48.6**	**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)	**22.0**	**Phosphorus concentration (ppm)**	
COD concentration (ppm)	**1,025**	**COD concentration (ppm)**	
Nitrogen mass (kg)	**78.9**	**Nitrogen mass (kg)**	**166**
Phosphorus mass (kg)	**35.7**	**Phosphorus mass (kg)**	**64.2**
COD mass (kg)	**1,663**	**COD mass (kg)**	**3,851**
Animal feedlot rating number	47	**Animal feedlot rating number**	-
Cell # 318		Cell # 590	
Nitrogen concentration (ppm)	**26.8**	**Nitrogen concentration (ppm)**	**18.8**
Phosphorus concentration (ppm)	**11.0**	**Phosphorus concentration (ppm)**	**5.96**
COD concentration (ppm)	**508**	**COD concentration (ppm)**	**257**
Nitrogen mass (kg)	**16.0**	**Nitrogen mass (kg)**	**7.84**
Phosphorus mass (kg)	**6.58**	**Phosphorus mass (kg)**	**2.48**
COD mass (kg)	**302**	**COD mass (kg)**	**107**
Animal feedlot rating number	23	**Animal feedlot rating number**	9
Cell # 318		Cell # 590	
Nitrogen concentration (ppm)	**52.9**	**Nitrogen concentration (ppm)**	**0.93**
Phosphorus concentration (ppm)	**22.1**	**Phosphorus concentration (ppm)**	**0.15**
COD concentration (ppm)	**1,021**	**COD concentration (ppm)**	**4.66**
Nitrogen mass (kg)	**12.0**	**Nitrogen mass (kg)**	**2.46**
Phosphorus mass (kg)	**5.03**	**Phosphorus mass (kg)**	**0.41**
COD mass (kg)	**232**	**COD mass (kg)**	**12.3**
Animal feedlot rating number	19	**Animal feedlot rating number**	0
Cell # 318		Cell # 590 TOTAL	
Nitrogen concentration (ppm)	**38.9**	**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)	**11.1**	**Phosphorus concentration (ppm)**	
COD concentration (ppm)	**1,083**	**COD concentration (ppm)**	
Nitrogen mass (kg)	**59.4**	**Nitrogen mass (kg)**	**10.3**
Phosphorus mass (kg)	**16.9**	**Phosphorus mass (kg)**	**2.89**
COD mass (kg)	**1,653**	**COD mass (kg)**	**119**

Animal feedlot rating number	47	Animal feedlot rating number	-

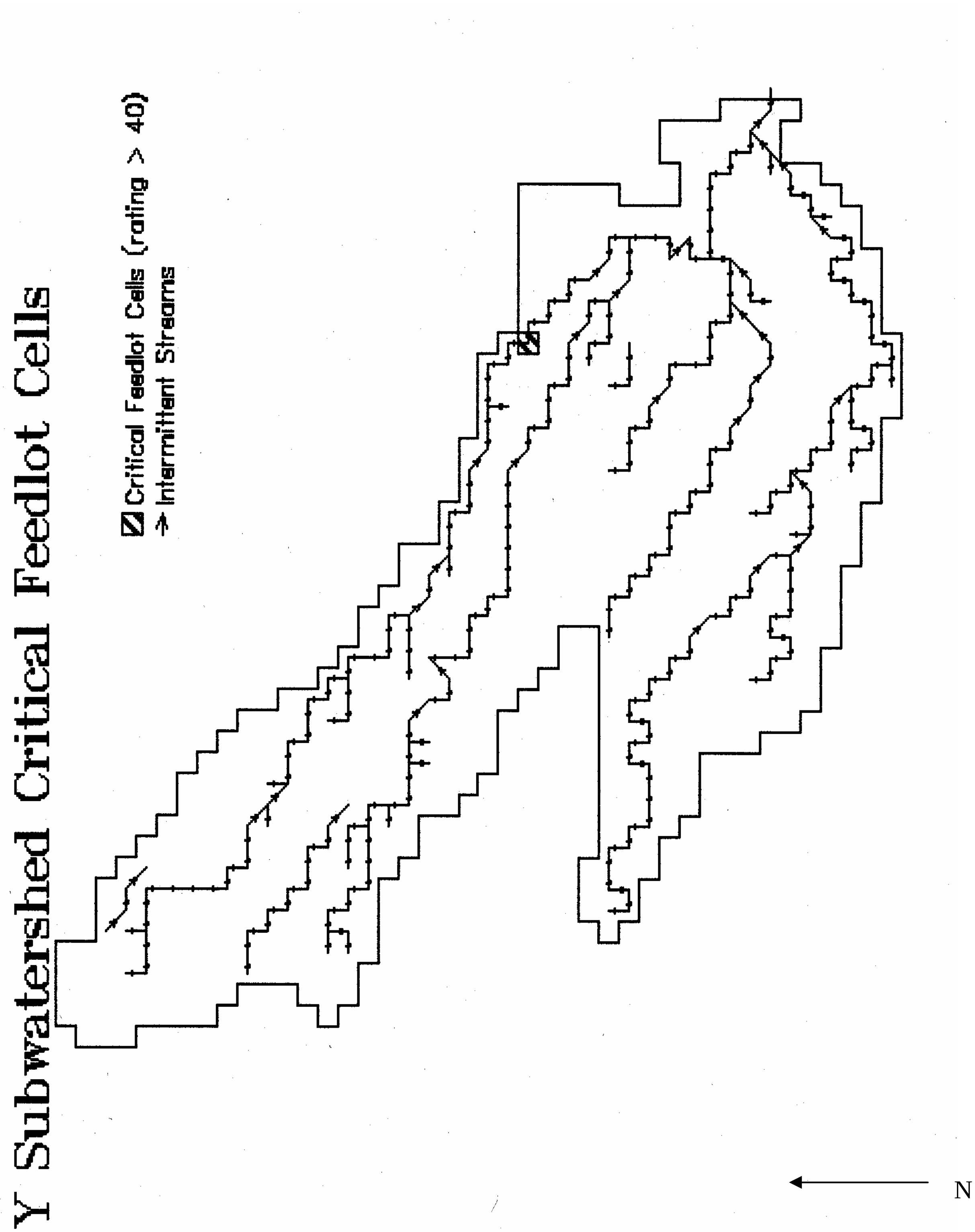


Figure C-105. Critical feedlot cells for the Y sub-watershed of Mina Lake.

Modeled Sediment, Nitrogen and Phosphorus Reductions (Y Sub-watershed)

Several Best Management Practices (BMP) were modeled using the AGNPS computer model. These included installation of Animal Waste Management Systems (AWMS), grassed waterways, reduction of crop ground fertilizer application levels, and conversion of conventional till practices to minimum or no-till methods.

Seventeen feeding areas within the Y sub-watershed were identified. The AGNPS assessment of field feedlot data rated one feeding area as critical (rated above 40, based on objective criteria). Efforts to improve feeding areas would result in minimal reductions of total nitrogen and phosphorus.

AGNPS compared fertilizer application rates using the current rate of application (approx. 45.4 kg or 100 lbs/acre nitrogen and 18.1 kg or 40 lbs/acre phosphorus) to a reduced rate rate (22.7 kg/acre or 50 lbs/acre nitrogen and 9.1 kg/acre or 20 lbs/acre phosphorus). The sub-watershed model indicated a reduction in the total nitrogen load from 33,009 kg/year or 36.4 tons/year to 31,553 kg/year or 34.8 tons/year (4 percent). The total phosphorus would be reduced from 8,037 kg/year or 8.9 tons/year to 7,777 kg/year or 8.6 tons/year (3 percent).

The model estimated that modifying tilled acreage within critical erosion cells to conservation tillage practices would reduce the sediment load delivered by Snake Creek from 1,296,058 kg/year to 1,153,492 kg/year (11 percent reduction). The sub-watershed model indicated a reduction in the total nitrogen load from 33,009 kg/year or 36.4 tons/year to 30,233 kg/year or 33.3 tons/year (8 percent) and total phosphorus from 8,037 kg/year or 8.9 tons/year to 7,258 kg/year or 8.0 tons/year (9 percent). Based on AGNPS reduction estimates, conversion from conventional to minimum/no tillage will have the greatest impact on the watershed.

BMP recommendations should be implemented within the sub-watershed and site priority critical cells (Table C-78 and Table C-79). Field data for priority critical cells should be field-verified prior to BMP planning and implementation. The AGNPS model did not simulate grass waterways or gully and streambank erosion, however, these BMPs should also be evaluated.

Table C-134. AGNPS modeling reductions for the Y sub-watershed BMPs[1].

BMP	Unit	Percent		
		Sediments	Nitrogen	Phosphorus
Feedlot	**Y**	**0**	**0**	**0**
Fertilizer	**Y**	**0**	**4**	**3**
Minimum Till	**Y**	**11**	**8**	**9**
Sub-watershed Total		**11**	**12**	**12**

[1] = Reductions calculated 1999-2000 field data

Table C-135. AGNPS modeling reductions for the Snake Creek 6 (SC-6) sub-watershed BMPs[1].

BMP	Unit	Percent		
		Sediments	Nitrogen	Phosphorus
Feedlot	**SC-6**	**0**	**0**	**0**
Fertilizer	**SC-6**	**0**	**5**	**3**
Minimum Till	**SC-6**	**11**	**12**	**11**
Site Total		**11**	**17**	**14**

[1] = Reductions calculated 1999-2000 field data

AGNPS Ungauged Sub-watershed AGNPS Analysis (A Sub-watershed of Mina Lake)

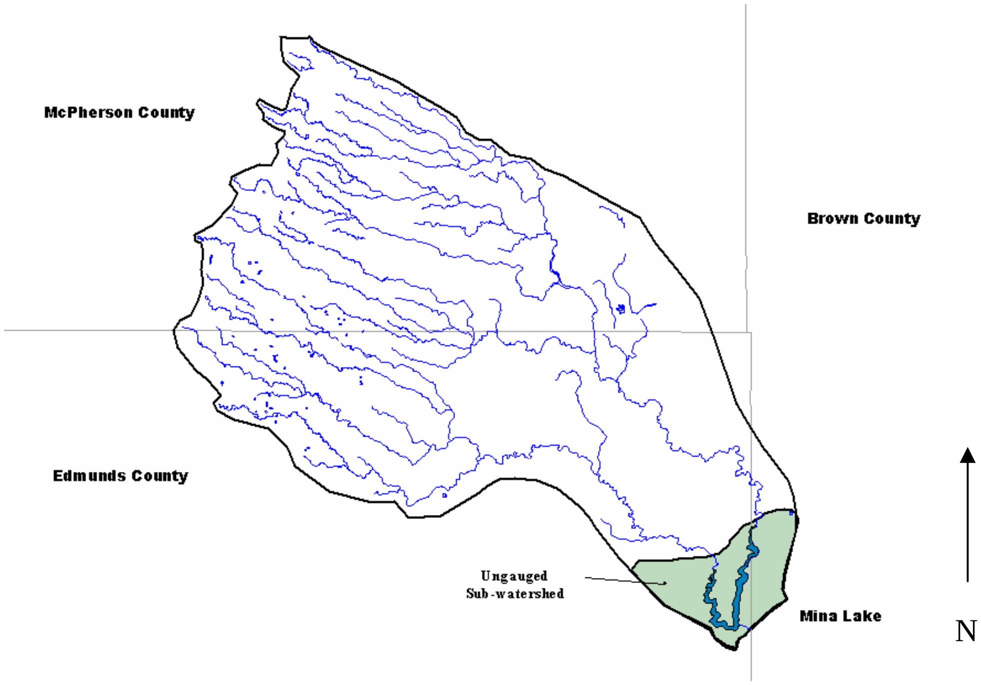


Figure C-106. The AGNPS Ungauged Sub-watershed within the Mina Lake watershed.

The AGNPS Ungauged sub-watershed is located within Edmunds County, in northeastern South Dakota, and encompasses the land mass adjacent to Mina Lake. AGNPS Ungauged acreage contributes 4 percent of total hydrologic input to the Mina system and has an approximate area of 2,574 hectares (6,360 acres). The AGNPS Ungauged sub-watershed is a very shallow basin that drops 11 meters or 36 feet over 4.7 kilometers or 2.9 miles (0.2 percent grade) and serves as the discharge for the entire watershed (Figure C-36).

The AGNPS Ungauged sub-watershed is not one of the seven stream networks in the Mina Lake Watershed Assessment Project. Instead, the AGNPS Ungauged acreage contributes directly to sediment and nutrient loads by virtue of its immediate proximity to the lake. Five monitoring sites were set up at various locations along Snake Creek to collect water quantity and quality parameters within the creek. No sites were located within the AGNPS Ungauged sub-watershed.

Due to the lack of site-specific water quality data, a computer model was selected to assess the Non-point Source (NPS) loads throughout the Mina Lake watershed. The West Mina watershed is one of seven sub-watersheds in the Mina Lake Watershed Assessment Project. The data was used to model current loading to Snake Creek and was used for comparisons to other sub-watersheds in the Mina Lake drainage.

Cropping practices, including tillage and fertilizer use, and range management directly influence the intensity of sediment and nutrient runoff. None of the AGNPS Ungauged

sub-watershed is used for cropland; the acreage may instead be used as rangeland, pasture and lake front home sites. Tillage, fertilizer, and feedlot Best Management Practices (BMPs) were modeled and analyzed to estimate the runoff reduction potential within the sub-watershed.

Evaluation/Quantification of Sub-watershed Non-Point Source Loading

Delineation and Location of Sub-watershed

The following AGNPS outlet cell numbers correlate to AGNPS sub-watershed and water quality monitoring sites used in the Mina Lake watershed assessment study in 1999 and 2000 (Table C-80):

Table C-136. Outlet cell number for the AGNPS Ungauged sub-watershed of Mina Lake.

Sub-watershed	AGNPS outlet cell number
AGNPS Ungauged	**West Mina - 736**

The following tables estimate the delivery coefficients, annual loading and critical values for priority cells for sediment (Table C-81), nitrogen (Table C-82), and phosphorus (Table C-83) in the AGNPS Ungauged sub-watershed:

Table C-137. Export coefficients (kg/acre) for the Ungauged sub-watersheds of Mina Lake♣.

				Export Coefficients					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area acres	Percent of Watershed	Sediment kg/acre	Attached-N kg/acre	Dissolved-N kg/acre	Total Nitrogen kg/acre	Attached-P kg/acre	Dissolved-P kg/acre	Total Phosphorus kg/acre
Ungauged (AGNPS)	**6,360**	**4**	**214**	**0.73**	**1.68**	**2.41**	**0.36**	**0.31**	**0.67**
Ungauged (Site)	**12,880**	**8**	**108**	**0.40**	**1.20**	**1.60**	**0.21**	**0.24**	**0.45**

Table C-138. Annualized loading (kg) for the Ungauged sub-watersheds of Mina Lake♣.

				Sub-watershed Loading					
				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area acres	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
Ungauged (AGNPS)	**6,360**	**4**	**1,363,961**	**4,628**	**10,711**	**15,340**	**2,307**	**1,976**	**4,282**
Ungauged (Site)	**12,880**	**8**	**1,397,137**	**5,112**	**15,515**	**20,626**	**2,720**	**3,096**	**5,816**

Table C-139. Priority cell threshold values for the AGNPS ungauged sub-watershed of Mina Lake♣.

	Critical Values (kg/acre)		
Parameter	Priority 1	Priority-2	Priority-3
Sediment	**3,645**	**2,650**	**1,654**
Nitrogen	**3.47**	**2.63**	**1.78**
Phosphorus	**1.36**	**1.01**	**0.66**

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulative rainfall events during a average year. This includes a 1-year, 24-hour event of 1.85 inches (EI = 17.5), 3 semiannual rainfall events of 1.23 inches (EI = 7.4) and a series of 10 small rainfall events of 0.8 inch (EI = 3.0) for a total "R" factor of 69.7.

Identification of Critical Non-Point Source Cells (25-Year Event)

Priority 1, 2, and 3 critical cell thresholds were established based upon 1, 2 and 3 standard deviations of the mean using NPS cell yield data, event rainfall amount of 4.1 inches, and Event Intensity (EI) of 104.0, as follows:

Sediment erosion rate >1,654 kg/acre or 1.82 ton/acre
Total nitrogen cell yields > 1.78 kg/acre or 3.92 lbs/acre
Total phosphorus cell yields > 0.66 kg/acre or 1.46 lbs/acre

The yields for each of these cells are listed in Tables C-84 through C-89 and their locations in the sub-watershed are documented within East and West Mina sub-watershed maps. Priority 1 and 2 critical cells should be given high priority during BMP planning and implementation.

Analysis of the Mina Lake watershed data indicates that 31 of 344 AGNPS Ungauged sub-watershed cells, or 9 percent, have a sediment yield greater than 1,654 kg/acre (approximately 20 in-lake water cells were not included in the total). This is approximately 0.8 percent of the cells found within the Mina Lake watershed. The AGNPS model predicted that 163,629 kilograms (180 tons) of sediment would be generated during a single 25-year event from this sub-watershed.

The model estimated 31 of 344 AGNPS Ungauged cells, or 9 percent, have a total nitrogen yield greater than 1.78 kg/acre. The AGNPS model predicted that 1.79 kilograms of nitrogen would be generated per acre, for a total of 11,395 kg (12.6 tons) of nitrogen, during a single 25-year event.

The model also estimated 26 cells, or 7.6 percent, have a total phosphorus yield greater than 0.66 kg/acre. The AGNPS model predicted that 0.67 kilograms of phosphorus would be generated per acre, for a total of 4,270 kg (4.71 tons) of phosphorus, during a single 25-year event. A correlation between dissolved and sediment-bound nutrients was not determined.

Table C-140. AGNPS Ungauged sub-watersheds priority 1 and 2 critical cells for sediment.

West Mina Sub-watershed			East Mina Sub-watershed		
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)
654	**3,520**	**554,209**	528	**2,295**	**107,583**
661	**2,585**	**95,880**	547	**2,295**	**109,788**
632	**2,295**	**113,979**	531	**2,005**	**83,497**
730	**2,295**	**61,008**	523	**1,860**	**285,927**
707	**2,105**	**56,119**			
633	**2,014**	**194,328**			
660	**2,014**	**52,018**			
676	**1,923**	**82,917**			
Critical Acres			Critical Acres		
Priority 1		80	Priority 1		0
Priority 2		240	Priority 2		160

Shaded areas are Priority-1 cells

Table C-141. AGNPS Ungauged sub-watershed priority-3 critical cells for sediment.

AGNPS Ungauged Sub-watershed Sediment Priority-3 Cells					
West Mina Sub-watershed			East Mina Sub-watershed		
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)
649	**1,751**	**48,798**	510	**1,769**	**46,657**
636	**1,742**	**43,808**	527	**1,733**	**46,339**
653	**1,660**	**163,629**	540	**1,361**	**30,745**
637	**1,415**	**58,087**	514	**1,297**	**34,936**
656	**1,352**	**53,460**			
735	**1,243**	**28,504**			
Critical Acres			Critical Acres		
Priority 3		240	Priority 3		160

Table C-142. AGNPS Ungauged sub-watershed priority-1 and 2 critical cells for nitrogen.

AGNPS Ungauged sub-watershed Nitrogen Priority-1 and 2 Cells							
West Mina Sub-watershed				East Mina Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
730	**2.50**	**3.27**	**5.77**	527	**2.00**	**2.19**	**4.20**
707	**2.34**	**1.48**	**3.82**	510	**2.02**	**1.66**	**3.67**
650	**0.88**	**2.84**	**3.72**	514	**1.60**	**1.30**	**2.90**
661	**1.49**	**2.01**	**3.50**	528	**1.30**	**1.25**	**2.54**
649	**1.20**	**1.54**	**2.74**				
660	**1.27**	**1.38**	**2.65**				
Critical Acres				Critical Acres			
Priority 1			160	Priority 1			80
Priority 2			80	Priority 2			80

Shaded areas are Priority-1 cells

Table C-143. AGNPS Ungauged sub-watershed priority-3 critical cells for nitrogen.

AGNPS Ungauged sub-watershed Nitrogen Priority-3 Cells							
West Mina Sub-watershed				East Mina Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
731	**0.76**	**1.74**	**2.50**	538	**0.47**	**1.74**	**2.21**
687	**0.73**	**1.43**	**2.16**	540	**1.45**	**0.63**	**2.08**
637	**1.00**	**0.91**	**1.91**	547	**0.76**	**1.22**	**1.97**
688	**0.72**	**1.12**	**1.83**	529	**0.72**	**1.04**	**1.76**
636	**1.10**	**0.72**	**1.82**				
732	**0.52**	**1.23**	**1.76**				
Critical Acres				Critical Acres			
Priority 3			240	Priority 3			200

Table C-144. AGNPS Ungauged sub-watershed priority-1 and 2 critical cells for phosphorus.

AGNPS Ungauged sub-watershed Phosphorus Priority-1 and 2 Cells							
West Mina Sub-watershed				East Mina Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
730	**1.25**	**0.73**	**1.98**	527	**1.00**	**0.47**	**1.47**
707	**1.17**	**0.30**	**1.47**	510	**1.01**	**0.35**	**1.36**
661	**0.74**	**0.43**	**1.17**	514	**0.80**	**0.26**	**1.06**
650	**0.44**	**0.63**	**1.07**	528	**0.65**	**0.25**	**0.90**
649	**0.60**	**0.33**	**0.93**				
660	**0.63**	**0.29**	**0.92**				
Critical Acres				Critical Acres			
Priority 1			120	Priority 1			0
Priority 2			120	Priority 2			160

Shaded areas are Priority-1 cells

Table C-145. AGNPS Ungauged sub-watershed priority-3 critical cells for phosphorus.

AGNPS Ungauged sub-watershed Phosphorus Priority-3 Cells							
West Mina Sub-watershed				East Mina Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
731	**0.38**	**0.37**	**0.75**	540	**0.72**	**0.11**	**0.83**
636	**0.55**	**0.14**	**0.68**	538	**0.23**	**0.44**	**0.67**
637	**0.50**	**0.18**	**0.68**	547	**0.38**	**0.27**	**0.65**
687	**0.36**	**0.29**	**0.65**	523	**0.59**	**0.06**	**0.65**
654	**0.48**	**0.13**	**0.61**				
Critical Acres				Critical Acres			
Priority 3			200	Priority 3			160

Sediment Analysis

The AGNPS model calculated that the sediment delivered from the AGNPS Ungauged sub-watershed is 214 kg/acre/year (highest of all sub-watersheds) for an estimated annual load. As a result, 1,363,961 kg or 1,503 tons of sediment would be generated annually from this sub-watershed. In summary, AGNPS Ungauged acreage was estimated to contribute 14 percent of the total load to Mina Lake. The AGNPS Ungauged sub-watershed contains 7 percent of the critical erosion cells within 4 percent of the watershed surface area. Based on the export coefficient, the sub-watershed is ranked first of eight on a list of priorities for sediment improvements.

The high sediment yield within the sub-watershed critical cells can be attributed to land use, land slope, and proximity to surface water conduits. Common critical cell characteristics for the Mina Lake system include croplands with a slope greater than 2 percent that are closer than 152 meters (500 feet) to a stream.

Total Nutrient Analysis

The AGNPS data indicates that the AGNPS Ungauged sub-watershed had the highest total nitrogen (soluble + sediment-bound) transport rate of 2.41 kg/acre/year (equivalent to a total of 15,340 kg or 17 tons per year). Seventy percent of the transported nitrogen from this sub-watershed was estimated to be in dissolved form while 77 percent of the total nitrogen load to Mina Lake was estimated to be in dissolved form. The total nitrogen load delivered from all sub-watersheds to Mina Lake was estimated to be 211,203 kg or 233 tons/year. As a result, the AGNPS Ungauged load to Mina Lake is 7 percent of the total nitrogen load to Mina Lake. Based on the transport coefficients for nitrogen, the AGNPS Ungauged sub-watershed was rated first of eight for nitrogen reduction priority.

This sub-watershed also had the highest total phosphorus (soluble + sediment-bound) transport rate of 0.67 kg/acre/year (equivalent to a total of 4,282 kg or 9,440 lbs per year). Forty-six percent of the transported phosphorus from this sub-watershed was estimated to be in dissolved form while 56 percent of the total phosphorus load to Mina Lake was estimated to be in dissolved form. The total phosphorus load delivered from all sub-watersheds to Mina Lake was estimated to be 53,300 kg/year or 59 tons/year. As a result, the AGNPS Ungauged load to Mina Lake was 8 percent of the total phosphorus load (tied with West Crompton). Based on the transport coefficients for phosphorus, the AGNPS Ungauged sub-watershed was rated first of eight for phosphorus reduction priority.

Dissolved nitrogen and phosphorus nutrient levels from AGNPS Ungauged sub-watershed acreages were estimated to be 70 and 46 percent, respectively.

Priority Ranking of Animal Feeding Areas for AGNPS Ungauged Sub-watershed (25-Year Event)

A total of eight animal feeding areas were identified during the AGNPS data acquisition phase of the project. Table C-92 lists the AGNPS analysis of each feeding area. Of these, two were found to have an AGNPS ranking of greater than 40. AGNPS ranks feeding areas from zero to 100 with a zero ranked feeding area having a smaller pollution potential and a 100 ranking having a large pollution potential. AGNPS estimates the total impact of having a feeding area or multiple feeding areas within a cell by combining and recalculating all values to arrive at nutrient and COD values to the cell. Critical feeding area map locations are depicted in the East (Figure C-8) and West Mina (Figure C-24) Feedlot maps.

In order to determine the impact of the feeding areas, AGNPS outputs from nutrient and feeding area critical cell data were analyzed (Table C-90). A reduction efficiency coefficient was determined by calculating a ratio of the difference (per acre) between the overall amount of nutrients generated per cell (acres multiplied by transport coefficient) and feedlot-generated nutrient loads. The results were then used to estimate the cell capacity, or lack of capacity, to reduce nutrient levels under current conditions. Topographical gradient, size, location of buffering zones and proximity to surface conduits were possible conditions influencing reduction and diffusion of nutrients.

Reduction efficiency coefficients range from positive to negative values and were interpreted using a sliding scale with values and ratings based on Table C-91. All feeding areas critical or not were analyzed for reduction potential to determine trends and ratings. These values may be used to estimate the sensitivity or resistance potential of the cell to perturbations within the feeding area(s) (increasing the number of animal units/area) or within the cell (changes in landscape/landuse, buffer reduction, tillage practices, etc.) based on current conditions. BMP improvements in the feeding areas or the cell with favorable/marginally favorable ratings should respond/improve more rapidly than the cell with a neutral to unfavorable rating. Another use for this rating may be to prioritize/rank all critical feeding areas (feeding areas needing BMPs) within a watershed by reduction efficiency (improvement potential) to target/select feeding areas to realize maximum nutrient reduction in the watershed when implementation funds are limited.

No feedlot cells exceeded overall nutrient level limits. Cell #525 (East Mina) and Cell #682 (West Mina) exceeded critical feedlot nutrient limits. The higher efficiency ratio may indicate that the feeding area nutrients had a greater impact on nutrient output than the cell, but were cell supportable. Overall, the sub-watershed was found to have a marginally unfavorable efficiency ratio when the very high values from cell #682 were ignored. Nutrient levels are cell-supportable; however, cell output would be sensitive to elevated (increased) nutrient concentrations.

The animal feeding areas rated above 40 should be monitored for animal density or use-intensity. If use intensifies without modification of current conditions, the potential for sediment and nutrient yield will increase, especially in unfavorable to marginally unfavorable cells. Positive steps should be taken to identify and modify existing conditions within critical feeding areas. Careful study of feeding area size, animal density/intensity of use, and buffering capacity may be needed to reduce the AGNPS feedlot ratings and increase the reduction efficiencies (ratings).

Improvements in feeding areas and cells with favorable to marginally favorable rating would be expected to show marked improvement. Sources of nutrient loads not modeled through this study were those from septic systems or livestock with direct access to the lake or adjacent streams.

Table C-146. Critical Cell (CC) reduction efficiency ratio for the AGNPS Ungauged sub-watershed.

Cell Number and Parameter	Feedlot Mass Generated (kg)	Transport Coefficient from (CC) Load Data **	Total Mass Transported (kg)	Difference (kg)	Reduction Efficiency Coefficient (kg/acre)	Rating (Table C- 91)
#525 Nitrogen *	**33.9**	**1.04**	**41.6**	**-7.70**	**-0.19**	**MU**
#525 Phosphorus *	**16.7**	**0.44**	**17.6**	**-0.90**	**-0.02**	**N**
#537 Nitrogen	**17.3**	**0.79**	**31.6**	**-14.3**	**-0.36**	**MU**
#537 Phosphorus	**12.4**	**0.35**	**14.0**	**-1.60**	**-0.04**	**N**
#445 Nitrogen	**4.24**	**1.09**	**43.6**	**-39.4**	**-0.98**	**MU**
#445 Phosphorus	**1.96**	**0.45**	**18.0**	**-16.0**	**-0.40**	**MU**
#682 Nitrogen *	**385**	**1.24**	**49.6**	**335**	**8.39**	**F**
#682 Phosphorus *	**141**	**0.4**	**16.0**	**125**	**3.13**	**F**
Average with #682 value					1.19	MF
Average w/o #682 value					-0.36	MU

Shaded area indicates critical nutrient cells
* = Indicates critical feedlot cell
** = Indicates threshold values for the AGNPS Ungauged sub-watershed (nitrogen yields > 1.78 kg/acre or phosphorus yields > 0.66 kg/acre)

Table C-147. Nutrient reduction efficiency rating scale for Mina Lake.

Rating	Criteria
Favorable (F)	**Greater than 2.0 kg/acre**
Marginally Favorable (MF)	**Between 0.1 and 2.0 kg/acre**
Neutral (N)	**Between -0.1 and 0.1 kg/acre**
Marginally Unfavorable (MU)	**Between –2 and –0.1 kg/acre**
Unfavorable (U)	**Less than –2.0 kg/acre**

Table C-148. AGNPS Ungauged sub-watershed feedlot ratings and data from the East Mina sub-watershed of Mina Lake.

Feedlot Analysis			
Cell # 537		Cell # 525	
Nitrogen concentration (ppm)	**5.17**	**Nitrogen concentration (ppm)**	**6.33**
Phosphorus concentration (ppm)	**8.68**	**Phosphorus concentration (ppm)**	**1.48**
COD concentration (ppm)	**438**	**COD concentration (ppm)**	**68.0**
Nitrogen mass (kg)	**3.98**	**Nitrogen mass (kg)**	**3.88**
Phosphorus mass (kg)	**6.68**	**Phosphorus mass (kg)**	**0.91**
COD mass (kg)	**337**	**COD mass (kg)**	**41.6**
Animal feedlot rating number	25	**Animal feedlot rating number**	0
Cell # 537		Cell # 525	
Nitrogen concentration (ppm)	**13.6**	**Nitrogen concentration (ppm)**	**11.1**
Phosphorus concentration (ppm)	**5.85**	**Phosphorus concentration (ppm)**	**5.84**
COD concentration (ppm)	**265**	**COD concentration (ppm)**	**572**
Nitrogen mass (kg)	**13.4**	**Nitrogen mass (kg)**	**30.0**
Phosphorus mass (kg)	**5.76**	**Phosphorus mass (kg)**	**15.8**
COD mass (kg)	**261**	**COD mass (kg)**	**1,547**
Animal feedlot rating number	21	**Animal feedlot rating number**	47
Cell # 537 TOTAL		Cell # 525 TOTAL	
Nitrogen concentration (ppm)		**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)		**Phosphorus concentration (ppm)**	
COD concentration (ppm)		**COD concentration (ppm)**	
Nitrogen mass (kg)	**17.3**	**Nitrogen mass (kg)**	**33.9**
Phosphorus mass (kg)	**12.4**	**Phosphorus mass (kg)**	**16.7**
COD mass (kg)	**599**	**COD mass (kg)**	**1,589**
Animal feedlot rating number	-	**Animal feedlot rating number**	-

Table C-149. AGNPS Ungauged sub-watershed feedlot ratings and data from the West Mina sub-watershed of Mina Lake.

Feedlot Analysis

Cell # 445		Cell # 682	
Nitrogen concentration (ppm)	**4.21**	**Nitrogen concentration (ppm)**	**2.85**
Phosphorus concentration (ppm)	**2.40**	**Phosphorus concentration (ppm)**	**0.98**
COD concentration (ppm)	**146**	**COD concentration (ppm)**	**34.0**
Nitrogen mass (kg)	**1.9**	**Nitrogen mass (kg)**	**359**
Phosphorus mass (kg)	**1.08**	**Phosphorus mass (kg)**	**124**
COD mass (kg)	**65.9**	**COD mass (kg)**	**4,273**
Animal feedlot rating number	2	**Animal feedlot rating number**	62
Cell # 445		Cell # 682	
Nitrogen concentration (ppm)	**4.97**	**Nitrogen concentration (ppm)**	**9.87**
Phosphorus concentration (ppm)	**1.86**	**Phosphorus concentration (ppm)**	**6.87**
COD concentration (ppm)	**81.4**	**COD concentration (ppm)**	**333**
Nitrogen mass (kg)	**2.33**	**Nitrogen mass (kg)**	**25.6**
Phosphorus mass (kg)	**0.87**	**Phosphorus mass (kg)**	**17.8**
COD mass (kg)	**38.2**	**COD mass (kg)**	**864**
Animal feedlot rating number	0	**Animal feedlot rating number**	40
Cell # 445 TOTAL		Cell # 682 TOTAL	
Nitrogen concentration (ppm)		**Nitrogen concentration (ppm)**	
Phosphorus concentration (ppm)		**Phosphorus concentration (ppm)**	
COD concentration (ppm)		**COD concentration (ppm)**	
Nitrogen mass (kg)	**4.24**	**Nitrogen mass (kg)**	**385**
Phosphorus mass (kg)	**1.96**	**Phosphorus mass (kg)**	**141**
COD mass (kg)	**104**	**COD mass (kg)**	**5,138**
Animal feedlot rating number	-	**Animal feedlot rating number**	-

Modeled Sediment, Nitrogen and Phosphorus Reductions (AGNPS Ungauged Sub-watershed)

Several Best Management Practices (BMP) were modeled using the AGNPS computer model. These included installation of Animal Waste Management Systems (AWMS), grassed waterways, reduction of crop ground fertilizer application levels, and conversion of conventional till practices to minimum or no-till methods.

Eight feeding areas within the AGNPS Ungauged sub-watershed were identified. The AGNPS assessment of field feedlot data rated two feeding areas as critical (rated above 40, based on objective criteria). Efforts to improve feeding areas would reduce total nitrogen from 15,340 kg/year or 16.9 tons/year to 14,240 kg/year or 15.7 tons/year (7 percent) and from 4,282 kg/year or 4.7 tons/year to 4,065 kg/year or 4.5 tons/year (5 percent) in total phosphorus.

AGNPS compared fertilizer application rates using the current rate of application (approx. 45.4 kg or 100 lbs/acre nitrogen and 18.1 kg or 40 lbs/acre phosphorus) to a reduced rate (22.7 kg/acre or 50 lbs/acre nitrogen and 9.1 kg/acre or 20 lbs/acre phosphorus). The sub-watershed model indicated a reduction in the total nitrogen load of 15,340 kg/year or 16.9 tons/year to 13,858 kg/year or 15.3 tons/year (9 percent) and in total phosphorus from 4,282 kg/year or 4.7 tons/year to 4,006 kg/year or 4.4 tons/year (6 percent).

The model estimated that modifying tilled acreage within critical erosion cells to conservation tillage practices would reduce the sediment load delivered by Snake Creek from 1,363,961 kg/year or 1,503.5 tons/year to 1,304,765 kg/year or 1,438.3 tons/year (4 percent reduction). The sub-watershed model indicated a reduction in the total nitrogen load of 15,340 kg/year or 16.9 tons/year to 13,858 kg/year or 15.3 tons/year (9 percent) and total phosphorus load from 4,282 kg/year year or 4.7 tons/year to 4,006 kg/year or 4.4 tons/year (6 percent). Based on AGNPS reduction estimates, conversion from conventional to minimum/no tillage will have the greatest impact on the watershed.

BMP recommendations should be implemented within the sub-watershed and site priority critical cells (Tables C-94 and C-95). Field data for priority critical cells should be field-verified prior to BMP planning and implementation. The AGNPS model did not simulate grass waterways, gully and streambank erosion; however, these BMPs should also be evaluated.

Table C-150. AGNPS modeling reductions for AGNPS Ungauged sub-watershed BMPs[1]

BMP	Unit	Percent		
		Sediments	Nitrogen	Phosphorus
Feedlot	**AGNPS Ungauged**	**0**	**7**	**5**
Fertilizer	**AGNPS Ungauged**	**0**	**9**	**6**
Minimum Till	**AGNPS Ungauged**	**4**	**9**	**6**
Sub-watershed Total		**4**	**25**	**17**

[1] = Reductions calculated 1999-2000 field data

Table C-151. Modeled reductions for AGNPS Site Ungauged BMPs[1].

BMP	Unit	Percent		
		Sediments	Nitrogen	Phosphorus
Feedlot	**AGNPS Site Ungauged**	**0**	**6**	**18**
Fertilizer	**AGNPS Site Ungauged**	**0**	**10**	**18**
Minimum Till	**AGNPS Site Ungauged**	**4**	**10**	**10**
Site Total		**4**	**26**	**46**

[1] = Reductions calculated 1999-2000 field data

Conclusion

Delivery export coefficients for all sub-watersheds (by AGNPS and by water quality monitoring site) are listed in Table C-99 and Table C-100. Total estimated delivered load for total, sediment-derived and dissolved nitrogen and phosphorus for AGNPS and water quality monitoring site sub-watersheds are provided in Table C-101 and Table C-102.

Priority sub-watershed ranking based on AGNPS modeling for sediment, nitrogen and phosphorus are listed in Table C-96, Table C-97 and Table C-98. Priority sub-watersheds by water quality monitoring site for sediment, nitrogen and phosphorus are summarized on Table 51 in the main body of this report (page 123).

Sediment

An analysis of all critical sediment cells in the Mina Lake watershed for sediment yield indicated that the primary source of elevated sedimentation within the critical cells was from agricultural lands which have land slopes of 2 percent or greater and are utilized as cropland (high C-factor). AGNPS-derived sediment-loading data for Mina Lake and each sub-watershed from AGNPS sub-watersheds and water quality monitoring sites modeling are provided in Table C-101 and Table C-102, respectively. In order to determine the amount of reduction in sedimentation from these critical cells, the AGNPS model was run with reduced C-factors. The AGNPS model was run with reduced C-factors to simulate conservation tillage practices to determine the amount of sediment that could be retained.

The C-factors were changed on sediment priority cells to a value that would simulate a change from conventional tillage to conservation tillage practices. Installing these practices will reduce the amount of sediment entering Mina Lake annually from 9,743,382 kilograms (10,740 tons) to

8,903,502 kilograms (9,814 tons), an 8.62 percent reduction. Therefore, it is recommended that efforts to reduce sediment should be focused within the identified critical/priority sub-watersheds and individual critical erosion cells located throughout specific sub-watersheds. It is recommended that these areas be targeted for conversion to rangeland or the implementation of a high residue management plan. It is recommended that any targeted cell should be field-verified prior to the installation of any Best Management Practices. AGNPS priority sub-watersheds by delivery coefficients for sediment are provided in Table C-96.

Table C-152. AGNPS-derived priority sub-watersheds based on sediment delivery coefficients for Mina Lake in 1999 and 2000.

Sediment Priority Sub-watershed	Sub-watershed	Export Coefficient (kg/acre)
1	**AGNPS Ungauged**	**214.0**
2	**West Crompton**	**108.0**
3	**North Crompton**	**86.2**
4	**West Mina**	**42.4**
5	**Y**	**41.0**
6	**East Mina**	**40.5**
7	**Brooks West**	**38.0**
8	**Rosette**	**3.67**

Nutrients

The AGNPS data estimates 211,203 kilograms (232.8 tons) of nitrogen and 53,299 kilograms (58.8 tons) of phosphorus were delivered to Mina Lake based on 1999 and 2000 data. When a detailed sub-watershed analysis was performed on all priority nitrogen and phosphorus critical cells with excessive nutrient deliverability coefficients, AGNPS Ungauged, Brooks West, West Mina, East Mina and West Crompton sub-watersheds were found to be contributing excessive amounts of nitrogen. Likewise, AGNPS Ungauged, Brooks West, West Mina, West Crompton and East Mina sub-watersheds were found to be contributing elevated amounts of phosphorus (Table C-97 and Table C-98).

Modeled BMPs reductions were: conventional tillage to conservation tillage, feeding area runoff and fertilizer reduction. Installing these practices on priority critical cells will reduce the amount of nitrogen entering Mina Lake annually by 26.6 percent from 211,203 kilograms (232.8 tons) to 155,023 kilograms (170.9 tons) and phosphorus by 21.2 percent from 53,299 kilograms (58.8 tons) to 42,000 kilograms (46.3 tons). The AGNPS output showed that most of the nitrogen and phosphorus from critical cells throughout the watershed is in a water-soluble form (Table C-101 and Table C-102).

The suspected source of the elevated nutrient levels found within the Mina Lake watershed is probably runoff from fertilized cropland. Therefore, it is recommended that efforts to reduce nutrients should be focused within the identified critical sub-watersheds and individual critical nutrient cells.

Table C-153. AGNPS-derived priority sub-watersheds based on nitrogen delivery coefficients for Mina Lake in 1999 and 2000.

Nitrogen Priority Sub-watershed	Sub-watershed	Export Coefficient (kg/acre)
1	**AGNPS Ungauged**	**2.41**
2	**Brooks West**	**1.82**
3	**West Mina**	**1.76**
4	**East Mina**	**1.60**
5	**West Crompton**	**1.16**
6	**Y**	**1.04**
7	**North Crompton**	**0.91**
8	**Rosette**	**0.32**

Table C-154. AGNPS-derived priority sub-watersheds based on sediment delivery coefficients for Mina Lake in 1999 and 2000.

Phosphorus Priority Sub-watershed	Sub-watershed	Export Coefficient (kg/acre)
1	**AGNPS Ungauged**	**0.67**
2	**Brooks West**	**0.41**
3	**West Mina**	**0.40**
4	**West Crompton**	**0.38**
5	**East Mina**	**0.36**
6	**North Crompton**	**0.29**
7	**Y**	**0.25**
8	**Rosette**	**0.05**

Best Management Practices

It is recommended that efforts to reduce sediment and nutrients be targeted to the installation of appropriate BMPs (minimum/no tillage) on cropland (≥ 2% slope), conversion of highly erodible cropland lands to rangeland, pasture or CRP, improvement of land surface cover (C-factor) on cropland and rangeland and measures initiated to reduce nutrient runoff from animal feeding areas. Buffer and filter strips and riparian management should also be implemented/installed on at least the top four nutrient priority watersheds in the Mina Lake system.

The implementation of appropriate BMPs targeting identified critical cells, priority sub-watersheds and priority feeding areas upon the completion of a field-verification process, should produce the most cost-effective treatment plan in reducing sediment and nutrient yields from the Mina Lake watershed.

Table C-155. AGNPS estimated export coefficients (kg/acre) by AGNPS sub-watershed.

Sub-watershed	Drainage Area Acres	Percent of Watershed Percent	Sediment kg/acre	Nitrogen Attached-N kg/acre	Nitrogen Dissolved-N kg/acre	Nitrogen Total Nitrogen kg/acre	Phosphorus Attached-P kg/acre	Phosphorus Dissolved-P kg/acre	Phosphorus Total Phosphorus kg/acre
West Tributary									
Rosette	**5,760**	**4**	**3.67**	**0.02**	**0.29**	**0.32**	**0.01**	**0.04**	**0.05**
Y	**31,640**	**20**	**41.0**	**0.24**	**0.81**	**1.04**	**0.12**	**0.14**	**0.25**
West Mina	**23,920**	**15**	**42.4**	**0.21**	**1.55**	**1.76**	**0.11**	**0.29**	**0.40**
East Tributary									
Brooks West	**21,720**	**14**	**38.0**	**0.20**	**1.62**	**1.82**	**0.10**	**0.31**	**0.41**
North Crompton	**36,800**	**23**	**86.2**	**0.43**	**0.48**	**0.91**	**0.20**	**0.09**	**0.29**
West Crompton	**11,400**	**7**	**108**	**0.51**	**0.65**	**1.16**	**0.26**	**0.11**	**0.38**
East Mina	**20,360**	**13**	**40.5**	**0.23**	**1.37**	**1.60**	**0.11**	**0.25**	**0.36**
AGNPS Ungauged	**6,360**	**4**	**214**	**0.73**	**1.68**	**2.41**	**0.36**	**0.31**	**0.67**
Total	**157,960**	**100**							

Table C-156. AGNPS estimated export coefficients (kg) by water quality monitoring site.

Water Quality Monitoring Site	Drainage Area Acres	Percent of Watershed Percent	Sediment kg/acre	Nitrogen Attached-N kg/acre	Nitrogen Dissolved-N kg/acre	Nitrogen Total Nitrogen kg/acre	Phosphorus Attached-P kg/acre	Phosphorus Dissolved-P kg/acre	Phosphorus Total Phosphorus kg/acre
West Tributary									
Snake Creek 6 (SC-6)	**8,080**	**5**	**45.7**	**0.24**	**0.30**	**.55**	**0.12**	**0.04**	**0.16**
Snake Creek 1 (SC-1)	**50,400**	**32**	**36.3**	**0.20**	**1.20**	**1.39**	**0.09**	**0.21**	**0.31**
East Tributary									
Snake Creek 7 (SC-7)	**21,600**	**14**	**49.7**	**0.21**	**1.61**	**1.82**	**0.11**	**0.31**	**0.43**
Snake Creek 8 (SC-8)	**49,400**	**31**	**91.0**	**0.44**	**0.54**	**0.98**	**0.21**	**0.10**	**0.31**
Snake Creek 2 (SC-2)	**15,600**	**10**	**37.1**	**0.27**	**1.53**	**1.80**	**0.13**	**0.27**	**0.40**
AGNPS Site Ungauged	**12,880**	**8**	**108**	**0.40**	**1.20**	**1.60**	**0.21**	**0.24**	**0.45**
Grand Total	**157,960**	**100**							

Table C-157. AGNPS estimated total loading (kg) to Mina Lake by sub-watershed.

				Nitrogen			Phosphorus		
Sub-watershed	Drainage Area acres	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
West Tributary									
Rosette	**5,760**	**4**	**21,119**	**131**	**1,698**	**1,829**	**26**	**235**	**261**
Y	**31,640**	**20**	**1,296,058**	**7,463**	**25,546**	**33,099**	**3,731**	**4,305**	**8,037**
West Mina	**23,920**	**15**	**1,013,480**	**5,099**	**37,107**	**42,206**	**2,712**	**6,944**	**9,656**
Tributary Total	61,320	39	2,330,657	12,693	64,351	77,134	6,469	11,484	17,954
East Tributary									
Brooks West	**21,720**	**14**	**825,221**	**4,236**	**35,270**	**39,507**	**2,069**	**6,798**	**8,867**
North Crompton	**36,800**	**23**	**3,171,373**	**15,691**	**17,694**	**33,384**	**7,178**	**3,338**	**10,516**
West Crompton	**11,400**	**7**	**1,227,938**	**5,791**	**7,446**	**13,238**	**2,999**	**1,293**	**4,292**
East Mina	**20,360**	**13**	**824,232**	**4,725**	**27,875**	**32,600**	**2,309**	**5,079**	**7,388**
Tributary Total	90,280	57	6,048,764	30,443	88,285	118,729	14,555	16,508	31,063
AGNPS Ungauged	**6,360**	**4**	**1,363,961**	**4,628**	**10,711**	**15,340**	**2,307**	**1,976**	**4,282**
Grand Total	157,960	100	9,743,382	47,764	163,347	211,203	23,331	29,968	53,299

Table C-158. AGNPS estimated total loading (kg) to Mina Lake by water quality monitoring site sub-watershed.

				Nitrogen			Phosphorus		
Water Quality Monitoring Site	Drainage Area acres	Percent of Watershed	Sediment kg	Attached-N kg	Dissolved-N kg	Total Nitrogen kg	Attached-P kg	Dissolved-P kg	Total Phosphorus kg
West Tributary									
Snake Creek 6 (SC-6)	**8,080**	**5**	**369,321**	**1,979**	**2,456**	**4,435**	**990**	**330**	**1,319**
Snake Creek 1 (SC-1)	**50,400**	**32**	**1,831,470**	**9,917**	**60,263**	**70,180**	**4,776**	**10,713**	**15,489**
Tributary Total	58,480	37	2,200,795	11,896	62,719	74,615	5,766	11,043	16,808
East Tributary									
Snake Creek 7 (SC-7)	**21,600**	**14**	**1,073,154**	**4,605**	**34,683**	**39,288**	**2,449**	**6,760**	**9,210**
Snake Creek 8 (SC-8)	**49,400**	**31**	**4,493,703**	**21,924**	**26,516**	**48,440**	**10,408**	**4,863**	**15,271**
Snake Creek 2 (SC-2)	**15,600**	**10**	**578,593**	**4,228**	**23,915**	**28,143**	**1,988**	**4,207**	**6,195**
Tributary Total	86,600	55	6,145,450	30,757	85,114	115,871	14,845	15,830	30,676
AGNPS Site Ungauged	**12,880**	**8**	**1,397,137**	**5,112**	**15,515**	**20,626**	**2,720**	**3,096**	**5,816**
Grand Total	157,960	100	9,743,382	47,765	163,348	211,112	23,331	29,969	53,300

ATTACHMENT A

AGNPS-Derived Critical Cells for Water Quality Monitoring Sites

Table A-1. AGNPS-derived SC-1 priority-1 and 2 critical cells.

SC-1 Sediment Priority-1 and 2 Cells								
Rosette Sub-watershed			West Mina Sub-watershed			Y Sub-watershed		
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)
111	9,825	91,290	23	10,142	278,307	72	8,682	309,087
45	6,595	63,548	474	5,162	162,795	394	8,410	220,764
131	5,761	330,524	10	4,091	112,509	254	8,065	764,068
130	4,990	166,677	247	4,064	996,027	479	7,838	472,671
106	2,948	24,839	248	4,064	110,913	239	7,103	579,565
140	2,849	79,252	166	3,792	174,225	477	6,895	186,980
			249	3,121	89,376	509	6,895	657,937
			26	3,075	691,793	373	5,017	136,341
			188	2,785	74,045	478	4,518	364,380
						163	4,246	139,371
						573	4,218	605,764
						436	4,173	159,057
						350	3,946	95,354
						410	3,946	212,853
						272	3,946	861,863
						445	3,475	238,771
						164	3,320	184,513
						73	3,230	107,964
						85	3,230	405,095
						143	3,230	226,443
						75	3,094	43,500
						370	3,048	71,114
						510	3,048	584,436
						694	2,994	191,543
						240	2,976	78,181
						681	2,858	78,118
						751	2,858	88,904
						290	2,812	871,534
						255	2,803	847,484
						71	2,794	108,763
Critical Acres			Critical Acres			Critical Acres		
Priority 1		160	Priority 1		240	Priority 1		600
Priority 2		80	Priority 2		120	Priority 2		600

Shaded areas are Priority-1 cells

Table A-2. AGNPS-derived SC-1 priority-3 critical cells.

SC-1 Sediment Priority-3 Cells								
Rosette Sub-watershed			West Mina Sub-watershed			Y Sub-watershed		
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)
129	**1,960**	**145,340**	293	**2,703**	**96,670**	471	**2,749**	**449,928**
102	**1,833**	**83,969**	270	**2,585**	**78,363**	221	**2,731**	**91,589**
			253	**2,558**	**67,095**	293	**2,513**	**830,937**
			92	**2,449**	**64,274**	508	**2,422**	**69,001**
			543	**2,422**	**268,881**	395	**2,377**	**198,828**
			539	**2,413**	**55,901**	125	**2,377**	**55,901**
			200	**2,295**	**468,435**	63	**2,368**	**22,235**
			223	**2,295**	**61,008**	651	**2,322**	**3,953,117**
			298	**2,295**	**61,008**	664	**2,204**	**115,820**
			269	**2,195**	**72,421**	585	**2,195**	**3,152,798**
			323	**2,014**	**85,148**	615	**2,195**	**59,384**
			8	**1,978**	**109,280**	646	**2,195**	**84,259**
			11	**1,960**	**52,735**	647	**2,195**	**59,384**
			37	**1,923**	**50,657**	710	**2,195**	**59,384**
			38	**1,923**	**50,657**	114	**2,132**	**395,896**
			320	**1,869**	**857,962**	563	**2,114**	**51,120**
			44	**1,860**	**695,050**	291	**2,114**	**841,406**
			470	**1,823**	**41,658**	223	**2,087**	**51,873**
			507	**1,823**	**88,677**	645	**1,978**	**19,260**
			545	**1,805**	**2,138,691**	722	**1,878**	**892,063**
						285	**1,860**	**45,314**
						663	**1,851**	**79,724**
						454	**1,842**	**46,911**
						222	**1,842**	**47,600**
						495	**1,823**	**49,015**
						84	**1,823**	**54,286**
						113	**1,823**	**378,414**
						126	**1,823**	**84,559**
						146	**1,823**	**49,832**
Critical Acres			Critical Acres			Critical Acres		
Priority 3		80	Priority 3		800	Priority 3		1,160

Table A-3. AGNPS-derived SC-1 priority-1 and 2 critical cells.

SC-1 Nitrogen Priority-1 and 2 Cells

Rosette Sub-watershed				West Mina Sub-watershed				Y Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
128	**0.17**	**4.84**	**5.02**	23	**8.42**	**1.05**	**9.48**	394	**7.00**	**0.11**	**7.11**
				10	**4.08**	**2.55**	**6.63**	373	**4.76**	**0.92**	**5.67**
				248	**4.03**	**2.37**	**6.40**	750	**0.89**	**4.06**	**4.95**
				439	**1.04**	**5.09**	**6.13**	647	**2.45**	**2.01**	**4.46**
				188	**2.92**	**2.73**	**5.65**	681	**3.05**	**1.21**	**4.26**
				270	**3.06**	**2.37**	**5.43**	751	**1.94**	**2.30**	**4.24**
				253	**2.70**	**2.73**	**5.42**	395	**3.70**	**0.11**	**3.81**
				92	**2.61**	**2.37**	**4.98**	615	**2.45**	**1.21**	**3.66**
				298	**2.50**	**2.37**	**4.87**	710	**2.45**	**1.21**	**3.66**
				11	**2.23**	**2.55**	**4.78**	646	**1.86**	**1.61**	**3.47**
				293	**1.31**	**3.45**	**4.76**	495	**2.10**	**1.30**	**3.40**
				37	**2.15**	**2.55**	**4.70**	648	**1.38**	**2.01**	**3.40**
				38	**2.15**	**2.55**	**4.70**	240	**3.05**	**0.17**	**3.22**
				290	**1.89**	**2.73**	**4.62**	493	**0.83**	**2.33**	**3.16**
				131	**1.80**	**2.73**	**4.52**	430	**2.98**	**0.11**	**3.09**
				88	**1.80**	**2.55**	**4.35**	550	**1.03**	**2.01**	**3.04**
				105	**1.80**	**2.55**	**4.35**	223	**2.20**	**0.85**	**3.04**
				201	**1.75**	**2.55**	**4.30**	370	**2.83**	**0.13**	**2.96**
				226	**1.89**	**2.37**	**4.26**				
				108	**1.63**	**2.55**	**4.18**				
				71	**1.60**	**2.55**	**4.15**				
				70	**1.27**	**2.80**	**4.07**				
				58	**1.69**	**2.37**	**4.06**				
				255	**1.82**	**2.19**	**4.01**				
				528	**1.28**	**2.73**	**4.01**				
				223	**2.50**	**1.48**	**3.98**				
				225	**1.51**	**2.37**	**3.88**				
				292	**1.16**	**2.64**	**3.79**				
				155	**1.38**	**2.37**	**3.76**				
				123	**1.33**	**2.37**	**3.70**				
				146	**1.31**	**2.37**	**3.68**				
				474	**3.15**	**0.44**	**3.59**				
				178	**1.03**	**2.55**	**3.58**				
				59	**1.19**	**2.37**	**3.57**				
				12	**1.04**	**2.46**	**3.50**				
				60	**0.94**	**2.37**	**3.31**				
				13	**0.88**	**2.43**	**3.31**				
				238	**1.89**	**1.30**	**3.19**				
				460	**0.51**	**2.62**	**3.13**				
				79	**0.78**	**2.33**	**3.11**				
				286	**0.78**	**2.33**	**3.11**				
				96	**0.76**	**2.33**	**3.09**				
				221	**1.59**	**1.48**	**3.07**				
				365	**1.26**	**1.75**	**3.00**				
				77	**1.69**	**1.30**	**2.99**				
				312	**0.64**	**2.33**	**2.98**				
				87	**1.91**	**1.05**	**2.96**				
Critical Acres				Critical Acres				Critical Acres			
Priority 1			0	Priority 1			1,040	Priority 1			240
Priority 2			40	Priority 2			840	Priority 2			480

Shaded areas are Priority-1 cells

Table A-4. AGNPS-derived SC-1 priority-3 critical cells.

SC-1 Nitrogen Priority-3 Cells											
Rosette Sub-watershed				West Mina Sub-watershed				Y Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
45	**1.91**	**0.79**	**2.70**	433	**0.53**	**2.39**	**2.92**	222	**2.05**	**0.85**	**2.90**
				94	**1.59**	**1.30**	**2.88**	454	**2.03**	**0.85**	**2.88**
				109	**0.97**	**1.91**	**2.88**	775	**1.45**	**1.39**	**2.84**
				42	**1.50**	**1.30**	**2.79**	349	**1.77**	**1.05**	**2.82**
				203	**1.09**	**1.68**	**2.77**	693	**1.75**	**0.98**	**2.74**
				204	**1.77**	**0.98**	**2.75**	350	**2.05**	**0.66**	**2.72**
				179	**0.83**	**1.85**	**2.69**	557	**1.80**	**0.92**	**2.71**
				57	**1.67**	**0.98**	**2.65**	463	**1.38**	**1.30**	**2.68**
				264	**0.48**	**2.17**	**2.65**	743	**1.64**	**0.98**	**2.63**
				51	**1.21**	**1.37**	**2.58**	678	**1.30**	**1.28**	**2.58**
				28	**0.69**	**1.88**	**2.57**	403	**1.95**	**0.54**	**2.49**
				240	**1.27**	**1.30**	**2.56**	125	**2.33**	**0.11**	**2.44**
				540	**1.09**	**1.46**	**2.55**	285	**1.97**	**0.47**	**2.44**
				239	**1.22**	**1.30**	**2.52**	644	**0.54**	**1.87**	**2.41**
				539	**2.33**	**0.19**	**2.52**	84	**2.28**	**0.11**	**2.39**
				557	**1.13**	**1.38**	**2.51**	704	**1.17**	**1.21**	**2.38**
				262	**0.54**	**1.95**	**2.49**	732	**1.09**	**1.21**	**2.30**
				157	**1.16**	**1.28**	**2.44**	277	**1.43**	**0.85**	**2.28**
				291	**0.68**	**1.76**	**2.44**	425	**1.14**	**1.12**	**2.26**
				311	**1.14**	**1.30**	**2.44**	402	**1.69**	**0.54**	**2.24**
				412	**0.61**	**1.83**	**2.44**	525	**1.09**	**1.12**	**2.21**
				527	**0.58**	**1.85**	**2.43**	431	**2.07**	**0.11**	**2.18**
				156	**0.92**	**1.50**	**2.42**	399	**1.93**	**0.24**	**2.16**
				263	**0.46**	**1.95**	**2.41**	464	**1.91**	**0.24**	**2.15**
				269	**1.65**	**0.74**	**2.39**	556	**1.07**	**1.02**	**2.09**
				492	**2.05**	**0.32**	**2.38**	562	**1.64**	**0.44**	**2.08**
				47	**1.28**	**1.08**	**2.35**	566	**1.61**	**0.44**	**2.05**
				39	**0.69**	**1.65**	**2.35**				
				261	**0.89**	**1.44**	**2.33**				
				276	**0.86**	**1.47**	**2.33**				
				195	**1.23**	**1.08**	**2.31**				
				196	**1.23**	**1.08**	**2.31**				
				3	**1.09**	**1.08**	**2.16**				
				323	**0.90**	**1.18**	**2.08**				
				89	**1.45**	**0.63**	**2.08**				
				202	**0.71**	**1.37**	**2.07**				
				147	**0.71**	**1.36**	**2.07**				
				224	**0.75**	**1.29**	**2.04**				
				470	**1.84**	**0.19**	**2.03**				
				180	**0.63**	**1.38**	**2.01**				
Critical Acres				Critical Acres				Critical Acres			
Priority 3			40	Priority 3			1,600	Priority 3			1,080

Table A-5. AGNPS-derived SC-1 priority-1 and 2 critical cells.

SC-1 Phosphorus Priority-1 and 2 Cells											
Rosette Sub-watershed				West Mina Sub-watershed				Y Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
128	**0.09**	**1.23**	**1.32**	23	**4.21**	**0.21**	**4.42**	394	**3.50**	**0.01**	**3.51**
45	**0.96**	**0.15**	**1.11**	10	**2.04**	**0.56**	**2.60**	373	**2.38**	**0.18**	**2.56**
				248	**2.02**	**0.52**	**2.54**	395	**1.85**	**0.01**	**1.86**
				188	**1.46**	**0.60**	**2.06**	681	**1.52**	**0.24**	**1.77**
				270	**1.53**	**0.52**	**2.05**	647	**1.22**	**0.43**	**1.66**
				253	**1.35**	**0.60**	**1.95**	240	**1.52**	**0.01**	**1.53**
				92	**1.30**	**0.52**	**1.82**	430	**1.49**	**0.01**	**1.50**
				298	**1.25**	**0.52**	**1.77**	751	**0.97**	**0.50**	**1.47**
				439	**0.52**	**1.15**	**1.67**	615	**1.22**	**0.24**	**1.47**
				11	**1.11**	**0.56**	**1.67**	710	**1.22**	**0.24**	**1.47**
				474	**1.57**	**0.07**	**1.64**	370	**1.42**	**0.01**	**1.42**
				37	**1.08**	**0.56**	**1.64**	750	**0.44**	**0.91**	**1.35**
				38	**1.08**	**0.56**	**1.64**	495	**1.05**	**0.26**	**1.31**
				223	**1.25**	**0.30**	**1.56**	646	**0.93**	**0.34**	**1.27**
				290	**0.95**	**0.60**	**1.55**	223	**1.10**	**0.16**	**1.26**
				131	**0.90**	**0.60**	**1.50**	222	**1.03**	**0.16**	**1.19**
				226	**0.95**	**0.52**	**1.47**	454	**1.01**	**0.16**	**1.17**
				88	**0.90**	**0.56**	**1.46**	125	**1.17**	**0.01**	**1.17**
				105	**0.90**	**0.56**	**1.46**	350	**1.03**	**0.12**	**1.15**
				201	**0.88**	**0.56**	**1.43**	84	**1.14**	**0.01**	**1.15**
				293	**0.65**	**0.77**	**1.42**	648	**0.69**	**0.43**	**1.12**
				255	**0.91**	**0.47**	**1.38**				
				108	**0.81**	**0.56**	**1.37**				
				58	**0.85**	**0.52**	**1.37**				
				71	**0.80**	**0.56**	**1.36**				
				433	**0.26**	**1.05**	**1.31**				
				225	**0.75**	**0.52**	**1.27**				
				70	**0.64**	**0.61**	**1.24**				
				528	**0.64**	**0.60**	**1.24**				
				238	**0.95**	**0.26**	**1.21**				
				155	**0.69**	**0.52**	**1.21**				
				123	**0.67**	**0.52**	**1.18**				
				539	**1.17**	**0.01**	**1.17**				
				146	**0.65**	**0.52**	**1.17**				
				87	**0.95**	**0.21**	**1.16**				
				292	**0.58**	**0.58**	**1.16**				
				59	**0.59**	**0.52**	**1.11**				
				77	**0.85**	**0.26**	**1.11**				
				221	**0.79**	**0.30**	**1.10**				
Critical Acres				Critical Acres				Critical Acres			
Priority 1			0	Priority 1			760	Priority 1			400
Priority 2			80	Priority 2			800	Priority 2			440

Shaded areas are Priority-1 cells

Table A-6. AGNPS-derived SC-1 priority-3 critical cells.

SC-1 Phosphorus Priority-3 Cells											
Rosette Sub-watershed				West Mina Sub-watershed				Y Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
				204	**0.88**	**0.20**	**1.08**	349	**0.88**	**0.21**	**1.09**
				178	**0.52**	**0.56**	**1.08**	557	**0.90**	**0.18**	**1.08**
				492	**1.03**	**0.04**	**1.07**	403	**0.98**	**0.10**	**1.07**
				12	**0.52**	**0.54**	**1.06**	693	**0.88**	**0.20**	**1.07**
				94	**0.79**	**0.26**	**1.06**	285	**0.98**	**0.08**	**1.07**
				57	**0.83**	**0.20**	**1.03**	431	**1.03**	**0.01**	**1.04**
				42	**0.75**	**0.26**	**1.01**	743	**0.82**	**0.20**	**1.02**
				365	**0.63**	**0.37**	**0.99**	775	**0.73**	**0.29**	**1.01**
				60	**0.47**	**0.52**	**0.99**	399	**0.97**	**0.01**	**0.98**
				13	**0.44**	**0.53**	**0.97**	464	**0.96**	**0.01**	**0.97**
				269	**0.83**	**0.14**	**0.96**	463	**0.69**	**0.26**	**0.96**
				470	**0.92**	**0.01**	**0.93**	402	**0.85**	**0.10**	**0.94**
				203	**0.54**	**0.35**	**0.90**	550	**0.51**	**0.43**	**0.94**
				79	**0.39**	**0.50**	**0.89**	493	**0.42**	**0.50**	**0.92**
				109	**0.49**	**0.41**	**0.89**	678	**0.65**	**0.26**	**0.91**
				240	**0.63**	**0.26**	**0.89**	562	**0.82**	**0.08**	**0.89**
				286	**0.39**	**0.50**	**0.89**	566	**0.81**	**0.08**	**0.88**
				51	**0.60**	**0.28**	**0.88**	164	**0.83**	**0.05**	**0.88**
				96	**0.38**	**0.50**	**0.88**	72	**0.87**	**0.01**	**0.88**
				239	**0.61**	**0.26**	**0.88**	277	**0.71**	**0.16**	**0.88**
				47	**0.64**	**0.21**	**0.85**	704	**0.59**	**0.24**	**0.83**
				557	**0.57**	**0.29**	**0.85**	621	**0.72**	**0.09**	**0.81**
				540	**0.54**	**0.30**	**0.85**	195	**0.71**	**0.10**	**0.81**
				63	**0.83**	**0.01**	**0.84**	163	**0.80**	**0.01**	**0.81**
				157	**0.58**	**0.26**	**0.84**	692	**0.79**	**0.01**	**0.80**
				89	**0.72**	**0.11**	**0.83**	425	**0.57**	**0.22**	**0.79**
				311	**0.57**	**0.26**	**0.83**	732	**0.54**	**0.24**	**0.79**
				460	**0.25**	**0.58**	**0.83**	662	**0.76**	**0.01**	**0.77**
				195	**0.62**	**0.21**	**0.83**	525	**0.54**	**0.22**	**0.77**
				196	**0.62**	**0.21**	**0.83**	537	**0.70**	**0.06**	**0.76**
				312	**0.32**	**0.50**	**0.83**	617	**0.66**	**0.10**	**0.76**
				2	**0.80**	**0.01**	**0.81**	410	**0.72**	**0.04**	**0.75**
				179	**0.42**	**0.39**	**0.81**	436	**0.74**	**0.01**	**0.75**
				156	**0.46**	**0.31**	**0.77**	477	**0.73**	**0.02**	**0.75**
				1	**0.75**	**0.01**	**0.76**	124	**0.74**	**0.01**	**0.75**
				3	**0.54**	**0.21**	**0.76**	190	**0.74**	**0.01**	**0.75**
				363	**0.63**	**0.13**	**0.76**	396	**0.73**	**0.01**	**0.74**
				132	**0.64**	**0.11**	**0.75**				
				133	**0.64**	**0.11**	**0.75**				
				261	**0.45**	**0.30**	**0.75**				
				28	**0.34**	**0.40**	**0.74**				
Critical Acres				Critical Acres				Critical Acres			
Priority 3			0	Priority 3			1,640	Priority 3			1,480

Table A-7. AGNPS-derived SC-2 priority-1 and 2 critical cells.

SC-2 Priority-1 and 2 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
146	**5,706**	**170,878**	66	**3.26**	**2.19**	**5.45**	66	**1.63**	**0.47**	**2.10**
129	**4,354**	**138,409**	104	**0.91**	**4.40**	**5.31**	145	**1.46**	**0.47**	**1.93**
201	**3,738**	**478,087**	146	**2.85**	**2.30**	**5.14**	146	**1.42**	**0.49**	**1.92**
66	**3,293**	**84,876**	145	**2.92**	**2.19**	**5.11**	119	**1.12**	**0.52**	**1.63**
328	**3,275**	**1,136,967**	119	**2.24**	**2.37**	**4.61**	378	**1.11**	**0.52**	**1.63**
211	**3,121**	**428,491**	378	**2.23**	**2.37**	**4.60**	225	**1.08**	**0.52**	**1.60**
407	**3,121**	**170,859**	225	**2.15**	**2.37**	**4.53**	132	**1.00**	**0.52**	**1.52**
133	**3,084**	**316,553**	132	**2.00**	**2.37**	**4.38**	106	**0.96**	**0.52**	**1.47**
372	**3,075**	**1,442,816**	103	**0.60**	**3.71**	**4.31**	104	**0.45**	**0.99**	**1.44**
233	**2,930**	**562,301**	106	**1.91**	**2.37**	**4.29**	87	**1.22**	**0.18**	**1.40**
409	**2,858**	**1,533,217**	83	**1.02**	**3.18**	**4.20**	129	**1.38**	**0.01**	**1.40**
145	**2,785**	**74,045**	110	**0.40**	**3.71**	**4.11**	235	**0.85**	**0.52**	**1.37**
373	**2,731**	**1,321,997**	235	**1.71**	**2.37**	**4.08**	92	**0.89**	**0.47**	**1.36**
			96	**0.35**	**3.71**	**4.06**	421	**1.05**	**0.29**	**1.33**
			52	**1.60**	**2.37**	**3.97**	52	**0.80**	**0.52**	**1.32**
			92	**1.77**	**2.19**	**3.96**	385	**0.79**	**0.52**	**1.31**
			385	**1.59**	**2.37**	**3.96**	232	**1.18**	**0.11**	**1.30**
			157	**0.40**	**3.45**	**3.85**	101	**1.10**	**0.18**	**1.28**
			82	**0.25**	**3.58**	**3.83**	83	**0.51**	**0.73**	**1.23**
			123	**0.36**	**3.45**	**3.81**	415	**0.71**	**0.50**	**1.21**
			53	**0.33**	**3.45**	**3.78**	64	**0.66**	**0.49**	**1.16**
			415	**1.41**	**2.33**	**3.74**	128	**1.12**	**0.01**	**1.13**
			64	**1.33**	**2.28**	**3.61**	103	**0.30**	**0.83**	**1.12**
			223	**1.20**	**2.37**	**3.57**	223	**0.60**	**0.52**	**1.12**
			224	**1.20**	**2.37**	**3.57**	224	**0.60**	**0.52**	**1.12**
			421	**2.10**	**1.39**	**3.49**				
			87	**2.45**	**0.92**	**3.37**				
			234	**0.43**	**2.91**	**3.33**				
			101	**2.20**	**0.92**	**3.12**				
Critical Acres			Critical Acres				Critical Acres			
Priority 1		120	Priority 1			440	Priority 1			280
Priority 2		400	Priority 2			720	Priority 2			720

Shaded areas are Priority-1 cells

Table A-8. AGNPS-derived SC-2 priority-3 critical cells for sediment, nitrogen, and phosphorus.

SC-2 Priority-3 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
416	**2,504**	**1,692,900**	65	**0.49**	**2.58**	**3.07**	317	**0.88**	**0.21**	**1.10**
130	**2,449**	**133,883**	232	**2.37**	**0.63**	**3.00**	110	**0.20**	**0.87**	**1.07**
131	**2,449**	**224,828**	80	**0.52**	**2.48**	**2.99**	134	**1.06**	**0.01**	**1.07**
362	**2,449**	**76,013**	129	**2.77**	**0.23**	**2.99**	96	**0.18**	**0.87**	**1.04**
222	**2,431**	**528,427**	514	**1.60**	**1.30**	**2.90**	396	**0.99**	**0.01**	**1.01**
232	**2,422**	**57,098**	236	**1.19**	**1.68**	**2.87**	157	**0.20**	**0.80**	**1.00**
317	**2,422**	**47,174**	317	**1.77**	**1.08**	**2.85**	362	**0.86**	**0.14**	**0.99**
147	**2,341**	**517,668**	114	**1.28**	**1.56**	**2.84**	284	**0.98**	**0.01**	**0.99**
235	**2,295**	**75,687**	386	**1.12**	**1.62**	**2.75**	130	**0.98**	**0.01**	**0.99**
87	**2,268**	**59,403**	237	**0.46**	**2.26**	**2.72**	123	**0.18**	**0.80**	**0.98**
434	**2,186**	**1,661,693**	226	**0.73**	**1.96**	**2.69**	114	**0.64**	**0.33**	**0.97**
134	**2,132**	**49,823**	182	**0.56**	**2.12**	**2.69**	53	**0.17**	**0.80**	**0.97**
128	**2,023**	**52,880**	238	**0.67**	**1.99**	**2.65**	82	**0.13**	**0.83**	**0.96**
119	**2,014**	**52,989**	78	**0.63**	**1.99**	**2.62**	236	**0.59**	**0.35**	**0.94**
101	**2,005**	**52,127**	73	**1.28**	**1.30**	**2.58**	161	**0.92**	**0.01**	**0.93**
83	**1,960**	**59,693**	128	**2.23**	**0.23**	**2.46**	386	**0.56**	**0.34**	**0.91**
378	**1,960**	**52,735**	362	**1.71**	**0.74**	**2.46**	73	**0.64**	**0.26**	**0.90**
284	**1,941**	**44,960**	134	**2.13**	**0.19**	**2.31**	234	**0.21**	**0.66**	**0.87**
73	**1,923**	**52,989**	248	**0.50**	**1.74**	**2.24**	65	**0.24**	**0.58**	**0.82**
225	**1,923**	**50,657**	244	**0.20**	**2.01**	**2.22**	80	**0.26**	**0.54**	**0.80**
422	**1,860**	**1,514,157**	396	**1.99**	**0.23**	**2.21**	226	**0.36**	**0.42**	**0.78**
431	**1,860**	**43,010**	130	**1.95**	**0.23**	**2.17**	238	**0.34**	**0.44**	**0.77**
216	**1,851**	**508,224**	284	**1.96**	**0.19**	**2.15**	285	**0.76**	**0.01**	**0.77**
421	**1,823**	**49,015**	397	**1.07**	**1.06**	**2.12**	397	**0.54**	**0.21**	**0.75**
132	**1,805**	**46,230**					78	**0.32**	**0.42**	**0.74**
54	**1,760**	**75,723**					182	**0.28**	**0.46**	**0.74**
161	**1,760**	**41,540**					164	**0.72**	**0.01**	**0.73**
396	**1,751**	**45,786**					237	**0.23**	**0.50**	**0.73**
430	**1,724**	**1,736,136**								
106	**1,669**	**43,627**								
385	**1,669**	**69,345**								
Critical Acres			Critical Acres				Critical Acres			
Priority 3		1,240	Priority 3			960	Priority 3			1,120

Table A-9. AGNPS-derived SC-6 priority-1 and 2 critical cells for sediment, nitrogen, and phosphorus.

SC-6 Priority-1 and 2 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
78	**7,375**	**216,291**	78	**6.89**	**0.24**	**7.12**	78	**3.44**	**0.01**	**3.46**
91	**6,777**	**610,309**	181	**4.60**	**0.98**	**5.58**	106	**2.46**	**0.09**	**2.55**
80	**6,632**	**300,152**	106	**4.93**	**0.51**	**5.44**	181	**2.30**	**0.20**	**2.49**
181	**4,853**	**130,671**	107	**4.49**	**0.51**	**5.00**	107	**2.24**	**0.09**	**2.33**
107	**4,663**	**126,634**	149	**3.74**	**0.98**	**4.73**	149	**1.87**	**0.20**	**2.07**
106	**4,318**	**142,392**	150	**3.27**	**0.61**	**3.88**	150	**1.64**	**0.11**	**1.75**
246	**4,173**	**1,326,614**	182	**2.42**	**0.98**	**3.40**	93	**1.35**	**0.10**	**1.45**
167	**4,001**	**738,150**	243	**2.67**	**0.61**	**3.28**	243	**1.33**	**0.11**	**1.44**
149	**3,810**	**101,015**	93	**2.69**	**0.58**	**3.27**	92	**1.32**	**0.10**	**1.42**
			92	**2.64**	**0.58**	**3.23**	182	**1.21**	**0.20**	**1.40**
Critical Acres			Critical Acres				Critical Acres			
Priority 1		120	Priority 1			200	Priority 1			200
Priority 2		240	Priority 2			200	Priority 2			200

Shaded areas are Priority-1 cells

Table A-10. AGNPS-derived SC-6 priority-3 critical cells for sediment, nitrogen, and phosphorus.

SC-6 Priority-3 Cells										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
230	**3,475**	**1,370,078**	241	**1.94**	**0.92**	**2.86**	151	**1.09**	**0.11**	**1.20**
147	**3,320**	**519,473**	151	**2.18**	**0.61**	**2.79**	241	**0.97**	**0.18**	**1.15**
150	**3,221**	**85,384**	263	**1.54**	**0.98**	**2.53**	263	**0.77**	**0.20**	**0.97**
148	**2,976**	**531,520**	231	**1.69**	**0.58**	**2.27**	231	**0.84**	**0.10**	**0.95**
245	**2,867**	**1,296,632**					123	**0.92**	**0.01**	**0.93**
77	**2,839**	**195,916**								
89	**2,839**	**280,565**								
165	**2,758**	**530,704**								
166	**2,513**	**616,660**								
92	**2,504**	**65,417**								
93	**2,504**	**66,887**								
94	**2,504**	**400,994**								
Critical Acres			Critical Acres				Critical Acres			
Priority 3		480	Priority 3			160	Priority 3			200

Table A-11. AGNPS-derived SC-7 priority-1 and 2 critical cells for sediment, nitrogen, and phosphorus.

SC-7 Priority-1 and 2 Cells											
Sediment			Nitrogen				Phosphorus				
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	
537	**2,795**	**66,969**	301	**0.77**	**4.40**	**5.17**	519	**1.20**	**0.47**	**1.67**	
538	**2,795**	**416,770**	300	**0.71**	**4.06**	**4.77**	127	**1.35**	**0.23**	**1.58**	
127	**2,759**	**67,205**	328	**0.71**	**4.06**	**4.77**	271	**0.98**	**0.47**	**1.46**	
199	**2,405**	**317,750**	519	**2.40**	**2.19**	**4.59**	490	**0.90**	**0.52**	**1.42**	
519	**2,359**	**57,958**	329	**1.67**	**2.55**	**4.22**	329	**0.83**	**0.56**	**1.39**	
346	**2,359**	**694,174**	490	**1.80**	**2.37**	**4.17**	334	**0.88**	**0.52**	**1.39**	
525	**2,350**	**237,668**	271	**1.97**	**2.19**	**4.16**	335	**0.88**	**0.52**	**1.39**	
256	**2,296**	**400,154**	334	**1.75**	**2.37**	**4.12**	276	**1.17**	**0.21**	**1.38**	
272	**2,296**	**77,260**	335	**1.75**	**2.37**	**4.12**	301	**0.39**	**0.99**	**1.37**	
427	**2,296**	**110,889**	516	**1.80**	**2.19**	**3.99**	516	**0.90**	**0.47**	**1.37**	
316	**2,223**	**633,485**	517	**1.80**	**2.19**	**3.99**	517	**0.90**	**0.47**	**1.37**	
276	**2,142**	**56,461**	491	**1.60**	**2.37**	**3.97**	491	**0.80**	**0.52**	**1.32**	
247	**2,051**	**48,875**	344	**1.58**	**2.37**	**3.95**	344	**0.79**	**0.52**	**1.31**	
444	**2,042**	**402,078**	127	**2.70**	**1.12**	**3.82**	247	**1.05**	**0.23**	**1.27**	
526	**2,033**	**103,221**	520	**1.60**	**2.19**	**3.79**	520	**0.80**	**0.47**	**1.27**	
277	**1,942**	**79,347**	492	**1.48**	**2.25**	**3.73**	300	**0.36**	**0.91**	**1.27**	
288	**1,942**	**630,799**	431	**1.16**	**2.55**	**3.71**	328	**0.35**	**0.91**	**1.26**	
257	**1,906**	**419,855**	518	**1.50**	**2.19**	**3.69**	492	**0.74**	**0.49**	**1.23**	
287	**1,906**	**593,485**	299	**1.47**	**2.19**	**3.66**	518	**0.75**	**0.47**	**1.22**	
175	**1,851**	**42,868**	464	**1.00**	**2.55**	**3.55**	299	**0.73**	**0.47**	**1.20**	
410	**1,851**	**684,946**	508	**1.13**	**2.37**	**3.50**	40	**0.20**	**1.00**	**1.20**	
			40	**0.40**	**3.01**	**3.42**	175	**0.94**	**0.21**	**1.15**	
			276	**2.35**	**1.05**	**3.40**	380	**0.92**	**0.23**	**1.15**	
			521	**1.11**	**2.28**	**3.39**	255	**0.93**	**0.21**	**1.14**	
			326	**1.13**	**2.19**	**3.32**	289	**0.93**	**0.21**	**1.14**	
			483	**1.07**	**2.19**	**3.26**	431	**0.58**	**0.56**	**1.13**	
			247	**2.10**	**1.12**	**3.22**	412	**0.97**	**0.16**	**1.13**	
			482	**0.97**	**2.19**	**3.16**	277	**0.88**	**0.21**	**1.09**	
			349	**1.41**	**1.66**	**3.06**	508	**0.56**	**0.52**	**1.08**	
			481	**0.87**	**2.19**	**3.06**	446	**0.88**	**0.20**	**1.07**	
			355	**1.04**	**2.01**	**3.05**	464	**0.50**	**0.56**	**1.06**	
							502	**0.88**	**0.18**	**1.06**	
							349	**0.70**	**0.35**	**1.05**	
							521	**0.55**	**0.49**	**1.05**	
Critical Acres			Critical Acres				Critical Acres				
Priority 1		280	Priority 1			520	Priority 1			440	
Priority 2		560	Priority 2			720	Priority 2			920	

Shaded areas are Priority-1 cells

Table A-12. AGNPS-derived SC-7 priority-3 critical cells for sediment, nitrogen, and phosphorus.

SC-7 Priority-3 Cells										
Sediment			Nitrogen				Phosphorus			
				Sediment	Soluble			Sediment	Soluble	
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Outlet (kg/a)	Outlet (kg/a)	Total (kg/a)	Cell Number	Outlet (kg/a)	Outlet (kg/a)	Total (kg/a)
128	**1,770**	**69,437**	380	**1.84**	**1.12**	**2.96**	500	**0.85**	**0.20**	**1.04**
177	**1,760**	**307,405**	175	**1.89**	**1.05**	**2.94**	200	**0.84**	**0.20**	**1.04**
412	**1,751**	**44,229**	255	**1.86**	**1.05**	**2.91**	326	**0.56**	**0.47**	**1.03**
413	**1,751**	**58,739**	289	**1.86**	**1.05**	**2.91**	501	**0.85**	**0.18**	**1.03**
262	**1,751**	**92,051**	451	**0.64**	**2.19**	**2.83**	128	**0.80**	**0.23**	**1.03**
271	**1,751**	**45,254**	277	**1.77**	**1.05**	**2.83**	496	**0.80**	**0.21**	**1.01**
176	**1,670**	**73,748**	412	**1.93**	**0.85**	**2.78**	483	**0.54**	**0.47**	**1.01**
178	**1,670**	**324,265**	446	**1.76**	**0.98**	**2.74**	229	**0.79**	**0.21**	**1.00**
228	**1,670**	**345,145**	128	**1.59**	**1.12**	**2.71**	126	**0.76**	**0.23**	**0.99**
255	**1,670**	**42,096**	272	**1.25**	**1.43**	**2.69**	184	**0.76**	**0.22**	**0.98**
289	**1,670**	**42,096**	502	**1.76**	**0.92**	**2.68**	324	**0.77**	**0.20**	**0.96**
317	**1,670**	**660,236**	500	**1.69**	**0.98**	**2.68**	139	**0.73**	**0.23**	**0.96**
426	**1,670**	**52,169**	200	**1.69**	**0.98**	**2.67**	482	**0.49**	**0.47**	**0.96**
373	**1,624**	**284,891**	496	**1.61**	**1.05**	**2.66**	355	**0.52**	**0.43**	**0.95**
207	**1,624**	**413,612**	126	**1.52**	**1.12**	**2.64**	343	**0.74**	**0.20**	**0.94**
411	**1,579**	**685,962**	184	**1.52**	**1.12**	**2.64**	272	**0.63**	**0.30**	**0.93**
446	**1,579**	**39,165**	229	**1.59**	**1.05**	**2.64**	305	**0.71**	**0.20**	**0.91**
376	**1,570**	**101,897**	501	**1.69**	**0.92**	**2.61**	481	**0.44**	**0.47**	**0.91**
502	**1,561**	**39,428**	139	**1.46**	**1.12**	**2.58**	49	**0.23**	**0.67**	**0.90**
503	**1,561**	**79,365**	324	**1.53**	**0.98**	**2.52**	473	**0.72**	**0.18**	**0.90**
314	**1,525**	**45,463**	49	**0.46**	**2.05**	**2.51**	475	**0.72**	**0.18**	**0.90**
490	**1,525**	**40,299**	343	**1.49**	**0.98**	**2.48**	246	**0.88**	**0.01**	**0.89**
516	**1,525**	**40,299**	305	**1.43**	**0.98**	**2.41**	403	**0.70**	**0.18**	**0.88**
517	**1,525**	**40,299**	203	**1.27**	**1.12**	**2.39**	537	**0.78**	**0.10**	**0.88**
518	**1,525**	**64,574**	242	**1.32**	**1.05**	**2.37**	242	**0.66**	**0.21**	**0.87**
137	**1,515**	**168,421**	473	**1.45**	**0.92**	**2.36**	203	**0.64**	**0.23**	**0.86**
334	**1,506**	**39,074**	475	**1.45**	**0.92**	**2.36**	413	**0.70**	**0.16**	**0.86**
335	**1,506**	**39,074**	204	**1.24**	**1.12**	**2.36**	204	**0.62**	**0.23**	**0.85**
200	**1,497**	**37,287**	403	**1.40**	**0.92**	**2.31**	106	**0.63**	**0.21**	**0.84**
201	**1,497**	**104,183**	106	**1.26**	**1.05**	**2.31**	543	**0.72**	**0.11**	**0.83**
500	**1,479**	**37,468**	219	**1.24**	**1.05**	**2.30**	290	**0.64**	**0.20**	**0.83**
501	**1,479**	**37,468**	291	**0.86**	**1.43**	**2.29**	219	**0.62**	**0.21**	**0.83**
329	**1,461**	**36,770**	118	**1.15**	**1.12**	**2.27**	514	**0.72**	**0.11**	**0.83**
459	**1,452**	**2,051,497**	233	**1.22**	**1.05**	**2.27**	375	**0.65**	**0.18**	**0.83**
493	**1,452**	**2,242,096**	400	**1.22**	**1.05**	**2.27**	387	**0.63**	**0.20**	**0.83**
495	**1,434**	**2,316,316**	290	**1.28**	**0.98**	**2.27**	465	**0.63**	**0.20**	**0.83**
375	**1,425**	**26,887**	387	**1.26**	**0.98**	**2.25**	233	**0.61**	**0.21**	**0.82**
202	**1,416**	**103,140**	413	**1.39**	**0.85**	**2.24**	400	**0.61**	**0.21**	**0.82**
229	**1,416**	**34,537**	445	**0.54**	**1.71**	**2.24**	318	**0.65**	**0.15**	**0.81**
254	**1,416**	**51,044**	465	**1.26**	**0.98**	**2.24**	118	**0.58**	**0.23**	**0.80**
286	**1,416**	**492,768**	375	**1.30**	**0.92**	**2.21**	451	**0.32**	**0.47**	**0.79**
158	**1,388**	**266,125**	263	**0.91**	**1.29**	**2.20**	445	**0.27**	**0.52**	**0.79**

Table A-12 (Continued). AGNPS-derived SC-7 priority-3 critical cells for sediment, nitrogen, and phosphorus.

SC-7 Priority-3 Cells (Continued)										
Sediment			Nitrogen				Phosphorus			
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
405	**1,388**	**382,913**	398	**0.90**	**1.30**	**2.20**	159	**0.59**	**0.20**	**0.78**
496	**1,388**	**35,045**	159	**1.17**	**0.98**	**2.15**	438	**0.58**	**0.20**	**0.77**
497	**1,388**	**232,396**	262	**0.83**	**1.32**	**2.15**	437	**0.56**	**0.20**	**0.76**
301	**1,370**	**33,430**	438	**1.15**	**0.98**	**2.13**	535	**0.64**	**0.10**	**0.74**
494	**1,370**	**2,247,740**					399	**0.53**	**0.21**	**0.74**
322	**1,361**	**97,142**								
323	**1,361**	**101,434**								
543	**1,361**	**30,753**								
324	**1,352**	**33,103**								
374	**1,352**	**360,935**								
246	**1,352**	**39,256**								
379	**1,343**	**644,546**								
315	**1,334**	**54,510**								
491	**1,325**	**34,855**								
492	**1,325**	**95,345**								
520	**1,325**	**34,855**								
243	**1,316**	**40,136**								
263	**1,316**	**120,272**								
126	**1,316**	**32,804**								
344	**1,307**	**34,365**								
279	**1,298**	**52,831**								
343	**1,279**	**31,987**								
Critical Acres			Critical Acres				Critical Acres			
Priority 3		2,560	Priority 3			1,840	Priority 3			1,880

Table A-13. AGNPS-derived SC-8 priority-1 and 2 critical cells for sediment.

SC-8 Sediment Priority-1 and 2 Cells								
East Mina Sub-watershed			North Crompton Sub-watershed			West Crompton Sub-watershed		
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)
144	**4,799**	**49,569**	99	**6,976**	**121,917**	248	**3,547**	**1,016,239**
188	**4,309**	**114,696**	25	**2,731**	**159,111**	77	**3,338**	**80,105**
143	**4,146**	**134,064**	208	**2,731**	**84,704**	274	**3,239**	**86,165**
187	**2,858**	**72,294**	585	**2,731**	**65,617**	258	**3,121**	**84,241**
191	**2,513**	**187,651**	315	**2,549**	**58,278**	120	**2,876**	**196,841**
			247	**2,440**	**196,052**	257	**2,395**	**948000**
			361	**2,295**	**159,547**	140	**2,377**	**607542**
			865	**2,295**	**151,681**	67	**2,341**	**48906**
			875	**2,277**	**2,561,186**	157	**2,186**	**794604**
			145	**2,268**	**144,016**	148	**2,150**	**695168**
			206	**2,268**	**91,227**	95	**2,050**	**364861**
			114	**2,268**	**56,318**			
			917	**2,186**	**2,138,110**			
Critical Acres			Critical Acres			Critical Acres		
Priority 1		160	Priority 1		80	Priority 1		200
Priority 2		40	Priority 2		440	Priority 2		240

Shaded areas are Priority-1 cells

Table A-14. AGNPS-derived SC-8 priority-3 critical cells for sediment.

SC-8 Sediment Priority-3 Cells								
East Mina Sub-watershed			North Crompton Sub-watershed			West Crompton Sub-watershed		
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)
			1	**2,023**	**52,571**	184	**2,023**	**835,627**
			883	**2,014**	**132,939**	149	**2,005**	**723,481**
			910	**2,014**	**52,989**	53	**1,823**	**133,592**
			701	**2,005**	**686,921**	168	**1,678**	**84,513**
			586	**2,005**	**101,051**	110	**1,669**	**153,859**
			115	**2,005**	**50,449**	109	**1,669**	**140,088**
			822	**1,923**	**345,720**	141	**1,633**	**634,758**
			847	**1,923**	**50,657**	93	**1,606**	**299,108**
			14	**1,760**	**61,997**	121	**1,533**	**39,181**
			537	**1,760**	**45,232**	180	**1,533**	**39,181**
			213	**1,760**	**41,431**	176	**1,424**	**34,736**
			823	**1,751**	**347,117**	66	**1,406**	**77,038**
			846	**1,751**	**303,245**	167	**1,388**	**63,186**
			700	**1,751**	**65,091**	41	**1,370**	**238,118**
			705	**1,751**	**57,906**	218	**1,352**	**63,068**
			906	**1,751**	**45,396**			
			450	**1,678**	**221,108**			
			328	**1,678**	**38,465**			
			699	**1,669**	**45,867**			
			334	**1,660**	**220,238**			
			864	**1,642**	**116,428**			
			44	**1,633**	**195,444**			
			619	**1,624**	**93,758**			
			38	**1,588**	**77,610**			
			400	**1,588**	**41,912**			
			550	**1,533**	**403,870**			
			866	**1,533**	**195,426**			
			144	**1,533**	**69,300**			
			257	**1,533**	**39,054**			
			817	**1,533**	**39,054**			
			867	**1,533**	**39,054**			
			207	**1,533**	**37,303**			
			818	**1,506**	**120,928**			
			418	**1,506**	**37,594**			
			876	**1,433**	**2,645,291**			
			796	**1,424**	**28,667**			
			43	**1,415**	**187,434**			
			378	**1,415**	**51,274**			
			420	**1,415**	**38,791**			
			377	**1,415**	**37,984**			
			191	**1,415**	**36,351**			
			505	**1,415**	**33,847**			
			214	**1,406**	**74,680**			

Table A-14 (Continued). AGNPS-derived SC-8 priority-3 critical cells for sediment.

SC-8 Sediment Priority-3 Cells (Continued)								
East Mina Sub-watershed			North Crompton Sub-watershed			West Crompton Sub-watershed		
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)
			256	**1,388**	**353,095**			
			880	**1,388**	**81,901**			
			180	**1,388**	**60,437**			
			756	**1,388**	**54,486**			
			321	**1,388**	**45,804**			
			755	**1,388**	**39,925**			
			816	**1,388**	**35,036**			
			335	**1,379**	**237,910**			
Critical Acres Priority 3		0	Critical Acres Priority 3		2,040	Critical Acres Priority 3		600

Table A-15. AGNPS-derived SC-8 priority-1 and 2 critical cells for nitrogen.

SC-8 Nitrogen Priority-1 and 2 Cells											
East Mina Sub-watershed				North Crompton Sub-watershed				West Crompton Sub-watershed			
Cell Number	Outlet (kg/a)	Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
188	**4.15**	**0.18**	**4.32**	374	**1.15**	**4.45**	**5.60**	258	**3.24**	**2.73**	**5.96**
187	**2.86**	**0.11**	**2.98**	910	**2.24**	**2.55**	**4.79**	274	**3.30**	**1.32**	**4.62**
143	**1.55**	**0.88**	**2.43**	847	**2.15**	**2.55**	**4.70**	177	**1.56**	**2.73**	**4.29**
				418	**1.70**	**2.55**	**4.25**	77	**3.11**	**0.81**	**3.92**
				704	**1.50**	**2.55**	**4.05**	121	**1.76**	**1.12**	**2.88**
				705	**1.38**	**2.55**	**3.93**	65	**1.22**	**1.19**	**2.41**
				99	**3.78**	**0.12**	**3.90**	176	**0.92**	**1.46**	**2.38**
				618	**2.89**	**0.85**	**3.74**	5	**1.31**	**0.98**	**2.30**
				585	**2.65**	**0.98**	**3.63**	267	**1.52**	**0.75**	**2.27**
				700	**2.64**	**0.92**	**3.55**	67	**2.10**	**0.17**	**2.27**
				114	**2.35**	**1.05**	**3.40**	164	**1.26**	**0.98**	**2.24**
				1	**2.22**	**1.12**	**3.34**				
				115	**2.15**	**1.05**	**3.20**				
				586	**2.15**	**0.98**	**3.13**				
				537	**1.97**	**0.98**	**2.95**				
				208	**1.87**	**1.05**	**2.92**				
				699	**1.99**	**0.92**	**2.91**				
				315	**2.41**	**0.44**	**2.86**				
				400	**1.85**	**0.98**	**2.83**				
				257	**1.75**	**1.05**	**2.80**				
				817	**1.75**	**1.05**	**2.80**				
				867	**1.75**	**1.05**	**2.80**				
				207	**1.69**	**1.05**	**2.74**				
				858	**1.54**	**1.12**	**2.66**				
				816	**1.61**	**1.05**	**2.66**				
				706	**0.73**	**1.76**	**2.49**				
Critical Acres				Critical Acres				Critical Acres			
Priority 1			40	Priority 1			520	Priority 1			160
Priority 2			80	Priority 2			520	Priority 2			280

Shaded areas are Priority-1 cells

Table A-16. AGNPS-derived SC-8 priority-3 critical cells for nitrogen.

SC-8 Nitrogen Priority-3 Cells

East Mina Sub-watershed

Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
144	**1.56**	**0.66**	**2.23**
217	**0.90**	**1.30**	**2.20**
189	**1.09**	**1.08**	**2.17**
190	**0.73**	**1.38**	**2.12**
Critical Acres Priority 3			160

North Crompton Sub-watershed

Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
495	**1.29**	**0.98**	**2.27**
145	**1.37**	**0.87**	**2.24**
859	**1.12**	**1.12**	**2.24**
530	**1.07**	**1.12**	**2.19**
906	**1.97**	**0.20**	**2.17**
587	**1.43**	**0.69**	**2.12**
531	**0.96**	**1.12**	**2.08**
28	**1.85**	**0.17**	**2.02**
457	**1.24**	**0.70**	**1.95**
144	**1.15**	**0.74**	**1.89**
371	**1.23**	**0.63**	**1.86**
413	**1.23**	**0.63**	**1.86**
719	**0.87**	**0.98**	**1.85**
191	**1.65**	**0.18**	**1.83**
800	**1.06**	**0.72**	**1.78**
146	**1.03**	**0.74**	**1.77**
214	**1.22**	**0.54**	**1.76**
718	**0.95**	**0.80**	**1.75**
505	**1.56**	**0.18**	**1.74**
613	**1.01**	**0.72**	**1.72**
456	**1.09**	**0.63**	**1.72**
792	**1.17**	**0.54**	**1.71**
415	**0.98**	**0.68**	**1.66**
886	**1.38**	**0.27**	**1.65**
Critical Acres Priority 3			960

West Crompton Sub-watershed

Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
168	**0.89**	**1.04**	**1.93**
180	**1.76**	**0.17**	**1.93**
171	**0.88**	**1.03**	**1.91**
167	**0.85**	**1.05**	**1.90**
165	**0.91**	**0.98**	**1.90**
166	**0.85**	**1.03**	**1.88**
217	**0.51**	**1.36**	**1.87**
191	**0.33**	**1.47**	**1.80**
218	**0.61**	**1.16**	**1.77**
268	**1.13**	**0.63**	**1.76**
Critical Acres Priority 3			400

Table A-17. AGNPS-derived SC-8 priority-1 and 2 critical cells for phosphorus.

SC-8 Phosphorus Priority-1 and 2 Cells											
East Mina Sub-watershed				North Crompton Sub-watershed				West Crompton Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
188	**2.07**	**0.01**	**2.08**	99	**1.89**	**0.01**	**1.90**	258	**1.62**	**0.60**	**2.22**
187	**1.43**	**0.01**	**1.44**	910	**1.12**	**0.56**	**1.67**	274	**1.65**	**0.27**	**1.92**
143	**0.78**	**0.17**	**0.94**	847	**1.08**	**0.56**	**1.64**	77	**1.56**	**0.15**	**1.71**
144	**0.78**	**0.12**	**0.91**	618	**1.44**	**0.16**	**1.61**	177	**0.78**	**0.60**	**1.38**
202	**0.79**	**0.01**	**0.80**	374	**0.57**	**1.02**	**1.59**	121	**0.88**	**0.23**	**1.10**
				585	**1.32**	**0.20**	**1.52**	67	**1.05**	**0.01**	**1.06**
				700	**1.32**	**0.18**	**1.49**	267	**0.76**	**0.14**	**0.90**
				418	**0.85**	**0.56**	**1.41**	180	**0.88**	**0.01**	**0.88**
				114	**1.17**	**0.21**	**1.38**	65	**0.61**	**0.24**	**0.85**
				1	**1.11**	**0.23**	**1.34**	5	**0.65**	**0.20**	**0.85**
				704	**0.75**	**0.56**	**1.31**	164	**0.63**	**0.20**	**0.83**
				115	**1.08**	**0.21**	**1.28**				
				315	**1.21**	**0.07**	**1.28**				
				586	**1.08**	**0.20**	**1.27**				
				705	**0.69**	**0.56**	**1.25**				
				537	**0.98**	**0.20**	**1.18**				
				699	**0.99**	**0.18**	**1.17**				
				208	**0.93**	**0.21**	**1.14**				
				400	**0.93**	**0.20**	**1.12**				
				257	**0.88**	**0.21**	**1.08**				
				817	**0.88**	**0.21**	**1.08**				
				867	**0.88**	**0.21**	**1.08**				
				207	**0.84**	**0.21**	**1.05**				
				816	**0.80**	**0.21**	**1.01**				
				858	**0.77**	**0.23**	**1.00**				
				906	**0.99**	**0.01**	**1.00**				
				28	**0.93**	**0.01**	**0.93**				
				145	**0.68**	**0.17**	**0.85**				
				587	**0.71**	**0.13**	**0.84**				
				495	**0.64**	**0.20**	**0.84**				
				191	**0.83**	**0.01**	**0.83**				
				505	**0.78**	**0.01**	**0.79**				
				859	**0.56**	**0.23**	**0.78**				
Critical Acres				Critical Acres				Critical Acres			
Priority 1			80	Priority 1			960	Priority 1			240
Priority 2			120	Priority 2			360	Priority 2			200

Shaded areas are Priority-1 cells

Table A-18. AGNPS-derived SC-8 priority-3 critical cells for phosphorus.

SC-8 Phosphorus Priority-3 Cells											
East Mina Sub-watershed				North Crompton Sub-watershed				West Crompton Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
189	**0.54**	**0.22**	**0.76**	530	**0.54**	**0.23**	**0.76**	176	**0.46**	**0.30**	**0.76**
229	**0.72**	**0.01**	**0.73**	457	**0.62**	**0.13**	**0.75**	268	**0.57**	**0.11**	**0.68**
217	**0.45**	**0.26**	**0.71**	706	**0.36**	**0.38**	**0.74**	168	**0.45**	**0.21**	**0.66**
158	**0.53**	**0.14**	**0.67**	128	**0.73**	**0.01**	**0.73**	165	**0.46**	**0.20**	**0.65**
190	**0.37**	**0.29**	**0.65**	371	**0.62**	**0.11**	**0.73**	171	**0.44**	**0.21**	**0.65**
203	**0.53**	**0.01**	**0.54**	413	**0.62**	**0.11**	**0.73**	167	**0.43**	**0.21**	**0.64**
172	**0.53**	**0.01**	**0.54**	144	**0.58**	**0.14**	**0.72**	166	**0.43**	**0.20**	**0.63**
				214	**0.61**	**0.10**	**0.71**	6	**0.60**	**0.01**	**0.61**
				531	**0.48**	**0.23**	**0.70**	217	**0.25**	**0.34**	**0.59**
				886	**0.69**	**0.01**	**0.70**	218	**0.31**	**0.28**	**0.59**
				792	**0.59**	**0.10**	**0.68**	181	**0.49**	**0.09**	**0.57**
				800	**0.53**	**0.13**	**0.66**	182	**0.41**	**0.11**	**0.53**
				456	**0.54**	**0.11**	**0.66**				
				146	**0.51**	**0.14**	**0.65**				
				798	**0.64**	**0.01**	**0.65**				
				8	**0.64**	**0.01**	**0.64**				
				107	**0.64**	**0.01**	**0.64**				
				891	**0.59**	**0.05**	**0.64**				
				613	**0.50**	**0.13**	**0.64**				
				15	**0.63**	**0.01**	**0.64**				
				651	**0.63**	**0.01**	**0.64**				
				379	**0.62**	**0.01**	**0.63**				
				536	**0.62**	**0.01**	**0.63**				
				549	**0.61**	**0.01**	**0.63**				
				718	**0.48**	**0.15**	**0.62**				
				147	**0.55**	**0.07**	**0.62**				
				719	**0.44**	**0.19**	**0.62**				
				415	**0.49**	**0.12**	**0.62**				
				399	**0.50**	**0.10**	**0.60**				
				619	**0.49**	**0.12**	**0.60**				
				100	**0.59**	**0.01**	**0.60**				
				328	**0.49**	**0.10**	**0.60**				
				890	**0.54**	**0.05**	**0.59**				
				213	**0.53**	**0.05**	**0.58**				
				248	**0.49**	**0.08**	**0.57**				
				551	**0.55**	**0.01**	**0.57**				
				10	**0.48**	**0.08**	**0.56**				
				51	**0.51**	**0.05**	**0.56**				
				329	**0.40**	**0.14**	**0.54**				
				691	**0.49**	**0.05**	**0.54**				
				363	**0.49**	**0.04**	**0.53**				
				794	**0.52**	**0.01**	**0.53**				
				419	**0.52**	**0.01**	**0.53**				
				620	**0.43**	**0.10**	**0.53**				
Critical Acres				Critical Acres				Critical Acres			
Priority 3			280	Priority 3			1,760	Priority 3			480

Table A-19. AGNPS Site Ungauged priority-1 and 2 critical cells for sediment.

West Mina Sub-watershed			East Mina Sub-watershed		
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)
654	**3,520**	**554,209**	447	**15,068**	**316,680**
661	**2,585**	**95,880**	445	**4,509**	**1,837,288**
632	**2,295**	**113,979**	394	**3,121**	**84,105**
730	**2,295**	**61,008**	407	**3,121**	**170,859**
707	**2,105**	**56,119**	532	**2,966**	**2,426,469**
633	**2,014**	**194,328**	468	**2,658**	**2,226,425**
660	**2,014**	**52,018**			
676	**1,923**	**82,917**			
551	**1,796**	**52,381**			
649	**1,751**	**48,798**			
636	**1,742**	**43,808**			
Critical Acres			Critical Acres		
Priority 1		0	Priority 1		80
Priority 2		440	Priority 2		160

Table A-20. AGNPS Site Ungauged priority-3 critical cells for sediment.

West Mina Sub-watershed			East Mina Sub-watershed		
Cell Number	Erosion (kg/a)	Yield (kg)	Cell Number	Erosion (kg/a)	Yield (kg)
653	**1,660**	**163,629**	439	**2,422**	**60,972**
			528	**2,295**	**107,583**
			547	**2,295**	**109,788**
			454	**2,050**	**1,881,458**
			531	**2,005**	**83,497**
			431	**1,860**	**43,010**
			523	**1,860**	**285,927**
			541	**1,860**	**1,296,559**
			455	**1,805**	**1,882,520**
			510	**1,769**	**46,657**
			527	**1,733**	**46,339**
			430	**1,724**	**1,736,136**
			446	**1,724**	**1,710,145**
Critical Acres			Critical Acres		
Priority 3		40	Priority 3		520

Table A-21. AGNPS Site Ungauged priority-1 and 2 critical cells for nitrogen.

AGNPS Site Ungauged Nitrogen Priority-1 and 2 Cells

West Mina Sub-watershed				East Mina Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
730	**2.50**	**3.27**	**5.77**	447	**9.34**	**0.63**	**9.97**
707	**2.34**	**1.48**	**3.82**	527	**2.00**	**2.19**	**4.20**
650	**0.88**	**2.84**	**3.72**	510	**2.02**	**1.66**	**3.67**
284	**1.21**	**2.33**	**3.54**	442	**0.87**	**2.76**	**3.63**
661	**1.49**	**2.01**	**3.50**	394	**1.86**	**1.28**	**3.14**
649	**1.20**	**1.54**	**2.74**	514	**1.60**	**1.30**	**2.90**
660	**1.27**	**1.38**	**2.65**	439	**2.50**	**0.19**	**2.69**
Critical Acres				Critical Acres			
Priority 1			200	Priority 1			160
Priority 2			80	Priority 2			120

Shaded areas are Priority-1 cells

Table A-22. AGNPS Site Ungauged priority-3 critical cells for nitrogen.

AGNPS Site Ungauged Nitrogen Priority-3 Cells

West Mina Sub-watershed				East Mina Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
731	**0.76**	**1.74**	**2.50**	528	**1.30**	**1.25**	**2.54**
687	**0.73**	**1.43**	**2.16**	431	**1.89**	**0.63**	**2.52**
308	**1.45**	**0.63**	**2.08**	407	**1.36**	**0.89**	**2.25**
637	**1.00**	**0.91**	**1.91**	538	**0.47**	**1.74**	**2.21**
483	**1.72**	**0.18**	**1.90**	540	**1.45**	**0.63**	**2.08**
307	**1.23**	**0.63**	**1.86**	443	**0.49**	**1.49**	**1.97**
688	**0.72**	**1.12**	**1.83**	547	**0.76**	**1.22**	**1.97**
636	**1.10**	**0.72**	**1.82**	441	**0.71**	**1.12**	**1.82**
				420	**0.62**	**1.17**	**1.79**
Critical Acres				Critical Acres			
Priority 3			320	Priority 3			360

Table A-23. AGNPS Site Ungauged priority-1 and 2 critical cells for phosphorus.

AGNPS Site Ungauged Phosphorus Priority-1 and 2 Cells							
West Mina Sub-watershed				East Mina Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
730	**1.25**	**0.73**	**1.98**	447	**4.67**	**0.11**	**4.78**
707	**1.17**	**0.30**	**1.47**	527	**1.00**	**0.47**	**1.47**
661	**0.74**	**0.43**	**1.17**	510	**1.01**	**0.35**	**1.36**
284	**0.61**	**0.50**	**1.11**	439	**1.25**	**0.01**	**1.26**
650	**0.44**	**0.63**	**1.07**	394	**0.93**	**0.26**	**1.19**
				514	**0.80**	**0.26**	**1.06**
				431	**0.94**	**0.11**	**1.06**
				442	**0.44**	**0.60**	**1.04**
Critical Acres				Critical Acres			
Priority 1			80	Priority 1			120
Priority 2			120	Priority 2			200

Shaded areas are Priority-1 cells

Table A-24. AGNPS Site Ungauged priority-3 critical cells for phosphorus.

AGNPS Site Ungauged Phosphorus Priority-3 Cells							
West Mina Sub-watershed				East Mina Sub-watershed			
Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)	Cell Number	Sediment Outlet (kg/a)	Soluble Outlet (kg/a)	Total (kg/a)
649	**0.60**	**0.33**	**0.93**	528	**0.65**	**0.25**	**0.90**
660	**0.63**	**0.29**	**0.92**	407	**0.68**	**0.17**	**0.85**
483	**0.86**	**0.01**	**0.87**	540	**0.72**	**0.11**	**0.83**
308	**0.72**	**0.11**	**0.83**	538	**0.23**	**0.44**	**0.67**
731	**0.38**	**0.37**	**0.75**				
307	**0.62**	**0.11**	**0.73**				
636	**0.55**	**0.14**	**0.68**				
334	**0.57**	**0.11**	**0.68**				
637	**0.50**	**0.18**	**0.68**				
Critical Acres				Critical Acres			
Priority 3			360	Priority 3			160

Appendix N

Snake Creek Tributary Chemical Data for 1999 and 2000

Table D-1. Tributary chemical data for Snake Creek by site and date for 1999 and 2000.

Site	Time	Date	Air Temp. (° C)	Field pH S.U	DO mg/L	Water Temp. (° C)	Fecal Coliform #/100ml	Alkalinity mg/L	Total Solids mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	TKN mg/L	Ammonia mg/L	Un-ionized Ammonia mg/L	Nitrate mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Total Dissolved Phosphorus mg/L	Volatile Total Suspended Solids mg/L
SC1	1100	06/30/99	24	7.98	6	19.8	7,400	402	1270	1240	30	2.83	0.02	0.0007207	0.1	2.81	2.93	1.97	1.86	7
SC1	1045	07/07/99	31	7.83	5.4	25.0	840	400	1277	1255	22	2.75	0.02	0.0007410	0.1	2.73	2.85	1.93	1.78	6
SC1	1300	07/13/99	31	8.16	5.2	30.0	550	183	904	804	100	2.62	0.02	-	0.1	2.6	2.72	1.17	1.08	1
SC1	1050	07/19/99	24	7.65	3.4	21.9	670	275	955	921	34	2.98	0.15	0.0029945	0.1	2.83	3.08	1.92	1.72	4
SC1	1000	07/23/99	28	7.73	3.4	25.4	-	245	1032	888	144	2.76	0.16	0.0048764	0.4	2.6	3.16	1.95	1.64	18
SC1	1145	07/27/99	31	7.67	4.2	26.3	450	213	856	842	14	2.04	0.02	0.0005668	0.1	2.02	2.14	1.6	1.46	4
SC1	1040	09/03/99	15	7.50	7.4	14.6	-	55	616	508	108	1.88	0.02	0.0001666	1.1	1.86	2.98	0.724	0.428	10
SC1	1130	10/21/99	16	8.25	8.4	8.0	20	287	1904	1895	9	1.59	0.02	0.0005503	0.1	1.57	1.69	0.204	0.164	1
SC1	1100	03/27/00	13	8.73	9.4	7.6	30	231	1909	1877	32	3.3	0.02	0.0015289	1.1	3.28	4.4	0.548	0.32	6
SC2	1045	06/29/99	-	-	-	-	310	313	964	908	56	2.7	0.02	0.0003069	0.1	2.68	2.8	2.46	2.2	11
SC2	1000	07/07/99	26	7.36	3.2	23.4	100	335	1045	1020	25	2.15	0.02	0.0002300	0.1	2.13	2.25	2.46	2.35	5
SC2	1200	07/08/99	28	7.38	3.6	23.8	15,100	70	930	346	584	2.92	0.28	0.0034667	23.2	2.64	26.12	1.33	0.547	60
SC2	1140	07/13/99	31	7.57	5.4	28.9	160	159	665	659	6	2.21	0.02	0.0005401	0.4	2.19	2.61	0.877	0.787	1
SC2	913	07/19/99	23	7.49	1.6	21.9	70	188	645	644	1	2.03	0.02	0.0002779	0.1	2.01	2.13	1.39	1.37	1
SC2	1100	07/23/99	29	7.65	4.2	29.8		170	578	563	15	2.03	0.02	0.0006856	1.4	2.01	3.43	1.36	1.27	2
SC2	1230	07/27/99	31	7.63	4.3	25.4	70	216	633	627	6	1.81	0.02	0.0004872	0.1	1.79	1.91	1.84	1.72	1
SC2	30	09/03/99	15	7.98	6.2	14.6		251	1672	652	1020	2.48	0.11	0.0027218	0.2	2.37	2.68	2.19	0.976	44
SC2	1051	10/21/99	16.3	8.02	8.2	11.1	40	246	924	914	10	1.19	0.02	0.0004164	0.1	1.17	1.29	0.381	0.348	3
SC2	1015	03/27/00	13	8.48	9.6	7.6	10	199	1462	1437	25	2.56	0.02	0.0008895	0.1	2.54	2.66	0.496	0.278	11
SC6	1000	06/30/99	19	7.8	-	-	600	330	1458	1449	9	2.86	0.02	0.0004821	0.1	2.84	2.96	1.36	1.32	4
SC6	1335	07/07/99	30	8.04	5	25.8	590	386	1541	1474	67	3.74	0.42	0.0260099	0.1	3.32	3.84	1.8	1.7	11
SC6	1020	07/08/99	29	7.4	4.6	23.5	25,000	67	919	793	126	2.84	0.35	0.0044402	5.7	2.49	8.54	1.49	1.09	22
SC6	820	07/13/99	22	7.53	6	22.6	320	183	589	582	7	1.67	0.02	0.0003198	0.1	1.65	1.77	1.22	1.13	2
SC6	800	07/19/99	22	7.82	6.2	20.4	260	267	845	842	3	2.3	0.02	0.0005262	0.1	2.28	2.4	1.76	1.7	1
SC6	800	07/23/99	22	7.58	3.2	21.6		242	763	733	30	2.41	0.02	0.0003337	0.1	2.39	2.51	1.66	1.59	3
SC6	750	07/27/99	22	7.84	5.7	20.3	350	261	880	871	9	2.06	0.02	0.0005465	0.1	2.04	2.16	1.66	1.52	3
SC6	930	09/03/99	13	7.61	6.8	13.8	-	60	621	594	27	2.39	0.02	0.0002016	3.9	2.37	6.29	1.69	1.53	6
SC6	830	10/21/99	6.5	8.35	8.4	5.6	40	349	2280	2275	5	1.55	0.02	0.0005709	0.1	1.53	1.65	0.47	0.455	1
SC6	800	03/27/00	10	8.5	10	2.5	10	265	1859	1833	26	2.88	0.02	0.0006242	0.1	2.86	2.98	0.737	0.553	10
SC7	1530	06/30/99	22	7.99	8	25.8	1200	380	1802	1438	364	2.88	0.02	0.0011114	0.1	2.86	2.98	2.97	2.57	52
SC7	1530	07/08/99	26	7.04	3.8	23.8	51,000	206	2364	514	1850	2.05	0.2	0.0011395	0.4	1.85	2.45	2.35	0.934	230

Table D-1 (Continued). Tributary chemical data for Snake Creek by site and date for 1999 and 2000.

Site	Time	Date	Air Temp. (° C)	Field pH S.U	DO mg/L	Water Temp. (° C)	Fecal Coliform #/100ml	Alkalinity mg/L	Total Solids mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	TKN mg/L	Ammonia mg/L	Un-ionized Ammonia mg/L	Nitrate mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Total Dissolved Phosphorus mg/L	Volatile Total Suspended Solids mg/L
SC7	**925**	**07/13/99**	**23**	**7.30**	**2.0**	**24.1**	**220**	**130**	**606**	**599**	**7**	**1.82**	**0.02**	**0.0002108**	**0.4**	**1.8**	**2.22**	**0.878**	**0.757**	**1**
SC7	**1345**	**07/19/99**	**36**	**-**	**3.2**	**24.7**	**110**	**241**	**990**	**926**	**64**	**2.56**	**0.12**	**-**	**0.1**	**2.44**	**2.66**	**1.750**	**1.650**	**5**
SC7	**1230**	**07/23/99**	**33**	**7.22**	**1.6**	**23.8**	**-**	**153**	**626**	**607**	**19**	**2.66**	**0.11**	**0.0009458**	**0.6**	**2.55**	**3.26**	**1.370**	**1.270**	**5**
SC7	**930**	**07/27/99**	**23**	**7.3**	**1.0**	**24.0**	**200**	**166**	**681**	**675**	**6**	**2.47**	**0.02**	**0.0002093**	**0.1**	**2.45**	**2.57**	**1.980**	**1.790**	**1**
SC7	**1430**	**09/03/99**	**15**	**7.6**	**6.2**	**15.6**	**-**	**112**	**609**	**568**	**41**	**1.68**	**0.02**	**0.0002256**	**0.5**	**1.66**	**2.18**	**0.749**	**0.551**	**8**
SC7	**922**	**10/21/99**	**12.1**	**7.91**	**7**	**7.1**	**60**	**299**	**1599**	**1588**	**11**	**1.46**	**0.02**	**0.0002379**	**0.1**	**1.44**	**1.56**	**0.264**	**0.212**	**4**
SC7	**930**	**03/27/00**	**12**	**8.17**	**9.4**	**6.0**	**10**	**176**	**1585**	**1568**	**17**	**2.58**	**0.02**	**0.0003932**	**0.7**	**2.56**	**3.28**	**0.658**	**0.494**	**2**
SC8	**1500**	**06/30/99**	**22**	**7.64**	**5.6**	**20.0**	**200**	**286**	**1083**	**1001**	**82**	**2.5**	**0.02**	**0.0003409**	**0.1**	**2.48**	**2.6**	**1.490**	**1.170**	**12**
SC8	**831**	**07/07/99**	**24**	**7.52**	**7.8**	**23.8**	**310**	**240**	**923**	**907**	**16**	**1.70**	**0.02**	**0.0003402**	**0.1**	**1.68**	**1.8**	**1.370**	**1.190**	**5**
SC8	**1630**	**07/08/99**	**26**	**7.32**	**3.9**	**24.1**	**6,100**	**81**	**549**	**433**	**116**	**2.62**	**0.38**	**0.0041919**	**1.7**	**2.24**	**4.32**	**3.170**	**2.510**	**14**
SC8	**1020**	**07/13/99**	**23**	**7.55**	**2.8**	**24.9**	**70**	**146**	**569**	**564**	**5**	**1.74**	**0.02**	**-**	**0.1**	**1.72**	**1.84**	**0.685**	**0.575**	**4**
SC8	**1500**	**07/19/99**	**37**	**7.63**	**4.8**	**26.1**	**100**	**188**	**631**	**626**	**5**	**2.18**	**0.08**	**0.0020448**	**0.1**	**2.1**	**2.28**	**1.260**	**1.180**	**3**
SC8	**1315**	**07/23/99**	**30**	**7.36**	**2.3**	**24.9**	**-**	**150**	**579**	**548**	**31**	**3.33**	**0.33**	**0.0042171**	**0.4**	**3**	**3.73**	**2.240**	**2.070**	**8**
SC8	**1030**	**07/27/99**	**26**	**7.4**	**2.2**	**24.1**	**380**	**200**	**679**	**646**	**33**	**1.81**	**0.02**	**0.0002647**	**0.1**	**1.79**	**1.91**	**1.150**	**0.988**	**8**
SC8	**1530**	**09/03/99**	**15**	**7.78**	**7.8**	**15.1**	**-**	**74**	**511**	**419**	**92**	**1.24**	**0.17**	**0.0027802**	**1.1**	**1.07**	**2.34**	**1.170**	**1.010**	**12**
SC8	**1000**	**10/21/99**	**13**	**8.10**	**7.4**	**7.9**	**30**	**227**	**919**	**633**	**286**	**1.59**	**0.02**	**0.0003897**	**0.1**	**1.57**	**1.69**	**0.240**	**0.192**	**12**
SC8	**900**	**03/27/00**	**12**	**8.46**	**9.6**	**5.4**	**10**	**178**	**1321**	**1301**	**20**	**3.02**	**0.02**	**0.0007182**	**0.1**	**3**	**3.12**	**0.311**	**0.137**	**10**
SC3*	**1130**	**03/27/00**	**13**	**8.60**	**9.6**	**7.8**	**10**	**200**	**728**	**716**	**12**	**1.29**	**0.02**	**0.0011737**	**0.1**	**1.27**	**1.39**	**0.722**	**0.634**	**1**
SC3*	**1010**	**07/19/99**	**26**	**-**	**6.4**	**23.8**	**10**	**194**	**969**	**962**	**7**	**2.02**	**0.02**	**-**	**0.1**	**2.00**	**2.12**	**0.886**	**0.838**	**4**
SC3*	**1245**	**09/21/99**	**16**	**8.00**	**8.8**	**17.4**	**10**	**198**	**717**	**711**	**6**	**1.99**	**0.02**	**0.0006350**	**0.1**	**1.97**	**2.09**	**1.090**	**1.040**	**4**
SC3*	**1400**	**07/01/99**	**20**	**8.60**	**9**	**23.0**	**100**	**176**	**664**	**642**	**22**	**1.66**	**0.02**	**0.0032845**	**0.1**	**1.64**	**1.76**	**0.734**	**0.639**	**6**
SC3*	**1430**	**07/08/99**	**25**	**8.40**	**6.4**	**25.1**	**430**	**183**	**664**	**646**	**18**	**1.44**	**0.02**	**0.0025168**	**0.1**	**1.42**	**1.54**	**0.766**	**0.667**	**7**

* SC-3 is the outlet from Mina Lake to Snake Creek.

Appendix O.

Mina Lake Algae Data for 1999 and 2000

Table E-1. Algae species, densities, biovolumes and nomenclature for Mina Lake by site for June 29, 1999.

Site	Date	*Taxon*	Cells/mL	Biovolume (μm^3/mL)	Algal Group	Algal Type	Algal Division
ML-4	**29-Jun-99**	***Anabaena flos-aquae***	**684**	**54,720**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**29-Jun-99**	***Cyclotella meneghiniana***	**19**	**4,750**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**29-Jun-99**	***Rhoicosphenia curvata***	**19**	**2,223**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**29-Jun-99**	***Ceratium hirundinella***	**19**	**186,200**	**Flagellated Algae (dino)**	**Dinoflagellate**	**Dinophyceae/Pyrrhophyta**
ML-4	**29-Jun-99**	***Asterionella formosa***	**840**	**184,800**	**Diatom (colonial, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**29-Jun-99**	***Cryptomonas erosa***	**77**	**38,654**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**29-Jun-99**	***Gloeocystic gigas***	**153**	**80,325**	**Non-Motile Green Algae (single or colonial)**	**Chlorophyceae**	**Chlorophyta**
ML-4	**29-Jun-99**	***Stephanodiscus astraea***	**384**	**1,313,664**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**29-Jun-99**	***Sphaerocystis schroeteri***	**153**	**41,004**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**29-Jun-99**	***Oocystis pusilla***	**153**	**8,262**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**29-Jun-99**	***Fragilaria crotonensis***	**767**	**644,280**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**29-Jun-99**	***Melosira granulata***	**9,942**	**5,468,100**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**29-Jun-99**	***Rhodomonas minuta***	**115**	**2,300**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**29-Jun-99**	***Stephanodiscus astraea***	**192**	**656,832**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**29-Jun-99**	***Anabaena flos-aquae***	**3,114**	**249,120**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**29-Jun-99**	***Rhodomonas minuta***	**122**	**2,440**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**29-Jun-99**	***Cryptomonas erosa***	**105**	**52,710**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**29-Jun-99**	**Unidentified flagellates**	**87**	**1,740**	**Flagellated Algae**	**Flagellated Algae**	**Flagellated Algae**
ML-5	**29-Jun-99**	***Ankistrodesmus falcatus***	**87**	**2,175**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**29-Jun-99**	***Scenedesmus quadricauda***	**70**	**10,990**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**29-Jun-99**	***Asterionella formosa***	**52**	**11,440**	**Diatom (colonial, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**29-Jun-99**	***Aphanizomenon flos-aquae***	**4,284**	**501,228**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**29-Jun-99**	***Synedra ulna***	**17**	**33,830**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**29-Jun-99**	***Cymbella muelleri***	**17**	**6,800**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**29-Jun-99**	***Ceratium hirundinella***	**35**	**343,000**	**Flagellated Algae (dino)**	**Dinoflagellate**	**Dinophyceae/Pyrrhophyta**
ML-5	**29-Jun-99**	***Pediastrum duplex***	**280**	**140,000**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**29-Jun-99**	***Oocystis pusilla***	**351**	**18,954**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**29-Jun-99**	***Sphaerocystis schroeteri***	**420**	**112,560**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**29-Jun-99**	***Fragilaria crotonensis***	**1,049**	**881,160**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**29-Jun-99**	***Melosira granulata***	**4,999**	**2,749,450**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**29-Jun-99**	***Chlamydomonas* sp.**	**17**	**2,550**	**Flagellated Algae (green)**	**Volvocales**	**Chlorophyceae**

Table E-2. Algae species, densities, biovolumes and nomenclature for Mina Lake by site for July 19, 1999.

Site	Date	*Taxon*	Cells/mL	Biovolume (μm^3/mL)	Algal Group	Algal Type	Algal Division
ML-4	**19-Jul-99**	***Ankistrodesmus falcatus***	**104**	**2,600**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**19-Jul-99**	***Fragilaria crotonensis***	**174**	**146,160**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**19-Jul-99**	***Rhodomonas minuta***	**93**	**1,860**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**19-Jul-99**	***Cryptomonas erosa***	**23**	**11,546**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**19-Jul-99**	***Sphaerocystis schroeteri***	**93**	**24,924**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**19-Jul-99**	***Melosira granulata***	**64**	**35,200**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**19-Jul-99**	**Unidentified flagellates**	**81**	**1,620**	**Flagellated Algae**	**Flagellated Algae**	**Flagellated Algae**
ML-4	**19-Jul-99**	***Ceratium hirundinella***	**35**	**343,000**	**Flagellated Algae (dino)**	**Dinoflagellate**	**Dinophyceae/Pyrrhophyta**
ML-4	**19-Jul-99**	***Stephanodiscus astraea***	**23**	**78,683**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**19-Jul-99**	***Euglena* sp.**	**6**	**3,480**	**Flagellated Algae (green)**	**Euglenales**	**Euglenophyta**
ML-4	**19-Jul-99**	***Chlorella* sp.**	**6**	**360**	**Non-Motile GreenAlgae**	**Chlorococcales**	**Chlorophyceae**
ML-4	**19-Jul-99**	***Stephanodiscus astraea minutula***	**6**	**2,100**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**19-Jul-99**	***Cymbella muelleri***	**6**	**2,400**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**19-Jul-99**	***Aphanizomenon flos-aquae***	**1,088**	**127,296**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**19-Jul-99**	***Selenastrum minutum***	**6**	**120**	**Non-Motile Green Algae**	**Chlorococcales**	**Chlorophyceae**
ML-5	**19-Jul-99**	**Unidentified flagellates**	**107**	**2,140**	**Flagellated Algae**	**Flagellated Algae**	**Flagellated Algae**
ML-5	**19-Jul-99**	***Ankistrodesmus falcatus***	**54**	**1,350**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**19-Jul-99**	***Melosira granulata***	**430**	**236,500**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**19-Jul-99**	***Rhodomonas minuta***	**537**	**10,740**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**19-Jul-99**	***Ceratium hirundinella***	**966**	**9,466,800**	**Flagellated Algae (dino)**	**Dinoflagellate**	**Dinophyceae/Pyrrhophyta**
ML-5	**19-Jul-99**	***Aphanizomenon flos-aquae***	**188,660**	**22,073,220**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**19-Jul-99**	***Cryptomonas erosa***	**54**	**27,108**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**

Table E-3. Algae species, densities, biovolumes and nomenclature for Mina Lake by site for August 25, 1999.

Site	Date	*Taxon*	Cells/mL	Biovolume (μm^3/mL)	Algal Group	Algal Type	Algal Division
ML-4	**25-Aug-99**	***Anabaena circinalis***	**1,037**	**149,328**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**25-Aug-99**	***Anabaena flos-aquae***	**1,638**	**131,040**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**25-Aug-99**	**Unidentified flagellates**	**91**	**1,820**	**Flagellated Algae**	**Flagellated Algae**	**Flagellated Algae**
ML-4	**25-Aug-99**	***Ceratium hirundinella***	**91**	**891,800**	**Flagellated Algae (dino)**	**Dinoflagellate**	**Dinophyceae/Pyrrhophyta**
ML-4	**25-Aug-99**	***Oocystis pusilla***	**121**	**6,534**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**25-Aug-99**	***Oocystis lacustris***	**121**	**37,268**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**25-Aug-99**	***Ankistrodesmus falcatus***	**333**	**8,325**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**25-Aug-99**	***Melosira granulata***	**333**	**183,150**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**25-Aug-99**	***Cryptomonas erosa***	**455**	**228,410**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**25-Aug-99**	***Botryococcus braunii***	**485**	**43,650**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**25-Aug-99**	***Rhodomonas minuta***	**1,334**	**26,680**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**25-Aug-99**	***Pediastrum duplex***	**1,940**	**970,000**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**25-Aug-99**	***Amphora ovalis***	**30**	**17,340**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**25-Aug-99**	***Aphanizomenon flos-aquae***	**23,086**	**2,701,062**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**25-Aug-99**	***Microcystis aeruginosa***	**3,579**	**118,107**	**Blue-Green Algae (colonial)**	**Cyanophyta**	**Myxophyceae**
ML-5	**25-Aug-99**	***Eudorina elegans***	**1,145**	**446,550**	**Flagellated Algae (green, colonial)**	**Volvocales**	**Chlorophyceae**
ML-5	**25-Aug-99**	***Sphaerocystis schroeteri***	**573**	**153,564**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**25-Aug-99**	***Aphanizomenon flos-aquae***	**142,392**	**16,659,864**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**25-Aug-99**	***Cryptomonas ovata***	**72**	**124,344**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**25-Aug-99**	***Ceratium hirundinella***	**72**	**705,600**	**Flagellated Algae (dino)**	**Dinoflagellate**	**Dinophyceae/Pyrrhophyta**
ML-5	**25-Aug-99**	***Anabaena circinalis***	**2,431**	**350,064**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**25-Aug-99**	***Ankistrodesmus falcatus***	**143**	**3,575**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**25-Aug-99**	***Anabaena flos-aquae***	**19,332**	**1,546,560**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**25-Aug-99**	***Rhodomonas minuta***	**215**	**4,300**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**25-Aug-99**	***Cryptomonas erosa***	**1,002**	**503,004**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**

Table E-4. Algae species, densities, biovolumes and nomenclature for Mina Lake by site for September 21, 1999.

Site	Date	*Taxon*	Cells/mL	Biovolume (μm^3/mL)	Algal Group	Algal Type	Algal Division
ML-4	**21-Sep-99**	***Melosira ambigua***	**27**	**15,903**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**21-Sep-99**	***Cryptomonas ovata***	**14**	**24,178**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**21-Sep-99**	***Microcystis aeruginosa***	**3,657**	**120,681**	**Blue-Green Algae (colonial)**	**Cyanophyta**	**Myxophyceae**
ML-4	**21-Sep-99**	Cryptomonas erosa	**27**	**13,554**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**21-Sep-99**	***Rhodomonas minuta***	**41**	**820**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**21-Sep-99**	***Closteriopsis longissima***	**108**	**38,448**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**21-Sep-99**	**Unidentified flagellates**	**122**	**2,440**	**Flagellated Algae**	**Flagellated Algae**	**Flagellated Algae**
ML-4	**21-Sep-99**	***Ankistrodesmus falcatus***	**135**	**3,375**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**21-Sep-99**	***Melosira granulata v. angustissima***	**163**	**40,750**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**21-Sep-99**	***Melosira granulata***	**176**	**96,800**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**21-Sep-99**	***Aphanizomenon flos-aquae***	**7,089**	**829,413**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**21-Sep-99**	***Anabaena flos-aquae***	**10,242**	**819,360**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**21-Sep-99**	***Fragilaria crotonensis***	**1,896**	**1,592,640**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**21-Sep-99**	***Stephanodiscus astraea***	**14**	**47,894**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**21-Sep-99**	***Fragilaria crotonensis***	**124**	**104,160**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**21-Sep-99**	***Cryptomonas erosa***	**41**	**20,582**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**21-Sep-99**	***Nitzschia acicularis***	**41**	**11,480**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**21-Sep-99**	***Ankistrodesmus falcatus***	**83**	**2,075**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**21-Sep-99**	***Closteriopsis longissima***	**83**	**29,548**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**21-Sep-99**	***Melosira granulata v. angustissima***	**83**	**20,750**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**21-Sep-99**	***Melosira ambigua***	**83**	**48,887**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**21-Sep-99**	**Unidentified flagellates**	**785**	**15,700**	**Flagellated Algae**	**Flagellated Algae**	**Flagellated Algae**
ML-5	**21-Sep-99**	***Microcystis aeruginosa***	**4,130**	**136,290**	**Blue-Green Algae (colonial)**	**Cyanophyta**	**Myxophyceae**
ML-5	**21-Sep-99**	***Anabaena flos-aquae***	**78,066**	**6,245,280**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**21-Sep-99**	***Aphanizomenon flos-aquae***	**16,711**	**1,955,187**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**

Table E-5. Algae species, densities, biovolumes and nomenclature for Mina Lake by site for October 12, 1999.

Site	Date	*Taxon*	Cells/mL	Biovolume (μm^3/mL)	Algal Group	Algal Type	Algal Division
ML-4	**12-Oct-99**	**Unidentified flagellates**	**291**	**5,820**	**Flagellated Algae**	**Flagellated Algae**	**Flagellated Algae**
ML-4	**12-Oct-99**	***Fragilaria crotonensis***	**4,268**	**3,585,120**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**12-Oct-99**	***Anabaena flos-aquae***	**5,526**	**442,080**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**12-Oct-99**	***Cryptomonas erosa***	**145**	**72,790**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**12-Oct-99**	***Stephanodiscus astraea***	**372**	**1,272,612**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**12-Oct-99**	***Melosira granulata v. angustissima***	**291**	**72,750**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**12-Oct-99**	***Melosira ambigua***	**517**	**304,513**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**12-Oct-99**	***Aphanizomenon flos-aquae***	**2,805**	**328,185**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**12-Oct-99**	***Ankistrodesmus falcatus***	**48**	**1,200**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**12-Oct-99**	***Synedra ulna***	**32**	**63,680**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**12-Oct-99**	***Rhodomonas minuta***	**16**	**320**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**12-Oct-99**	***Nitzschia palea***	**16**	**8,400**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**12-Oct-99**	***Melosira granulata***	**16**	**8,800**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**12-Oct-99**	***Melosira granulata***	**59**	**32,450**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**12-Oct-99**	***Cyclotella stelligera***	**29**	**4,495**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**12-Oct-99**	***Chlamydomonas* sp.**	**29**	**4,350**	**Flagellated Algae (green)**	**Volvocales**	**Chlorophyceae**
ML-5	**12-Oct-99**	***Cyclotella meneghiniana***	**29**	**7,250**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**12-Oct-99**	***Nitzschia acicularis***	**29**	**8,120**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**12-Oct-99**	***Rhodomonas minuta***	**59**	**1,180**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**12-Oct-99**	***Ankistrodesmus falcatus***	**88**	**2,200**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**12-Oct-99**	***Aphanizomenon flos-aquae***	**3,485**	**407,745**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**12-Oct-99**	**Unidentified flagellates**	**322**	**6,440**	**Flagellated Algae**	**Flagellated Algae**	**Flagellated Algae**
ML-5	**12-Oct-99**	***Melosira granulata v. angustissima***	**351**	**87,750**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**12-Oct-99**	***Cryptomonas erosa***	**410**	**205,820**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**12-Oct-99**	***Stephanodiscus astraea***	**439**	**1,501,819**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**12-Oct-99**	***Stephanodiscus astraea minutula***	**29**	**10,150**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**12-Oct-99**	***Anabaena flos-aquae***	**18,450**	**1,476,000**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**12-Oct-99**	***Fragilaria crotonensis***	**2,460**	**2,066,400**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**12-Oct-99**	***Melosira ambigua***	**1,084**	**638,476**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**

Table E-6. Algae species, densities, biovolumes and nomenclature for Mina Lake by site for April 6, 2000.

Site	Date	*Taxon*	Cells/mL	Biovolume (μm^3/mL)	Algal Group	Algal Type	Algal Division
ML-4	**06-Apr-00**	***Stephanodiscus hantzschii***	**1,480**	**296,000**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Synura uvella***	**20**	**26,160**	**Flagellated Algae (colonial)**	**Chrysophyceae**	**Chrysophyta**
ML-4	**06-Apr-00**	***Stephanodiscus niagarae***	**15**	**150,000**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Mallomonas akrokomos***	**13**	**19,539**	**Flagellated Algae (single, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**
ML-4	**06-Apr-00**	***Mallomonas tonsurata***	**10**	**15,000**	**Flagellated Algae (single, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**
ML-4	**06-Apr-00**	***Dinobryon sertularia***	**37**	**29,600**	**Flagellated Algae (colonial, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**
ML-4	**06-Apr-00**	***Eudorina* sp.**	**16**	**8,368**	**Flagellated Algae (green, colonial)**	**Volvocales**	**Chlorophyceae**
ML-4	**06-Apr-00**	***Chlamydomonas* sp.**	**50**	**7,500**	**Flagellated Algae (green)**	**Volvocales**	**Chlorophyceae**
ML-4	**06-Apr-00**	***Oscillatoria* sp.**	**50**	**1,050**	**Blue Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**06-Apr-00**	***Spermatozoopsis* sp.**	**40**	**2,560**	**Flagellated Algae**	**Volvocales**	**Chlorophyceae**
ML-4	**06-Apr-00**	***Anabaena* sp.**	**5**	**400**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-4	**06-Apr-00**	***Glenodinium* sp.**	**1**	**700**	**Flagellated Algae (dino)**	**Dinoflagellate**	**Dinophyceae/Pyrrhophyta**
ML-4	**06-Apr-00**	***Chrysochromulina* sp.**	**1,420**	**113,600**	**Flagellated Algae (single, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**
ML-4	**06-Apr-00**	***Chromulina* sp.**	**230**	**14,950**	**Flagellated Algae (single, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**
ML-4	**06-Apr-00**	***Cryptomonas* sp.**	**239**	**95,600**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**06-Apr-00**	***Chroomonas* sp.**	**590**	**38,350**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-4	**06-Apr-00**	***Platymonas elliptica***	**50**	**27,500**	**Flagellated Algae**	**Volvocales**	**Chlorophyceae**
ML-4	**06-Apr-00**	***Nitzschia* sp.**	**12**	**1,440**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Oocystis* sp.**	**3**	**450**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**06-Apr-00**	***Ankistrodesmus* sp.**	**10**	**250**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-4	**06-Apr-00**	**Unidentified pennate diatoms**	**9**	**900**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Cymatopleura solea***	**3**	**48,600**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	**Unidentified algae**	**1,800**	**36,000**	**Algae**	**Algae**	**Algae**
ML-4	**06-Apr-00**	***Cymbella triangulum***	**1**	**3,000**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Nitzschia vermicularis***	**4**	**480**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Nitzschia acicularis***	**5**	**1,400**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Cyclotella meneghiniana***	**100**	**25,000**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Fragilaria crotonensis***	**8**	**6,720**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Fragilaria capucina***	**154**	**39,270**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Asterionella formosa***	**11,735**	**2,581,700**	**Diatom (colonial, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-4	**06-Apr-00**	***Synedra acus***	**1**	**1,900**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**

Table E-6 (Continued). Algae species, densities, biovolumes and nomenclature for Mina Lake by site for April 6, 2000.

Site	Date	*Taxon*	Cells/mL	Biovolume (μm^3/mL)	Algal Group	Algal Type	Algal Division
ML-5	**06-Apr-00**	***Fragilaria capucina***	**165**	**42,075**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Synura uvella***	**69**	**90,252**	**Flagellated Algae (colonial)**	**Chrysophyceae**	**Chrysophyta**
ML-5	**06-Apr-00**	***Mallomonas tonsurata***	**21**	**31,500**	**Flagellated Algae (single, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**
ML-5	**06-Apr-00**	***Anabaena* sp.**	**15**	**1,200**	**Blue-Green Algae (filamentous)**	**Cyanophyta**	**Myxophyceae**
ML-5	**06-Apr-00**	**Unidentified algae**	**2,940**	**58,800**	**Algae**	**Algae**	**Algae**
ML-5	**06-Apr-00**	***Mallomonas akrokomos***	**5**	**7,515**	**Flagellated Algae (single, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**
ML-5	**06-Apr-00**	***Asterionella formosa***	**14,185**	**3,120,700**	**Diatom (colonial, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Dinobryon sertularia***	**16**	**12,800**	**Flagellated Algae (colonial, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**
ML-5	**06-Apr-00**	***Pandorina morum***	**16**	**2,800**	**Flagellated Algae (green, colonial)**	**Volvocales**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Chlorogonium* sp.**	**20**	**1,900**	**Flagellated Algae (green)**	**Volvocales**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Chlamydomonas* sp.**	**80**	**12,000**	**Flagellated Algae (green)**	**Volvocales**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Spermatozoopsis* sp.**	**30**	**1,920**	**Flagellated Algae**	**Volvocales**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Glenodinium* sp.**	**1**	**700**	**Flagellated Algae (dino)**	**Dinoflagellate**	**Dinophyceae/Pyrrhophyta**
ML-5	**06-Apr-00**	***Fragilaria crotonensis***	**22**	**18,480**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Scenedesmus quadricauda***	**6**	**942**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Platymonas elliptica***	**150**	**82,500**	**Flagellated Algae**	**Volvocales**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Synedra acus***	**3**	**5,700**	**Diatoms (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Dictyosphaerium pulchellum***	**44**	**660**	**Non-Motile Green Algae (colonial)**	**Chlorophyceae**	**Chlorophyta**
ML-5	**06-Apr-00**	***Closterium aciculare***	**1**	**750**	**Non-Motile Green Algae (desmid)**	**Desmidae**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Micractinium pusillum***	**8**	**272**	**Non-Motile Green Algae (colonial)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Ankistrodesmus* sp.**	**110**	**2,750**	**Non-Motile Green Algae (single)**	**Chlorococcales**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Chrysochromulina* sp.**	**2,020**	**161,600**	**Flagellated Algae (single, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**
ML-5	**06-Apr-00**	**Unidentified pennate diatoms**	**13**	**1,300**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Cymatopleura solea***	**1**	**16,200**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Fragilaria* sp.**	**4**	**800**	**Diatom (filamentous, pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Cymbella triangulum***	**6**	**18,000**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Nitzschia* sp.**	**10**	**1,200**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Nitzschia vermicularis***	**11**	**1,320**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Nitzschia acicularis***	**10**	**2,800**	**Diatom (pennate)**	**Pennate Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Cyclotella meneghiniana***	**150**	**37,500**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Stephanodiscus niagarae***	**72**	**720,000**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Stephanodiscus hantzschii***	**6,440**	**1,288,000**	**Diatom (centric)**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Melosira granulata***	**75**	**41,250**	**Diatom (centric)-filamentous**	**Centric Diatom**	**Bacillariophyceae**
ML-5	**06-Apr-00**	***Selenastrum gracile***	**4**	**240**	**Non-Motile GreenAlgae**	**Chlorococcales**	**Chlorophyceae**
ML-5	**06-Apr-00**	***Cryptomonas* sp.**	**238**	**95,200**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**
ML-5	**06-Apr-00**	***Chroomonas* sp.**	**820**	**53,300**	**Flagellated Algae**	**Cryptophyceae**	**Cryptophyta**

ML-5	**06-Apr-00**	***Chromulina* sp.**	**370**	**24,050**	**Flagellated Algae (single, yellow-brown)**	**Chrysophyceae**	**Chrysophyta**

Appendix P.

Mina Lake Surface and Bottom In-lake Chemical Data Tables 1999 through 2000

Table F-1. In-lake surface samples concentrations for Mina Lake by site and date from 1999 through 2000.

Site	Date	Field pH S.U	DO mg/L	Secchi m	Water Temp. (°C)	Fecal Coliform colonies/ 100ml	Alkalinity mg/L	Total Solids mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	TKN mg/L	Ammonia mg/L	Un-ionized Ammonia mg/L	Nitrate mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Total Dissolved Phosphorus mg/L	Volatile Total Suspended Solids mg/L	Chlorophyll-*a* mg/m^3	N:P Ratio
ML4	06/29/99	8.80	8.5	0.61	21.0	5	177	658	636	22	1.84	0.01	0.002	0.1	1.83	1.94	0.83	0.692	5	70.8	2.34
ML4	07/19/99	8.36	5.2	1.12	24.2	5	189	675	663	12	1.91	0.08	0.009	0.1	1.83	2.01	0.89	0.848	4	3.5	2.26
ML4	08/25/99	8.47	7.2	1.30	24.2	10	208	733	724	9	1.61	0.08	0.011	0.05	1.53	1.66	1.22	1.20	2	31.2	1.36
ML4	09/21/99	8.57	8.8	1.14	16.6	5	200	719	713	6	1.88	0.01	0.001	0.05	1.87	1.93	1.13	1.05	2	13.5	1.71
ML4	10/12/99	8.93	9.2	0.81	12.7	10	195	717	696	21	1.97	0.01	0.002	0.05	1.96	2.02	1.11	0.957	6	11.4	1.82
ML4	04/06/00	8.65	11.2	0.91	8.02	5	197	761	750	11	1.2	0.01	0.001	0.05	1.19	1.25	0.645	0.585	2		1.94
ML5	06/29/99	8.63	8.2	0.56	21.0	5	195	713	682	31	1.78	0.01	0.002	0.1	1.77	1.88	0.835	0.776	6	52.0	2.25
ML5	07/19/99	8.63	8.4	0.51	24.2	5	203	758	734	24	3.07	0.01	0.002	0.1	3.06	3.17	0.984	0.878	14	43.5	3.22
ML5	08/25/99	8.6	8.4	0.76	24.4	5	215	766	751	15	2.76	0.01	0.002	0.05	2.75	2.81	1.21	1.14	6	54.9	2.32
ML5	09/21/99	7.97	10.4	0.69	16.1	5	177	709	695	14	2.45	0.01	0.000	0.05	2.44	2.5	0.931	0.898	4	54.1	2.69
ML5	10/12/99	9.14	9.8	0.61	12.5	5	190	737	710	27	2.01	0.01	0.002	0.05	2.00	2.06	0.986	0.87	7	22.9	2.09
ML5	04/06/00	8.75	11.4	0.64	8.30	5	197	847	828	19	1.34	0.18	0.015	0.05	1.16	1.39	0.574	0.45	3	11.0	2.42

Table F-2. In-lake bottom samples concentrations for Mina Lake by site and date from 1999 through 2000.

Site	Date	Field pH S.U	DO mg/L	Secchi m	Water Temp. (°C)	Fecal Coliform colonies/ 100ml	Alkalinity mg/L	Total Solids mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	TKN mg/L	Ammonia mg/L	Un-ionized Ammonia mg/L	Nitrate mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Total Dissolved Phosphorus mg/L	Volatile Total Suspended Solids mg/L	N:P Ratio
ML4	06/29/99	8.82	8.6		21.0	10	178	658	635	23	2.05	0.01	0.002	0.05	2.04	2.1	0.746	0.684	9	2.82
ML4	07/19/99	8.41	7.2		23.0	10	188	672	661	11	1.92	0.08	0.009	0.05	1.84	1.97	0.908	0.83	3	2.17
ML4	08/25/99	7.4	7.4		24.2	10	210	739	713	26	1.96	0.1	0.001	0.05	1.86	2.01	1.26	1.22	1	1.60
ML4	09/21/99	8.11	6.8		16.9	10	201	719	712	7	1.9	0.01	0.000	0.05	1.89	1.95	1.13	1.04	2	1.73
ML4	10/12/99	8.97	8.9		11.9	10	194	721	699	22	1.75	0.01	0.002	0.05	1.74	1.8	1.07	0.954	6	1.68
ML4	04/06/00	8.63	11.4		8.2	10	198	761	750	11	1.16	0.25	0.016	0.05	0.91	1.21	0.664	0.588	1	1.82
ML5	06/29/99	8.62	7		21.0	10	194	728	684	44	2.05	0.07	0.011	0.1	1.98	2.15	0.845	0.763	6	2.54
ML5	07/19/99	8.37	6		23.7	10	208	781	762	19	2.09	0.06	0.007	0.1	2.03	2.19	1.07	0.881	3	2.05
ML5	08/25/99	8.3	1.8		23.7	10	218	781	758	23	1.76	0.16	0.015	0.1	1.6	1.86	1.35	1.15	5	1.38
ML5	09/21/99	9.05	8.2		16.2	10	180	724	698	26	2.6	0.01	0.003	0.05	2.59	2.65	1.01	0.887	7	2.62
ML5	10/12/99	9.07	6.2		12.3	10	190	739	714	25	2.04	0.01	0.002	0.05	2.03	2.09	1.08	0.884	4	1.94
ML5	04/06/00	8.76	11.8		8.3	10	198	870	841	29	1.42	0.01	0.001	0.1	1.41	1.52	0.588	0.457	4	2.59

Appendix Q.

Mina Lake In-lake Temperature and Dissolved Oxygen Profiles 1999

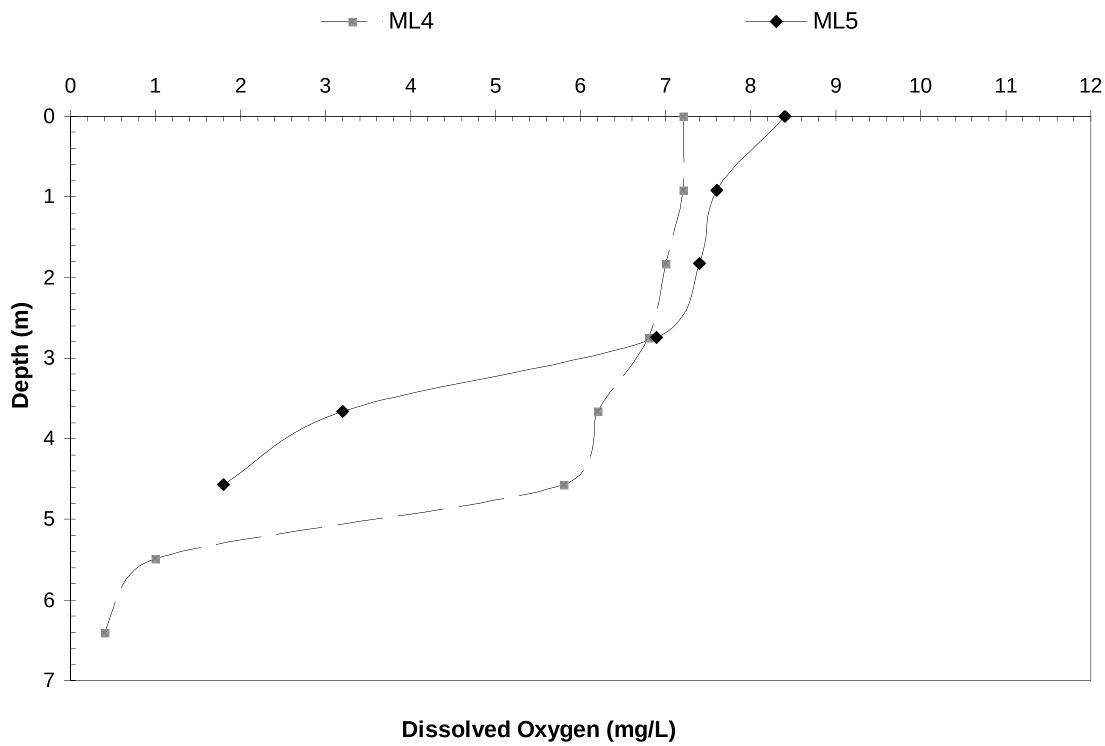


Figure G-1. Dissolved oxygen profiles for Mina Lake in August 25, 1999.

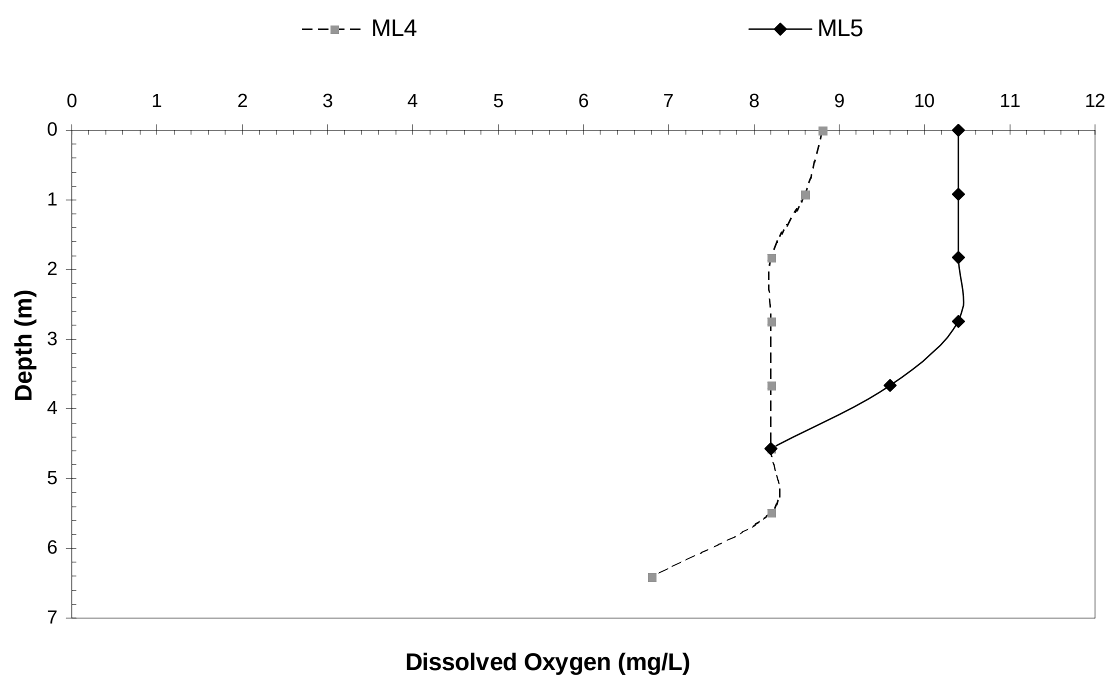


Figure G-2. Dissolved oxygen profiles for Mina Lake in September 21, 1999.

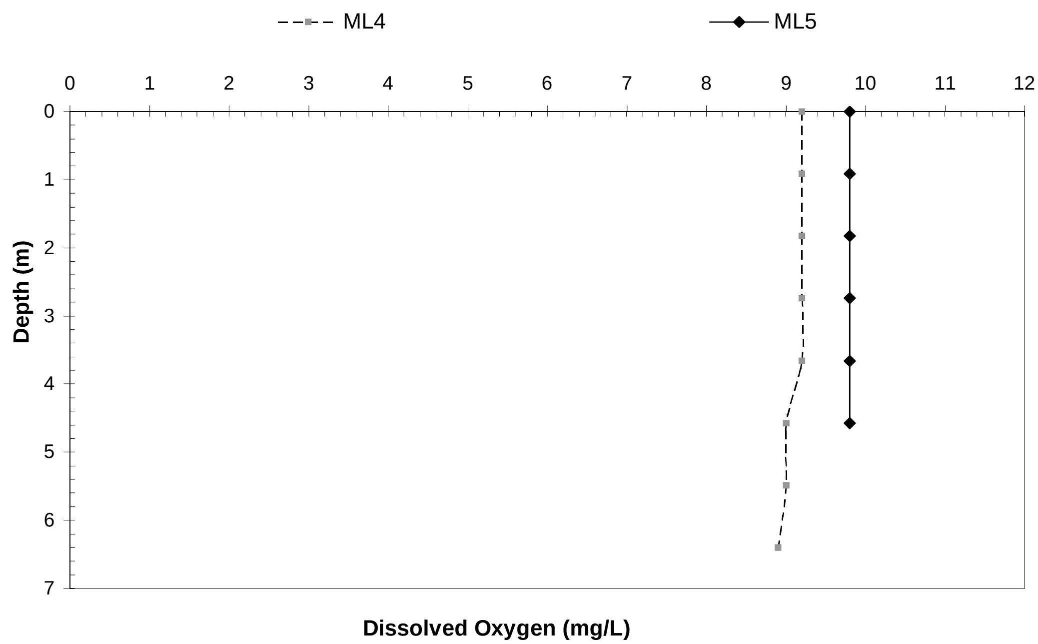


Figure G-3. Dissolved oxygen profiles for Mina Lake in October 12, 1999.

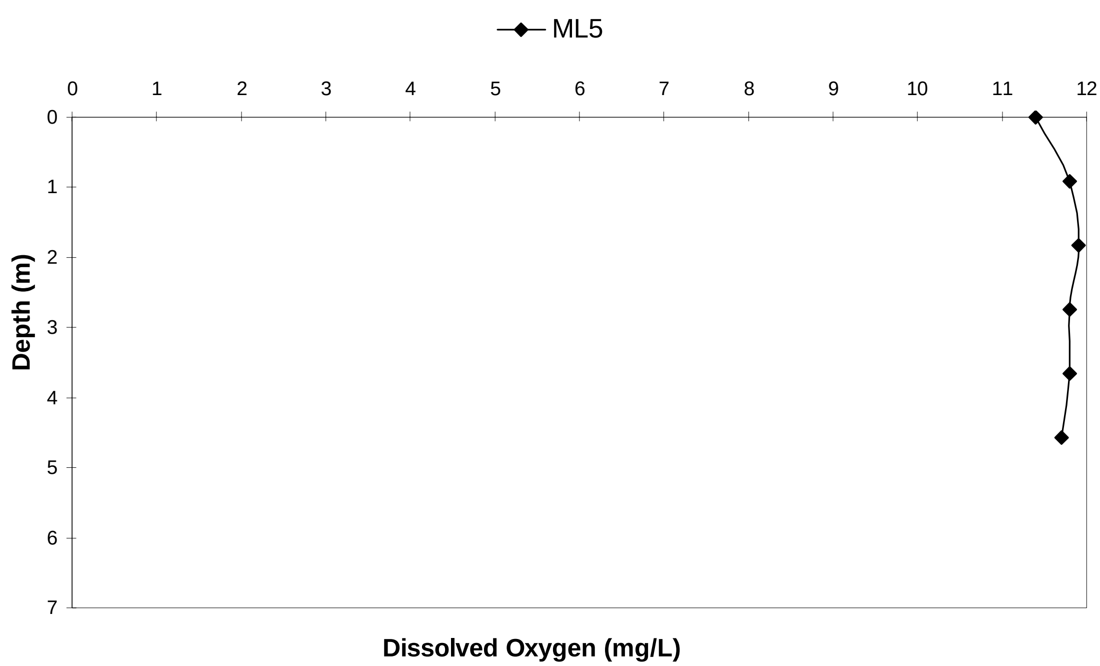


Figure G-4. Dissolved oxygen profiles for Mina Lake in April 6, 2000.

Appendix R.

South Dakota Game, Fish and Parks Fisheries Report for Mina Lake

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY
2102-F21-R-29

Name: Mina Lake County(ies): Brown/Edmunds
Legal description: T123N, R66W, Sect 12-14,23-26
Location from nearest town: Ten miles east of Aberdeen
Dates of present survey: August 6-8,1996.
Date last surveyed: August 8-10,1995.
Most recent lake management plan: F21-R-27 Date: 1994
Management classification: Warm water permanent.
Contour mapped: Y Date: 1964
Report prepared by: Matthew Hubers
Scales aged and digitized by: Randy Mount

Primary Species: (game and forage)
1. Walleye/Saugeye (SXW WAE)
2. Black Crappie (BLC)
3. Freshwater Drum (FWD)
4. Bluegill (BLG)
5. Black Bullhead (BLB)
6. Channel Catfish (CCF)
7. Smallmouth Bass (SMB)

Secondary and other species:
1. Northern Pike (NOP)
2. Yellow Perch (YEP)
3. White Bass (WHB)
4. White Sucker (WHS)
5. Common Carp (COC)
6. Common Shiner (CNS)
7. Largemouth Bass (LMB)

PHYSICAL CHARACTERISTICS

Surface Area: 806 acres; Watershed: 195,000 acres
Maximum depth: 27 feet; Mean depth: 9 feet
Lake elevation at survey (from known benchmark): Full feet

1. Describe ownership of lake and adjacent lakeshore property:

Mina Lake is owned by the State of South Dakota. Most adjacent property is under private ownership. Game, Fish and Parks owns a park and some game production areas.

2. Describe watershed condition and percentages of land use:

The watershed is comprised pasture(65%) and cropland(35%).

3. Describe aquatic vegetative condition:

Emergent and submergent vegetation is restricted to the upper portions of the impoundment. Steep and constantly eroding shoreline is not conducive to vegetation.

4. Describe pollution problems:

Erosion of shoreline and agricultural run-off are contributing silt and nutrients. Heavy blue-green algal blooms are common.

5. Condition of structures, i.e. spillway, boatramps, etc.:

All structures appear to be in good repair.

BIOLOGICAL DATA

Methods:

The 1996 survey was conducted using six monofilament gill net and seventeen frame net sets. Nets were fished for approximately 24-hour periods and then reset at new locations (Figure 4). Nets that had been rolled, collapsed or tampered with were not utilized for any data. Gill nets were 45.7 m (150 ft) x 1.8 m (6 ft) and were constructed of six panels of 7.6 m (25 ft). Each panel was of different mesh size and panels were ordered from smallest to largest. Mesh sizes were 1.3 cm (1/2"), 1.9 cm (3/4"), 2.5 cm (1"), 3.2 cm (1 1/4'), 3.8 cm (1 1/2"), and 5.1 cm (2"). Trap nets were of double frame design with frames of 1.2 x 1.5 m and mesh size was 1.9 cm (3/4). Fish weights (g) and lengths (mm) were collected from all species sampled. One-hundred lengths and fifty weight measurements were taken if possible. Calculations were performed on sample sizes down to twenty-five fish. PSD, RSD and Wr calculations were performed using FishCalc program. Results are summarized in tables one and two. Scales were taken from behind the left pectoral fin and below the lateral line. Age and growth calculations were done using the DisBcal program (Table 3). Walleye and saugeye were treated as one species for analysis. Loss of color from gill net sample prevented use of external characteristics for differentiation of the two species. Mina Lake is included in a multi-state study by SDSU of the impacts of saugeye introductions on high density panfish populations.

Results and Discussion:

Lake survey information prior to 1993 indicated low abundance of walleye. In 1992, as part of the ongoing study, walleye and saugeye were stocked concurrently to enable performance comparisons. It was found that small fingerlings are vulnerable to predation when stocked into high density panfish populations and that saugeye outperformed walleye in turbid reservoir environments. Although survey data strongly suggested that small saugeye fingerling stocks were contributing significantly to year class strength, beginning in 1994 only large saugeye fingerlings were being stocked. Deterioration of gill net samples did not allow for positive visual identification between walleye and saugeye but is thought that most are saugeye. Fall electrofishing in 1996 by Kevin Pope (SDSU) resulted in 192 saugeye (CPH 96.0) and one walleye being captured (Visual ID on external characteristics). It is assumed that the preponderance of fish present are resultant of stocks. In 1996 gill net CPUE at 15.5 was the highest seen since annual surveys were initiated in 1991. Six different year classes were detected. The 1994 year class accounted for almost 40% of all fish sampled (Table 3). These age 2 fish were also strongly sampled in 1995 when they comprised approximately 51% of all walleye/saugeye captured. In 1994 a good production year allowed for the stocking of 35,300 large fingerlings which resulted in a very strong year class being established (Table 4). Age one fish were the second most abundant year class followed by and age 3 and 4 fish (Table 3). 1993 and 1994 year classes are attributable to small fingerling stocks. Success of the 1994 saugeye stockings suggests that year class strength could be augmented considerably by escalating stocking densities. Growth of saugeye is slower than that of walleye in other area impoundments with fish reaching 359 at age four. Wr values fell outside of the optimum range at 88. Condition as well as growth rates suggests that forage or forage conditions may not be ideal. Figure 1 shows almost all cm groups from 20-46 cm. Using stock and quality lengths proposed for walleye, PSD was 19 and RSD was 2. Figure 2 shows two distinct clusters. The 13-17 cm range are age 0 large saugeye fingerlings stocked in late September. The second pulse are age 1 and 2 fish. It can preliminarily be concluded that stocking large fingerling saugeye is establishing consecutive strong year classes. The 356 mm minimum length limit is enabling saugeye to grow to a more desirable length prior to being harvested. Slow growth has prohibited these fish from entering the fishery sooner and at times anglers voice concerns that all they can catch are sublegal fish. The large 1994 year class should enter the fishery in 1998. Affects, if any, on the black crappie population are yet to be conclusively evaluated.

Frame net CPUE of 10.4 for bluegill is a substantial increase over the 2.1 seen in 1995. Bluegill frame net catches varied from 0-27. Most were sampled in the upper reaches and in the few shallow bays along the mainstem of the impoundment. PSD and RSD values of 55 and 10, respectively, indicate size distribution orientated towards larger fish. Figure 3 depicts length frequency of sample. Shoreline seining (Figure 4) resulted in catches of 1-90 young of year. Size structure and abundance should be sufficient to enable anglers to target this species. Most, however, are probably harvested while anglers fish for black crappie.

Table 1. Catch of eighteen 3/4 in. mesh frame net sets in Mina Lake, Edmunds/Brown County, August 6-7, 1996.

SPECIES	N	%COMP	CPUE (80% C.I)	4-YEAR MEAN	PSD	RSD	WR
WHB	3	0.36	0.2+-0.2	0.03	-	-	-
BLC	420	50.06	23.3+-5.6	20.6	27	4	-
BLG	188	22.41	10.4+-2.7	8.8	55	10	142
COC	7	0.83	0.4+-0.2	0.3	-	-	-
BLB	196	23.36	10.9+-10.0	0.5	25	0	-
WAE/SXW	6	0.72	0.3+-0.2	0.9	-	-	-
WHS	1	0.12	0.1+-0.1	0.2	-	-	-
YEP	3	0.36	0.2+-0.2	0.2	-	-	-
NOP	6	0.72	0.3+-0.2	0.1	-	-	-
FRD	2	0.24	0.1+-0.1	0.2	-	-	-
SMB	7	0.83	0.2+-0.2	0.03	-	-	-

The most numerous panfish sampled was black crappie. Catches ranged from 63 to 6 per frame net and CPUE was 23.3. As nets were moved from the upper reaches to the main reservoir catches decreased sharply. Over five years CPUE has ranged from a low of 10.2 to 28.0. The 10.2 found in 1994 was attributed to severe weather during the survey period. As in 1994 and 1995, sub-stock fish (<127 mm), were not sampled very heavily. Previously this was interpreted as suggesting that recruitment was variable. However, it is now thought that black crappie do not fully recruit to gear used until at least 14 cm. That would explain why the now 14-16 cm crappie were not sampled in 1995. Size structure was dominated by fish ranging from 14-16 cm resulting in a PSD of 27 (Figure 3). This is a decrease from the 79 seen in 1995. Although year class strength varies, shoreline seining as well as length frequency (Figure 3) suggest complete year class failures are rare. Abundance, as well as presence of acceptable quality and larger individuals present, should be sufficient to provide a acceptable fishery. Effects of sauger introduction and density on black crappie are still being evaluated.

White bass, not sampled since 1993, had a gill net CPUE of 5.2 and a frame net CPUE of 0.2. Bass sampled ranged in length from 20-25 cm and the 31 fish sample had a PSD of 58. Forty-eight percent fell into the 23 cm length group. It is not know what caused this sudden increase, if this population is expanding, or if this is just one year class produced because of conducive environmental factors. Gear used in surveys usually does not effectively sample white bass. Despite this increase in CPUE, it is still believed that a low density population exists and at present does not contribute substantially to the fishery.

Northern pike ranged in length from 335-874 mm. Gill net CPUE of 2.0 was the highest seen in the past three years. Except in times of drought, waterlevels in Mina Lake remain relatively stable. Shorelines, except in the upper reaches, are either eroded banks or ripraped. Almost all have steep gradients. During periods of low water little terrestrial vegetation establishes along the shoreline. Habitat in the upper arms is comprised mostly of cattail and bulrush. It is probable that available spawning habitat is limiting the northern pike population.

Other species sampled were common carp, black bullhead, white sucker, yellow perch, freshwater drum, smallmouth bass and catfish. All of these species provide only limited fisheries either by low abundance or unpopularity with anglers. Smallmouth bass were probably accidentally introduced with largemouth bass stocks bass. Several year classes are present and numbers seem to be increasing. It is hoped that in the future a fishery will develop. Black bullhead were the most numerous. Bullhead CPUE at 10.9 still indicates low abundance. Catches ranged from 0-135 per frame net and the sample had PSD of 25. Seventy-six percent of bullheads were from 19-23 cm. Channel catfish maintain a stable population and gill net CPUE has varied only slightly from 0.50-0.67. Length of the four fish sampled ranged from 59-71 cm. Reproduction seems limited as no smaller individuals are ever seen.

Table 2. Catch of six 150 ft. experimental gill net sets in Mina Lake, Edmunds/Brown County, August 6-7, 1996.

SPECIES	N	%COMP	CPUE (80% C.I)	2-YEAR MEAN	PSD	RSD	WR
SXW/WAE	93	41.52	15.5+-3.8	11.15	19	2	88
NOP	12	5.36	2.0+-1.1	0.25	-	-	-
YEP	21	9.38	3.5+-2.1	0.75	-	-	-
FRD	8	3.57	1.3+-0.5	3.60	-	-	-
CNS	18	8.04	3.0+-2.4	0.60	-	-	-
WHB	31	13.84	5.2+-3.7	-	58	0	94
BLC	15	6.70	2.5+-2.0	7.35	-	-	-
CCF	4	1.79	0.7+-0.3	0.50	-	-	-
COC	4	1.79	0.7+-0.7	1.20	-	-	-
BLB	18	8.04	3.0+-4.1	0	-	-	-

Table 3. Average back-calculated lengths for each age class for walleye/saugeye sampled in 1996, Mina Lake.

			Back-calculation Age							
Year Class	Age	N	1	2	3	4	5	6	7	8
1995	1	26	178.40							
1994	2	39	140.02	244.40						
1993	3	14	128.45	200.80	302.95					
1992	4	14	130.35	196.31	271.10	368.97				
1991	5	4	179.75	240.82	276.67	325.13	399.71			
1990	6	0	0.00	0.00	0.00	0.00	0.00	0.00		
1989	7	0	0.00	0.00	0.00	0.00	0.00	0.00		
1988	8	1	134.77	260.31	311.31	360.66	442.01	524.45	0.00	
ALL			148.73	226.59	286.51	359.30	408.17	524.45	589.53	609.25
N		98	98	72	33	19	5	1	1	1

RECOMMENDATIONS

1. Manage primarily for saugeye and black crappie. Continue large fingerling stockings at 1.0-2.0/lb per acre.
2. Electrofish to determine status of bass populations.
3. Determine feasibility of establishing a low density trophy muskellunge fishery or stocking northern pike to increase density.
4. Survey annually to monitor fish populations and assess effects of 356 mm minimum length limit on saugeye.

Table 4. Stocking record for Mina Lake, 1986-1996.

Species	Size	Number	Year
LMB	FGL	20,000	1986
NOP	FGL	15,000	1986
WAE	FGL	11,189	1987
LMB	FGL	60,000	1988
WAE	LFG	16,872	1989
LMB	FGL	40,000	1990
WAE	LFG	27,226	1990
WAE	SFG	80,000	1991
SXW	SFG	40,300	1992
WAE	SFG	40,300	1992
SXW	SFG	40,000	1993
WAE	SFG	40,000	1993
SXW	LFG	35,300	1994
SXW	LFG	9,899	1995
SXW	LFG	9,972	1996

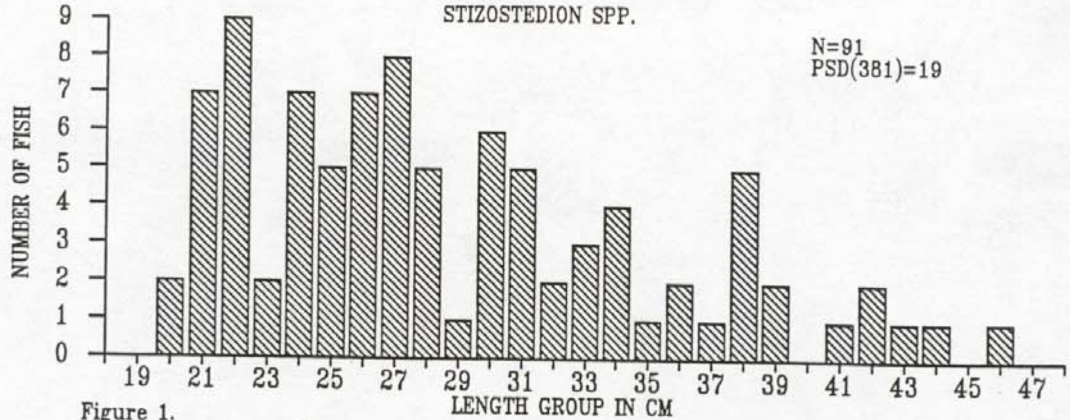


Figure 1.
Length frequency of Stizostedion Spp. from 150 ft. gill net sets in Mina Lake, 1996.

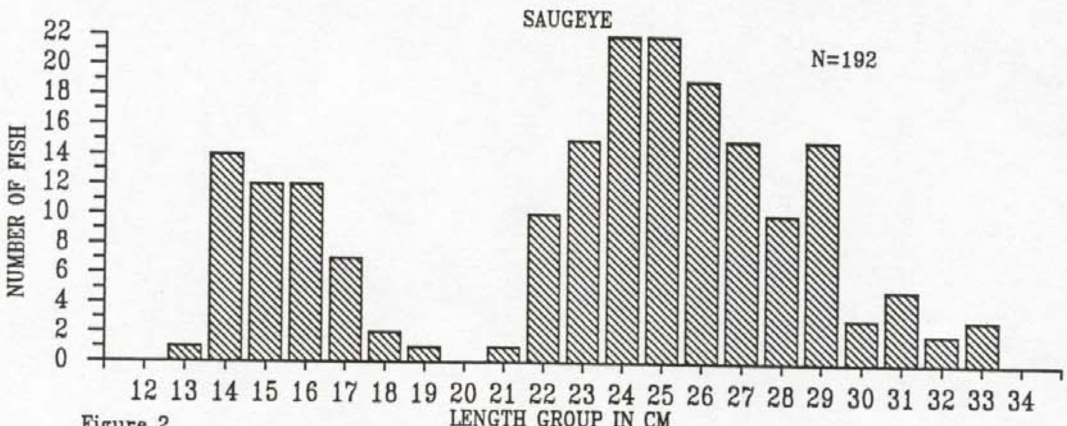


Figure 2.
Length frequency of saugeye collected by electrofishing on Oct 8, 1996 in Mina Lake by SDSU.

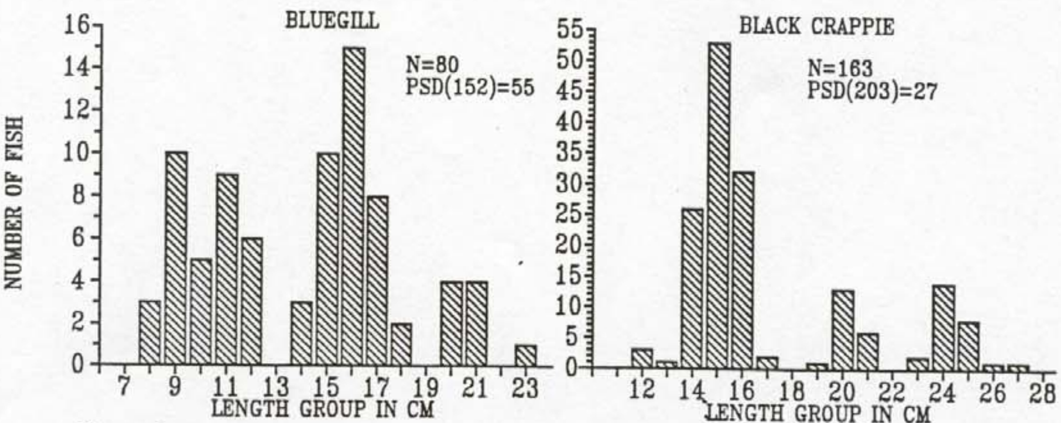


Figure 3.
Length frequency of bluegill and black crappie from frame net sets in Mina Lake, 1996.

Figure 4. Shoreline seining conducted for 1996 lake survey.

SHORELINE SEINING DATA

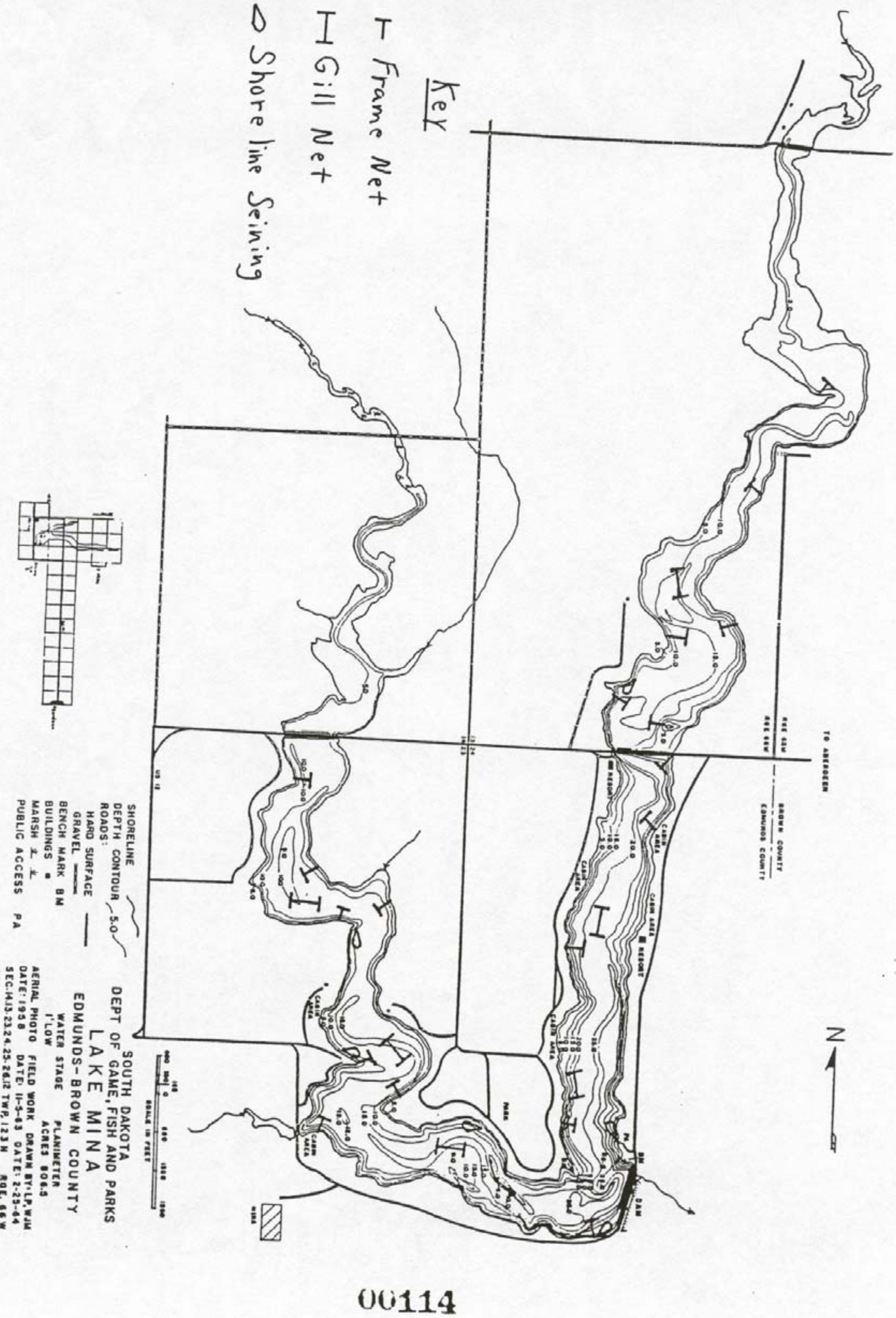
LAKE Mina
COUNTY Edmunds
DATE 8-28-96
CREW Dyer, Mount
H20 TEMP 76°
CONDITIONS Hot 85°
SEINE USED 1/4" 100ft
PULL MADE 1/4 arc

SITE	1		2		3		4	
SPECIES	YOY	OTHER	YOY	OTHER	YOY	OTHER	YOY	OTHER
BLG	90	–	1	–	20	–	10	2
BLC	6	1	2	–	2	–	3	2
GOS	–	11	–	–	–	–	–	2
IOD	–	–	–	1	–	–	–	–
COC	–	–	–	–	–	–	–	4
CCF	–	–	–	–	–	–	–	1

SITE	5		6		7		8	
SPECIES	YOY	OTHER	YOY	OTHER	YOY	OTHER	YOY	OTHER
BLC	–	1	1	–				
GOS	–	1	–	–				
BLG	1	–	30	–				

COMMENTS: Calm, no wind

Figure 5. Approximate net locations during 1996 lake survey.



Appendix S

Rare, Threatened or Endangered Species Documented in the Mina Lake Watershed, Edmunds, McPherson and Brown Counties, South Dakota

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 THE SNAKE CREEK WATERSHED, EDMUNDS, MCPHERSON AND BROWN COUNTIES, SOUTH DAKOTA

South Dakota Natural Heritage Database

July 17, 2001

COMMON NAME SCIENTIFIC NAME	TOWNSHIP RANGE & SECTION	LAST OBSERVED	FEDERAL STATUS	STATE STATUS	STATE RANK	GLOBAL RANK
Whooping Crane ***Grus Americana***	**124N068W 16**	**1977-04-24**	**LE**	**SE**	**SZN**	**G1**
Coopers Hawk ***Accipiter cooperii***	**123N066W 25**	**1999-05-12**			**S3B,SZN**	**G5**
Henslow's Sparrow ***Ammodramus henslowii***	**126N068W 19**	**1984-06-12**			**SUB,SZN**	**G4**
Kit or Swift Fox ***Vulpes velox***	**119N064W 32**	**1976-04-16**		**ST**	**S1**	**G3**

Appendix T

Mina Lake Total Maximum Daily Load Summary Document

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

TOTAL PHOSPHORUS (TSI TREND)

In

MINA LAKE

SNAKE CREEK WATERSHED

(HUC 10160008)

EDMUNDS, MCPHERSON AND BROWN COUNTIES, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

March, 2002

Mina Lake Total Maximum Daily Load March, 2002

Waterbody Type:	**Lake (Impounded)**
303(d) Listing Parameters:	**Total phosphorus (TSI trend)**
Designated Uses:	**Domestic Water Supply** **Warmwater permanent fish life propagation water;** **Immersion recreation water;** **Limited contact recreation waters;** **Fish and wildlife propagation, recreation and stock watering.**
Size of Waterbody:	**326.2 hectare (806 acres)**
Size of Watershed :	**63,924 hectare (157,960 acres)**
Water Quality Standards:	**Narrative and numeric**
Indicators:	**Average TSI**
Analytical Approach:	**BATHTUB, FLUX and AGNPS**
Location:	**HUC Code: 10160008**
TMDL Goal	
Total Phosphorus:	**38.8% reduction in total phosphorus (5,938 kg/yr.)**
TMDL Target	
Total Phosphorus:	**TSI 98.37, mean TSI 79.18 (9,366 kg/yr.)**

Objective:

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

Introduction

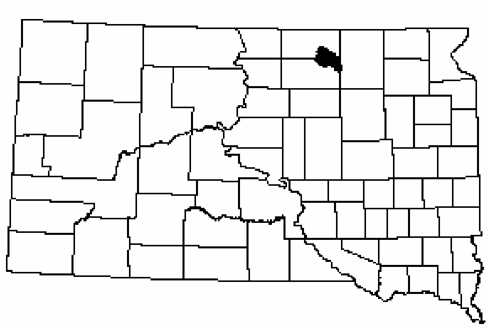


Figure 1. Watershed location in South Dakota

Mina Lake is a 326.2 hectare (806-acre) man-made impoundment located in northeastern Edmunds County, South Dakota (Figure 1). The 1998 South Dakota 303(d) Waterbody List (page 22) identified Mina Lake for TMDL development for trophic state index (TSI), increasing eutrophication trend.

The Mina Lake watershed encompasses approximately 63,924.4 ha (157,960 acres) and is drained by Snake Creek (Figure 2). The damming of Snake Creek near the town of Mina, South Dakota created the lake, which has an average depth of 3.38 meters (11.1 feet) and over 33.6 kilometers (20.9 miles) of shoreline. The lake has a maximum depth of 8.23 meters (27 feet) and holds 7,258.5 acre-feet of water. The outlet for the lake empties back into Snake Creek, which eventually reaches the James River.

Problem Identification

Snake Creek is the primary tributary to Mina Lake and drains predominantly agricultural

land (approximately 86 percent). Winter feeding areas for livestock are present within the watershed. The stream carries nutrient (total phosphorus) loads, which degrade the water quality of the lake, and cause increased eutrophication.

Data indicate that a 94.4 percent reduction in phosphorus is needed in this watershed to meet designated beneficial uses (fully supporting) based on reference lake criteria for ecoregion 46 (mean TSI $\leq$ 64.99). However, Mina Lake appears not to fit ecoregion-based beneficial use criteria based on the large reduction in total phosphorus needed to meet current ecoregional targets. Both economic and technical limitations preclude the realization of a 94.4 percent reduction in total phosphorus (pages 105 and 137). Current data indicate that a 38.8 percent reduction in phosphorus can be achieved in this watershed to meet the TMDL goal of 9,366 kg/yr or a mean in-lake TSI of 79.18.

Currently, the total phosphorus load to Mina Lake is 15,304 kg/year (16.9 tons/year). Total phosphorus loads need to be reduced by 5,938 kilograms (38.8 %), resulting in a total phosphorus TMDL of 9,366 kilogram per year producing an average Trophic State Index (TSI) of 79.18.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

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

(1) Domestic water supply
(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.

Individual parameters, including the lake's mean TSI value, determine the support of beneficial uses and compliance with standards. Mina Lake experiences nutrient enrichment and some nuisance algal blooms, which are typical signs of the eutrophication process. Mina Lake was identified in both the 1998 South Dakota 303(d) Waterbody List and "Ecoregion Targeting for Impaired Lakes in South Dakota" as not supporting its beneficial uses.

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 Mina Lake.

Figure 2. Mina Lake and Snake Creek watershed.

Mina Lake currently has a total phosphorus TSI of 104.73, a chlorophyll-*a* TSI of 70.43 and a Secchi TSI of 68.89 which translates to an average TSI of 81.35, which is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of high productivity is high total phosphorus loads from the watershed.

SD DENR recommended specific TSI parameters for Mina Lake are: 98.37 for total phosphorus, 70.36 for chlorophyll-*a* and 68.82 for Secchi visibility. The TMDL numeric target established to reduce total phosphorus loading to Mina Lake will lower the mean TSI to 79.18 (assessment final report, pages 135 through 138).

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

Analysis of the watershed through the use of the Agricultural Non-Point Source (AGNPS) model indicated that approximately 1.4% of the total phosphorus load was the result of livestock feeding area discharge, 11.3% from inadequate cropland tillage practices and 8.5% from fertilizer. See the AGNPS section of the final report (Appendix C).

Other tributary total phosphorus loads were estimated using published percent reductions expected for Best Management Practices (BMPs) on priority subwatersheds. BMPs included inadequate buffers (11.4%) and riparian management (6.2%) which contributes to the total phosphorus load to Mina Lake (assessment final report, pages 131 through 133).

In-lake total phosphorus reduction percentage in TSI was estimated using published data. Recommended total phosphorus reduction in TSI included aluminum sulfate treatment, 4.9% reduction in total phosphorus TSI (assessment final report, pages 134 through 135).

The remaining total phosphorus loading (3,428 kg/yr) was attributed to background sources in the Mina Lake watershed.

Linkage Analysis

Water quality data was collected from 8 monitoring sites within the Mina Lake / Snake Creek watershed. Samples collected at each site were taken according to South Dakota's EPA-approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on approximately 10% of the samples according to South Dakota's EPA-approved Clean Lakes Quality Assurance/ Quality Control Plan. Details concerning water-sampling techniques, analysis, and quality control are addressed on page 6, pages 12 through 14, 51 through 52 and 125 through 128 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AGNPS (Agricultural Nonpoint Source) model was used to estimate potential nutrient load reductions from feedlots, minimum tillage and fertilizer reduction within the watershed through the implementation of various BMPs. See the AGNPS section of the final report, Appendix C.

Other watershed (buffer strips and riparian management) and in-lake (aluminum sulfate treatment) BMPs were also used to estimate total phosphorus reductions. Two other BMPs were suggested (streambank stabilization and submerged aquatic macrophytes) however total phosphorus reduction percentages were not estimated because data was unavailable to calculate viable response. All estimates were based on conservative percent reductions applied to priority subwatersheds (assessment final report, pages 131 through 133).

Reducing the current total phosphorus load (15,304 kg/yr.) a minimum of 38.8% (5,938 kg/yr.) will reduce the average TSI value from 81.35 to 79.18. 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) = 38.8% reduction

	0 kg/yr	**(WLA)**
+	**5,938 kg/yr**	**(LA)**
+	**3,428 kg/yr**	**(Background)**
+	**Implicit**	**(MOS)**
	9,366 kg/yr	**(TMDL) [1]**

[1] = TMDL Equation implies a 38.8% based on BMP attainability in total phosphorus reduction with all possible 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 AGNPS model indicates that minimum tillage and reduced fertilizer application could achieve an 11.3% (1,729 kg/yr.) and 8.5% (1,301 kg/yr.) reductions in total phosphorus loading to Mina Lake.

Installing waste management systems on eleven animal feeding areas/operations within the watershed would account for an additional 1.4% (214 kg/yr.) of the total phosphorus load to the lake.

Tributary total phosphorus reductions for riparian management 6.2% (949 kg/yr.) and buffer strips 11.4% (1,745 kg/yr.) were estimated using various methods and best professional judgement.

In-lake total phosphorus reductions in TSI were also estimated for Mina Lake. They include and an aluminum sulfate treatment, 30% reduction in in-lake phosphorus concentrations resulting in a 4.9% reduction in in-lake total phosphorus TSI values.

A total phosphorus reduction of 38.8% is needed to improve the mean TSI of Mina Lake to 79.18.

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, Mina Lake samples were separated into spring (March-May), summer (June-August), fall (September-November).

Margin of Safety

All total phosphorus reductions were calculated based on extremely conservative estimations built into the model and conservative total phosphorus reduction percentages using best professional judgement. This translates to an implicit margin of safety (assessment final report, pages 135 and 138). Mina Lake needs a 38.8% total phosphorus reduction to improve average TSI values.

Critical Conditions

Based upon the 1999 and 2000 assessment data, impairments to Mina Lake 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

Mina Lake should remain on the round robin statewide lake assessment project and on the South Dakota Game, Fish and Parks normal lake survey and swimming beach sampling to monitor and evaluate long-term trophic status, biological communities and ecological trends.

Once the implementation project is completed, post-implementation monitoring will be necessary to assure that the TMDL has been reached and improvements in average TSI values occur.

Public Participation

The Mina Lake watershed assessment project was initiated during the summer of 1999 with EPA Section 319. Mina Lake was on the priority list of Section 319 Nonpoint Pollution Control projects. Edmunds County Conservation District agreed to sponsor the project. Federal grant funds totaled $68,446. Funds were used for water quality analyses, equipment, supplies, travel, and wages for the local coordinator.

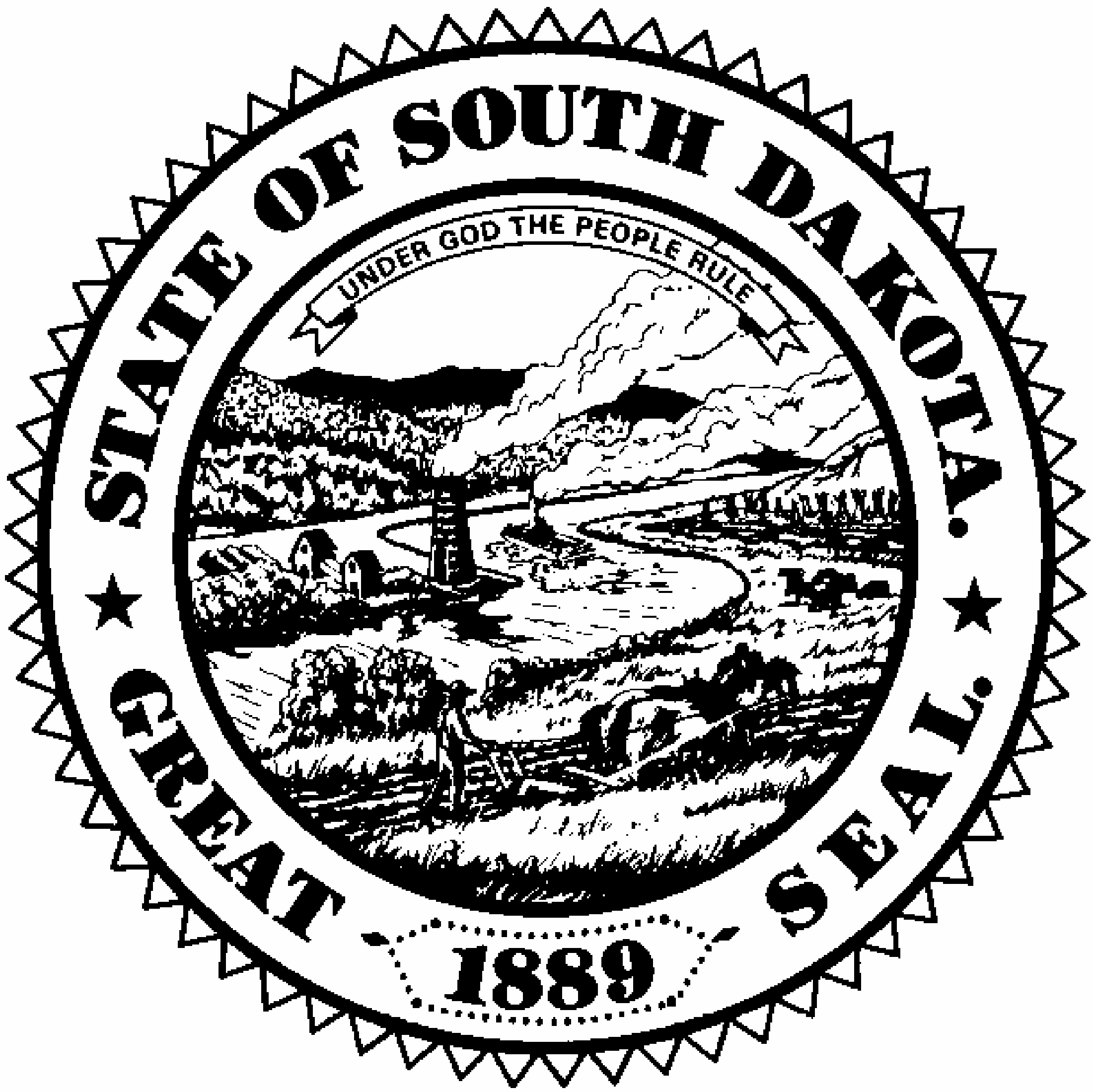
Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. **Edmunds County Conservation District Board Meetings (15)**
2. **McPherson County Conservation District Board Meetings (2)**
3. **Mina Lake Sanitary District meeting (2)**
4. **Dakota Central Conservation Association (1)**
5. **Individual contact with landowners in the watershed (continuous throughout the project).**
6. **Articles/pamphlets sent to landowners in the watershed (2)**
7. **Newspaper articles (3)**
8. **Final results presentation (1)**

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

Implementation Plan

The South Dakota DENR is working with the Edmunds and McPherson Counties Conservation Districts to initiate an implementation project beginning in 2003. It is expected that a local sponsor will request project assistance during the winter 2003 EPA Section 319 funding round.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