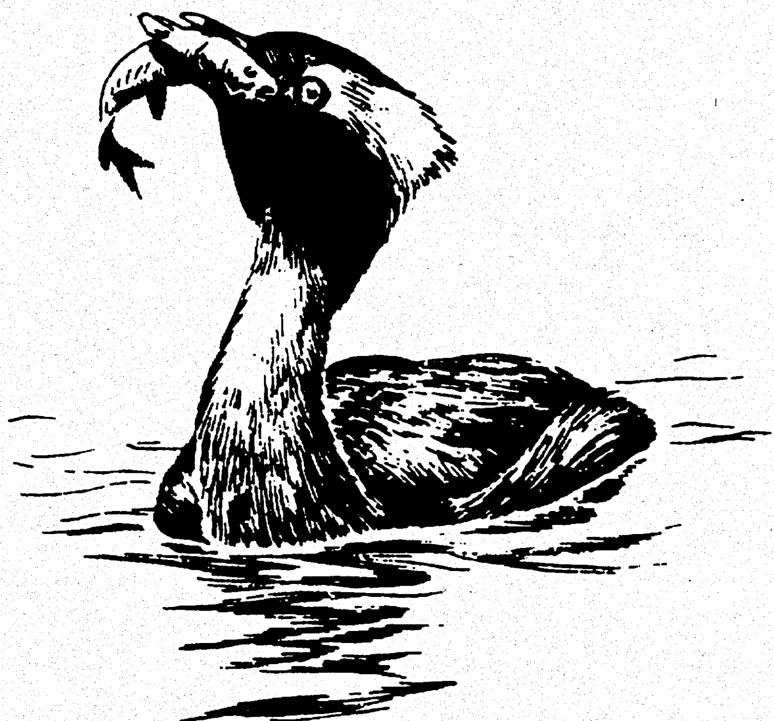
PHASE I
WATERSHED ASSESSMENT
FINAL REPORT

LAKE LOUISE /WOLF CREEK
HAND AND HYDE COUNTIES, SOUTH DAKOTA



South Dakota Watershed Protection Program
Division of Financial and Technical Assistance
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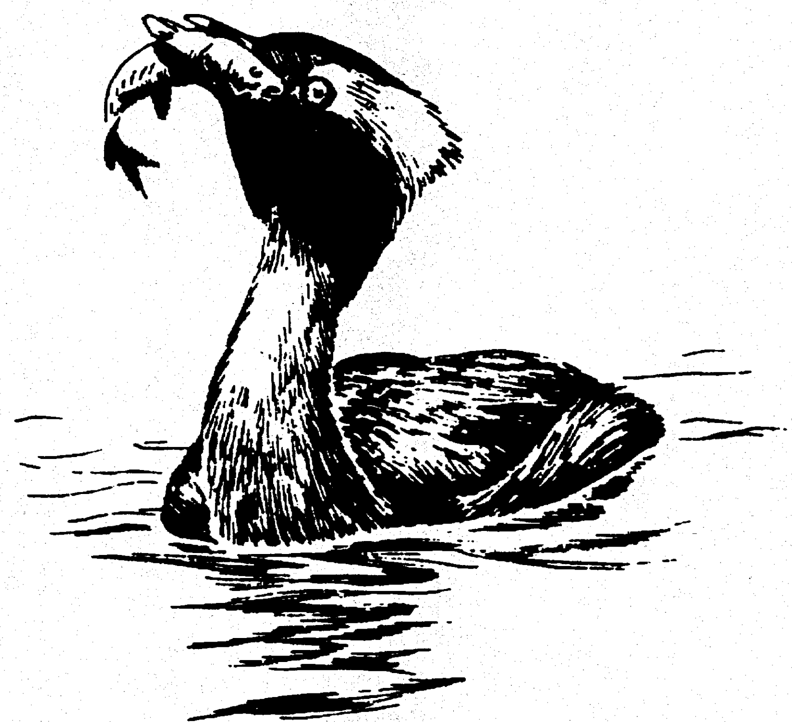

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SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM
ASSESSMENT/PLANNING PROJECT FINAL REPORT

LAKE LOUISE/ WOLF CREEK WATERSHED ASSESSMENT FINAL REPORT

By

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Andrew Repsys, Environmental Project Scientist

Sponsor

Central Plains Water Development District

3/13/01

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

Grant # 99-72

Acknowledgements

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

Central Plains Water Development District

Charolette Taylor, Hand County Conservation District

Cindy Steele, Natural Resources Conservation Service

Dale Simpson, Park Manager, Lake Louise

Dave Hauschild, Central Plains Water Development District Manager

Dianna Tong, Hand County Conservation District Manager

Duane Nielsen, Central Plains Water Development District

Hand County Conservation District

Hyde County Conservation District

Kelly Stout, Natural Resources Conservation Service

Mark Brannen, Natural Resources Conservation Service

Marvin Nelson, Natural Resources Conservation Service

Natural Resources Conservation Service

SD DENR – Watershed Resources Assistance Program

SD Department of Game, Fish and Parks

Table of Contents

Abbreviations

AFO's	Animal Feeding Operations
AGNPS	Agricultural Non-Point Source
BMP	Best Management Practice
CPUE	Catch per Unit Effort
CV	Coefficient of Variance
DC	District Conservationist
DO	Dissolved Oxygen
IJC	International Joint Commission
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Units
PSIAC	Pacific Southwest Interagency Committee
Q WTD C	Flow Weighted Concentration
SDDENR	South Dakota Department of Environment and Natural Resources
SDGF&P	South Dakota Department of Game Fish & Parks
su	Standard Units
TKN	Total Kjeldahl Nitrogen
TSI	Trophic Status Index
umhos/cm	microhmos/centimeter
USGS	United States Geologic Survey

Executive Summary

PROJECT TITLE: Lake Louise/ Wolf Creek Watershed Assessment

PROJECT START DATE: 5/1/99 PROJECT COMPLETION DATE: 5/1/00

FUNDING: TOTAL BUDGET: $169,032.00

TOTAL EPA GRANT:	$101,420.00
TOTAL EXPENDITURES OF EPA FUNDS:	$87,673.43
TOTAL SECTION 319 MATCH ACCRUED:	$66,749.55
BUDGET REVISIONS:	None
TOTAL EXPENDITURES:	$154,422.98

SUMMARY ACCOMPLISHMENTS

The Lake Louise and Wolf Creek assessment project began in May of 1999 and lasted through December of 2000 when data analysis and compilation into a final report was completed. The assessment was conducted as a result Lake Louise being placed on the 1998 303d list for an increasing TSI trend, fecal coliforms, and accumulated sediment problems. The project met all of its milestones in a timely manner, with the exception of completing the final report. This was delayed while completion of the final report on an additional watershed (Cottonwood Lake and Medicine Creek in Spink County, South Dakota), that was funded under the same grant, was completed.

An EPA section 319 grant provided a majority of the funding for this project. The South Dakota Conservation Commission, Central Plains Water Development District, Hand and Hyde County Conservation Districts and the Cottonwood Lake Association provided local matching funds for the project.

Water quality monitoring and watershed modeling resulted in the identification of several sources of impairment. These sources may be addressed through best management practices and the construction of several waste management systems at animal feeding operations. Aquatic plant, algae, and sediment surveys were also completed for the lake.

Through the utilization of best management practices, animal feeding operation discharge reductions, and lake aerators, a sufficient reduction of inlake phosphorus will occur to result in a positive shift (a decrease) in the lakes TSI value.

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

Introduction

Purpose

The purpose of this pre-implementation assessment is to determine the sources of impairment to Lake Louise in Hand and Hyde Counties, South Dakota and the tributaries in its watershed. The creeks and small tributaries are streams with loadings of sediment and nutrients related to rainfall and snowmelt events. The discharge from this watershed ultimately reaches the James River.

Wolf Creek is the primary tributary to Lake Louise and drains predominantly grazing lands with some cropland acres. Winter feeding areas for livestock are present in the watershed. The stream carries sediment loads and nutrient loads, which degrade water quality in the lake and cause increased eutrophication.

General Lake Description

Lake Louise is a 163-acre man-made impoundment located in central Hand County, South Dakota. Damming Wolf Creek 15 miles north of Ree Heights created the lake, which has an average depth of 9 feet (3 meters) and over 6 miles (9.7 km) of shoreline. The lake has a maximum depth of 22 feet (6.7 m), holds 1,463 acre-feet of water, and is subject to periods of stratification during the summer. The outlet for the lake empties into Wolf Creek, which eventually reaches Turtle Creek south of Redfield. Turtle Creek discharges into the James River near Redfield, South Dakota.

Lake Identification and Location

Lake Name: Lake Louise
County: Hand
Range: 69W
Nearest Municipality: Ree Heights
Longitude: -99.137372
Primary Tributary: Wolf Creek
HUC Code: 10160009

State: South Dakota
Township: 113N
Sections: 4
Latitude: 44.62351
EPA Region: VIII
Receiving Body of Water: Wolf Creek
HUC Name: Turtle

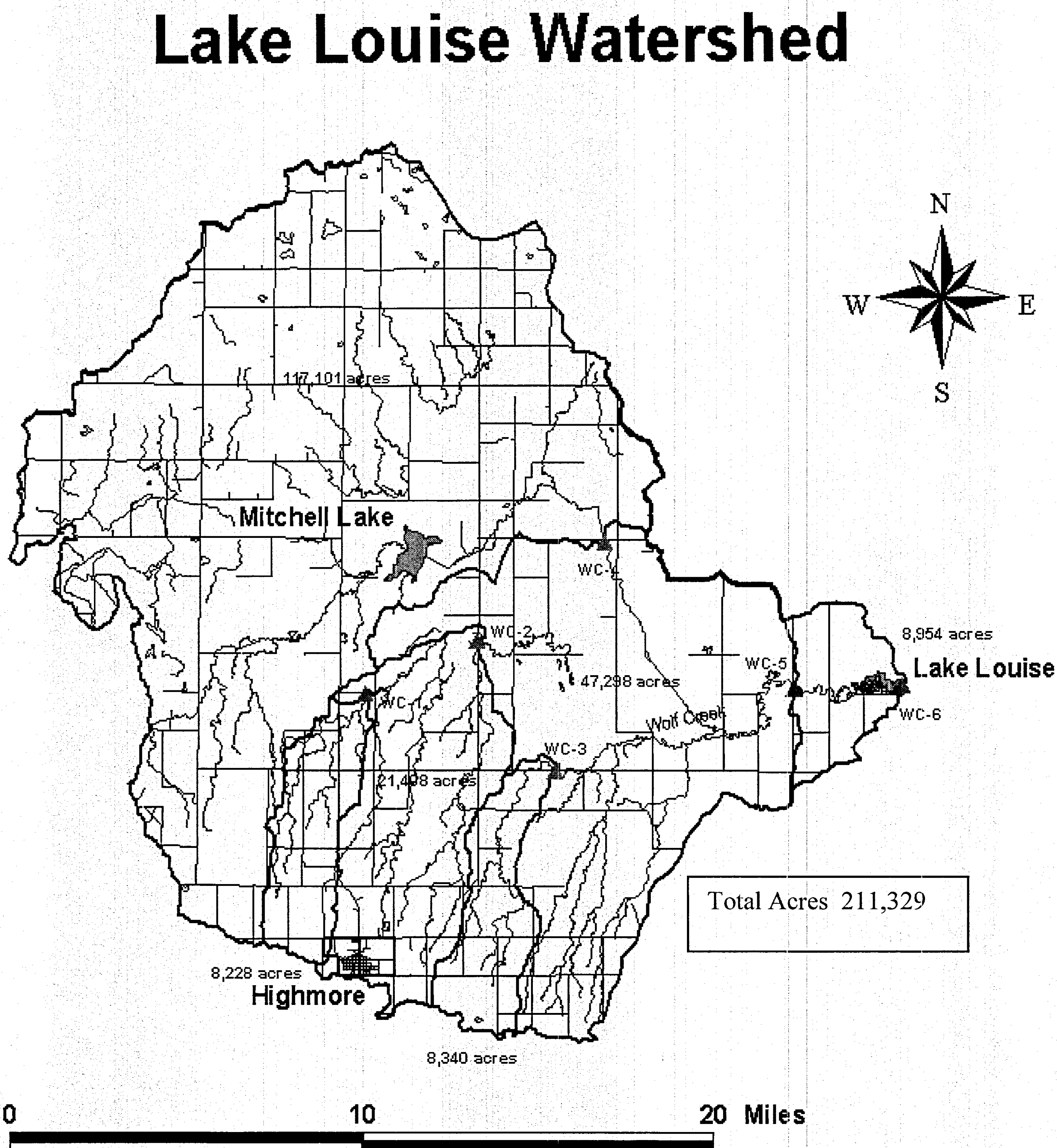


Figure 1. Lake Louise and Wolf Creek Watershed

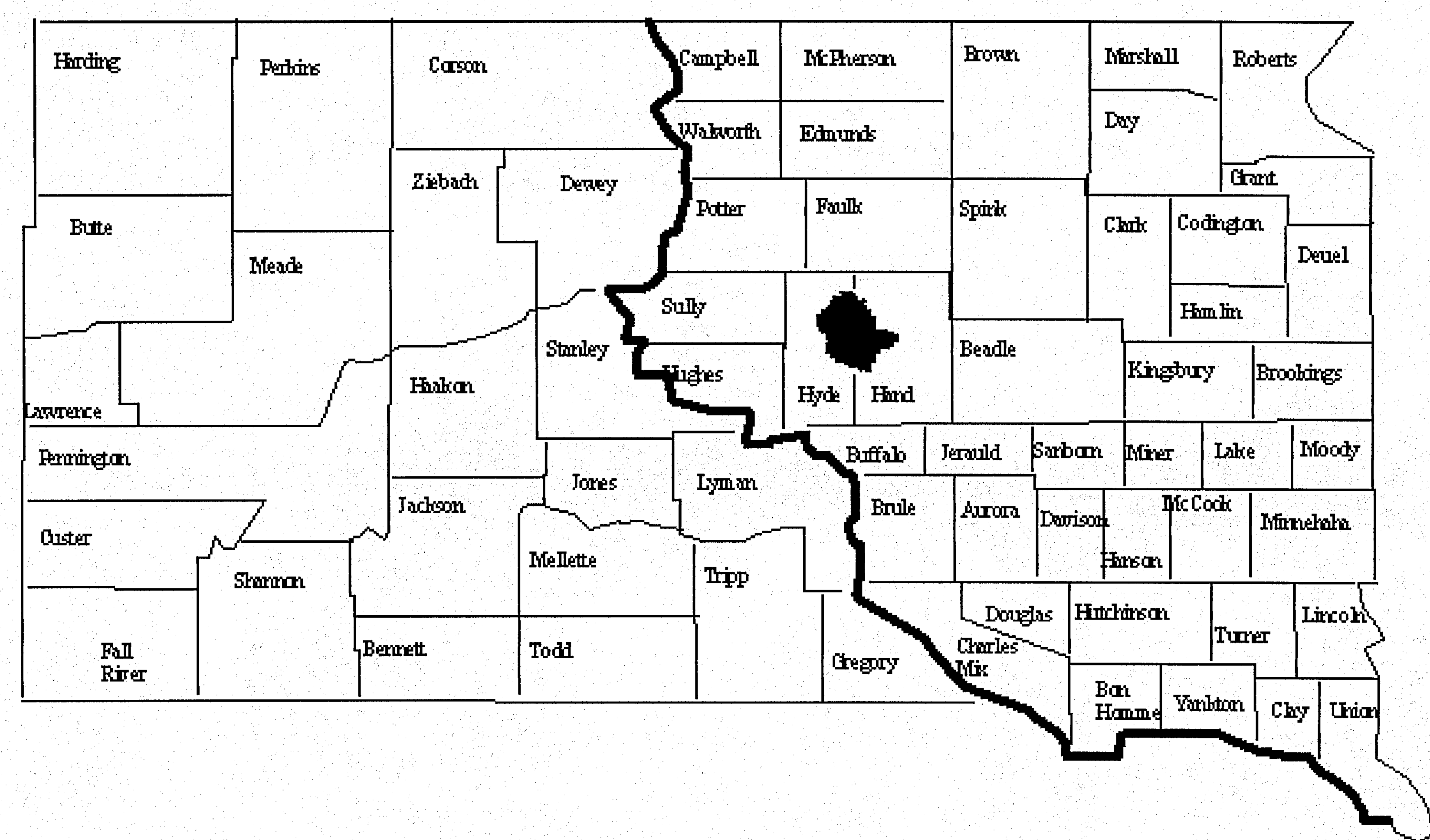


Figure 2. Watershed Location in South Dakota

Trophic Status Comparison

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

Table 1. TSI Comparison for Area Lakes

Lake	Nearest Municipality	TSI	Mean Trophic State
Redfield	Redfield	83.38	Hypereutrophic
Mina	Mina	79.76	Hypereutrophic
Rosette	Ipswich	78.45	Hypereutrophic
Cottonwood	Redfield	76.83	Hypereutrophic
Faulkton	Faulkton	76.32	Hypereutrophic
Louise	**Ree Heights**	**71.16**	**Hypereutrophic**
Bierman Gravel Pit	Chelsea	70.28	Hypereutrophic
Jones	St. Lawrence	68.30	Hypereutrophic
Loyalton Dam	Loyalton	65.28	Hypereutrophic
Richmond	Richmond	60.16	Eutrophic

Beneficial Uses

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

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

Individual parameters as well as the lake's TSI value determine the support of these beneficial uses. Lake Louise is identified in Ecoregion Targeting for Impaired Lakes in South Dakota and in the 1998 South Dakota 303d Waterbody List as not supporting its beneficial uses.

Recreational Use

The South Dakota Department of Game, Fish, and Parks provide a list of public facilities that are maintained at area lakes (Table 2). Lake Louise State Park is located on the south side of the lake and has a number of facilities including modern and primitive camping, boat launch, fish cleaning station, walking and hiking trails, a swimming beach, as well as an area Game, Fish, and Parks shop.

Table 2. Comparison of Recreational Uses on Area Lakes

Lake	Parks	Ramps	Boating	Camping	Fishing	Picnicking	Swimming	Nearest Municipality
Redfield	1	1	X	X	X	X	X	Redfield
Mina	1	3	X	X	X	X	X	Mina
Rosette		1	X		X			Ipswich
Cottonwood		2	X		X		X	Redfield
Faulkton	1	1	X	X	X	X	X	Faulkton
Louise	**1**	**1**	**X**	**X**	**X**	**X**	**X**	**Ree Heights**
Bierman Gravel Pit					X			Chelsea
Jones		1	X		X	X		St. Lawrence
Loyalton Dam					X			Loyalton
Richmond	1	2	X	X	X	X	X	Richmond

Geology

Lake Louise and its primary tributary, Wolf Creek, lie in the region known as the Missouri Coteau. Located east of the Missouri River, it was subject to several periods of glaciation. The glaciers formed the parent material of the present day soils. The Mankato Period of glaciation was the last to impact the area and had the greatest impact on the current soils. The landscape of the watershed is nearly level. This is due in part to the activity of the glaciers as well as water erosion.

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

The project area contains a number of aquifers that traditionally supplied the residents with a majority of their drinking water. A rural water system replaced the need for much of the groundwater in the area. The Tulare, Dakota, and Fall River-Sundance-Minnelusa are the primary aquifers in the region. The Tulare exists under artesian conditions and the water is suitable for stock watering and irrigation. The other two are bedrock aquifers and tend to contain too many dissolved solids to be suitable for irrigation. Other aquifers that are utilized in the region are the Elm Creek, Highmore, and Bad-Cheyenne River.

History

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

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

Hyde County was founded in 1882, and organized in 1883 through the Dakota Territorial Legislature. The county was named for James Hyde who came to the area following the end of the Civil War. Highmore was named the county seat in 1884 and is located at the junction of U. S. Highway 14, and State Highways 26, 34, and 47.

The Lake Louise Dam was constructed in 1932 as a result of a great deal of effort on the part of the Lake Louise Association headed by Dr. E. H. Wilson, president, and D.C. Walsh, secretary. The lake was named for Louise Wilson, mother of Dr. E. H. Wilson, and in 1946, was designated a state recreation area.

Shortly after construction of the dam, a number of human skeletons were unearthed during improvements to the county road that accesses the park. Recent cultural investigations deemed the site as having archeological significance (Buechler, 1988). Termed the Miller Village Site, some controversy remains as to the exact age and origin of the remains. The site is most easily recognized as the mound that lies between the road and the park shelterbelt. Although the site has been deemed significant, the cultural investigation showed the site was confined to the area along the road, and lakeshore stabilization activities have been allowed along the lake.

The recreation area on the south side of the lake, known as Lake Louise State Park, is well known for its scenic beauty. Many improvements to the park have occurred since its designation. In October of 1968 a boat ramp was installed to increase access to one of the finest largemouth bass and bluegill fisheries in the state. In 1974, a swimming beach and maintenance shop were installed to facilitate the growing interest in the area. In 1977, the campground was wired for electricity and a comfort station was installed.

The Wolf Creek Watershed is an area that is locally referred to as "The Start of Cattle Country." A majority of the population living in and around the watershed make their living primarily on beef cattle in addition to a moderate amount of grain farming.

Project Goals, Objectives, and Activities

Planned and Actual Milestones, Products, and Completion Dates

Objective 1. Lake Sampling

Sampling of Lake Louise was to begin in May 1999, however, the first samples were not collected until June, 1999 when sampling equipment arrived. Sampling of nutrient and solids parameters continued at the two scheduled sites through October 1999 as planned. Sufficient ice cover for foot travel lasted from late December 1999 through early February 2000, during which samples were collected through the ice. Spring samples were collected during March and May of 2000.

Objective 2. Tributary Sampling

Immediately after the start of the project, the local coordinator began tributary sampling. Detailed level and flow data were entered into a database that was used to assess the nutrient and solids loadings to the lake. Throughout the month of June, 1999, Stevens Type F Stage Recorders as well as ISCO Flowmeters were installed at the pre-selected monitoring sites along the tributaries of Wolf Creek. Two samples were collected during the months of November and December of 1999 at the inlet to Lake Louise. No discharge occurred as a result of a dry period that persisted throughout the remainder of the project, which resulted in a limited data set.

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

Duplicate and blank samples were collected during the course of the project to provide defendable proof that sample data were collected in a scientific and reproducible manner. QA/ QC data collection began in May of 1999 and was completed on schedule in April of 2000.

Objective 4. Watershed Modeling

On June 23, 1999, the project officer, coordinator, technician, and several range and soils specialists toured the watershed and made initial determinations for the Pacific Southwest Inter-Agency Committee (PSIAC) model. The NRCS office located in Huron finalized the PSIAC final that was used to determine potential sediment loading reductions with the implementation of BMPs. This objective was completed during June and July of 1999, sooner than the proposed start and finish date.

Objective 5. Public Participation

Many of the landowners were contacted individually to assess the condition of animal feeding operations located within the project area. Further information was provided at the Hand and Hyde County Conservation District meetings and Central Plains Water

Development District meetings and the local Kiwanis Club. Press releases were also provided to local papers at various points throughout the project.

Objective 6. Sediment Survey

The sediment survey was to be conducted during periods of safe ice cover. Due to a lack of safe ice cover, as a result of the mild winter, the survey was conducted during the first weeks of May 2000 from a boat.

Objectives 7 and 8. Restoration Alternatives and Final Report

Completion of the restoration alternatives and final report for Lake Louise and Wolf Creek in Hand and Hyde Counties was delayed until the completion of the final report for Cottonwood Lake (in Spink County) and watershed that was completed under the same grant.

Evaluation of Goal Achievements

The goal of the watershed assessment completed on Lake Louise was to determine and document sources of impairment to the lake and to develop feasible alternatives for restoration. This was accomplished through the collection of tributary and lake data and aided by the completion of the PSIAC and AGNPS watershed modeling tools. Through data analysis and modeling, identification of impairment sources was possible. The identification of these impairment sources will aid the state's nonpoint source (NPS) program by allowing strategic targeting of funds to portions of the watershed that will provide the greatest benefit per expenditure.

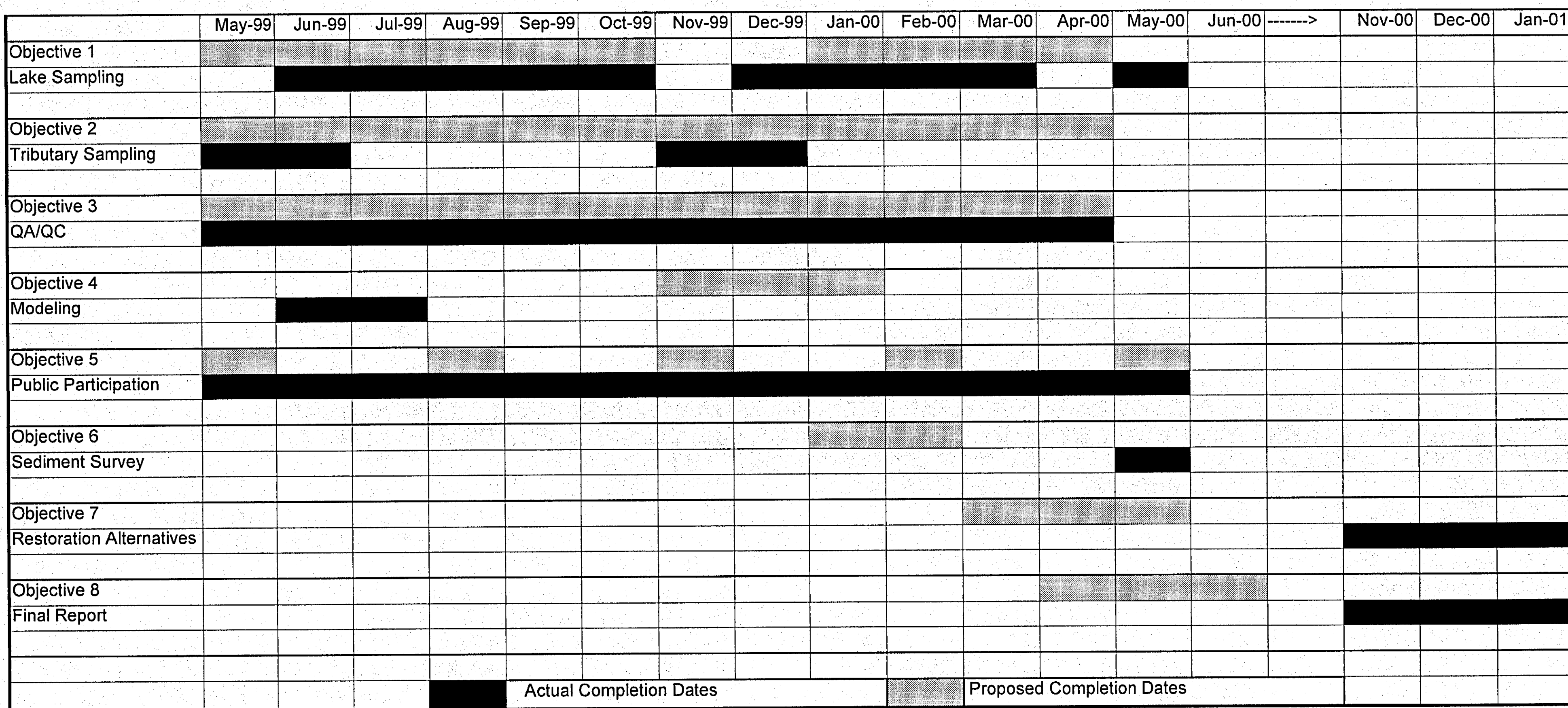


Table 3. Proposed and Actual Objective Completion Dates

Monitoring Results

Surface Water Chemistry (Wolf Creek)

Flow Calculations

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

Load Calculations

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

Tributary Sampling Schedule

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

Fecal Coliform Bacteria
Total Solids
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus
Alkalinity
Total Dissolved Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Total Volatile Suspended Solids

Personnel conducting the sampling at each of the sites recorded the following visual observations of weather and stream characteristics.

Precipitation
Odor
Dead Fish
Turbidity
Water Depth
Water Color

Wind
Septic
Film
Width
Ice Cover

Parameters measured in the field by sampling personnel were:

Water Temperature
Conductivity
Field pH

Air Temperature
Dissolved Oxygen

The state of South Dakota assigns at least two of the eleven beneficial uses to all bodies of water in the state. Fish and wildlife propagation, recreation and stock watering have the least stringent requirements and are assigned to all bodies of water. All portions of Wolf Creek located above Lake Louise are assigned uses nine and ten. In order for the creek to maintain these uses, there are five standards that must be maintained, these standards, along with their numeric criteria, are listed in Table 4.

Table 4. State Water Quality Standards

Nitrate	<50 (mean) <88 (single sample)
Alkalinity	<750 (mean) <1,313 (single sample)
pH	> 6.5 and <9.5 su
Total Dissolved Solids	<2,500 mg/L for a 30 day geometric mean < 4375 mg/L daily maximum for a Grab Sample
Conductivity	<4,000 (mean) <7,000 (single sample

Watershed Overview

Discharge from the Wolf Creek Watershed and rainfall are the two primary sources of water for Lake Louise, while very little groundwater enters the lake. For this reason it will not be considered a major contributor of hydrologic or nutrient loads. Wolf Creek drains approximately 211,329 acres or 330 square miles at its discharge from Lake Louise. While this is a relatively large watershed, hydrologic discharges are somewhat smaller than are typical for other watersheds in this region. This is due in part to the nearly level landscape and the large number of stock dams and manmade impoundment's that store surface runoff.

The USGS maintained a gauging station at the inlet to Lake Louise as well as several other local tributaries from 1959 through 1989. From the data that they collected, discharge estimates were calculated for 2, 5, and 10-year runoff events. For Wolf Creek, those discharge estimates were 30, 226, and 641 cfs, respectively. These numbers are significantly less than watersheds of similar or even smaller size, such as Medicine Creek above Cottonwood Lake. Although it is smaller in size, the Medicine Creek watershed discharges 1,280 cfs during a 10-year runoff event, nearly double that of Wolf Creek. Table 5 depicts the flood frequency characteristics of Wolf Creek as well as other streams located in Hand County.

Table 5. Watershed Discharge Comparison(Copied from USGS Water Resources of Hand County Report)

Flood characteristics, drainage area, annual precipitation, and mean Discharge in CFS for indicated recurrence intervals, in years					
Drainage Basin	Drainage Area (mi^2)	Mean Precip	2	5	10
Wolf Near Ree Heights (Inlet To Lake Louise)	**265**	**17.0**	**30**	**226**	**641**
Matter Creek Near Orient	5.41	17.6	15	102	245
Shaefer Creek Near Orient	45.1	17.5	82	334	694
Shaefer Creek Tributary Near Orient	6.08	17.5	37	117	190
Shaefer Creek Tributary Near Miller	5.75	17.5	17	65	130
Turtle Creek Near Tulare	1,120	17.5	101	846	2,820
Medicine Creek Near Zell (Inlet to Cottonwood Lake)	210	18.0	166	642	1,280
Pearl Creek at County Line	146	17.5	75	360	800
South Fork Medicine Knoll Creek at County Line	84	17.5	55	280	600

The average annual discharge for all years in which data is available is 2,499 acre-feet. It is important to note that in the 30 years of data used for this estimate, only 3 events produced discharges between 1,000 and 5,000 acre-feet. Assuming that discharges from each of the subwatesheds occur proportionately on an annual basis, an annual discharge from each of the subwatersheds can be calculated using the 30-year average of 2,499 acre-feet at the inlet to the lake.

Table 6. Annual Subwatershed Hydrologic Loads for the Wolf Creek Watershed

Subwatershed	1999 Discharge (Liters)	Percent of annual Discharge at WC-5	Estimated Annual Discharge (Acre-Feet)
WC-1	55,236,879	2%	59
WC-2	436,310,110	19%	469
WC-3	295,061,021	13%	317
WC-4	144,800,946	6%	155
WC-5	2,327,256,714	100%	2499
WC-6	2,391,043,059	103%	2567

Stream data collected by USGS indicates that Wolf Creek flows approximately 2 out of 3 years at the inlet to Lake Louise. Of these flows, approximately 50% can be considered significant, (1 out of 3 years) meaning that the water volume discharged is sufficient to completely replace the volume of water in the lake. The remainder of the flows discharge only enough water to refill the impoundment with little or no discharge occurring at the outlet. These smaller flows are not sufficient to replace the nutrients out of the lake. All of the flows consistently come during the spring snowmelt or immediately after as a result of heavy rains. At no time during the time that USGS monitored this site did significant discharge occur after the end of spring discharge.

During the years in which discharges occurred, flows were heavily related to snowmelt and spring rainstorms. Table 7 exhibits the average daily cfs for a typical calendar year, in which 96.5 % occurred during the spring months of March, April, and May. Of the remaining flow, 3.1% occurred during the summer while fall and winter discharges account for less than 0.4% of the annual discharge that occurred in the watershed. As a result, seasonalizing the loading data is of little use. Flows that occur after the end of spring discharge are infrequent and small enough in size that they do not account for any appreciable amount of loading.

Table 7. Average Monthly Flows at the Inlet to Lake Louise

Average Daily Flow (CFS)	Month	Percentage of Annual Flow
0.00	January	0.0%
0.03	February	0.1%
16.71	March	37.3%
21.90	April	48.9%
4.63	May	10.3%
1.01	June	2.2%
0.23	July	0.5%
0.17	August	0.4%
0.06	September	0.1%
0.07	October	0.1%
0.03	November	0.1%
0.00	December	0.0%

Subwatersheds

A comparison of the subwatersheds in the Wolf Creek drainage indicates that a majority of the discharge originated in the lower half of the watershed, or that portion immediately above the lake. This is related directly to the topography of the watershed. Subwatersheds WC-1 and WC-4 are both located in the flat plain that is formed between the Orient Hills of Faulk County and the Ree Hills of Hand County. Land slopes in this plain are generally less than 1%. Subwatershed WC-4 represents approximately 56% of the total Lake Louise watershed, which also includes Lake Mitchell. Lake Mitchell is a large and shallow impoundment in the Wolf Creek Drainage. Contact with local residents revealed that this subwatershed discharged only once every ten years. The shallow nature of Lake Mitchell may act as a natural sink for many nutrients and sediments that originate above it in the watershed. There are only two animal feeding operations located in this subwatershed.

Subwatersheds WC-2 and WC-3 both originate in the Ree Hills where land slopes are more distinct and drainages are more defined. As a result, discharge per unit area was significantly higher in these subwatersheds versus WC-1 and WC-4 (Figures 3). WC-2 has less discharge per square mile than WC-3. This is a result of a portion of this watershed being located in the same flat plain as WC-1 and WC-4. Seven of the animal feeding operations were located in these subwatersheds, with five of those located in WC-2 and the remaining two located in WC-3.

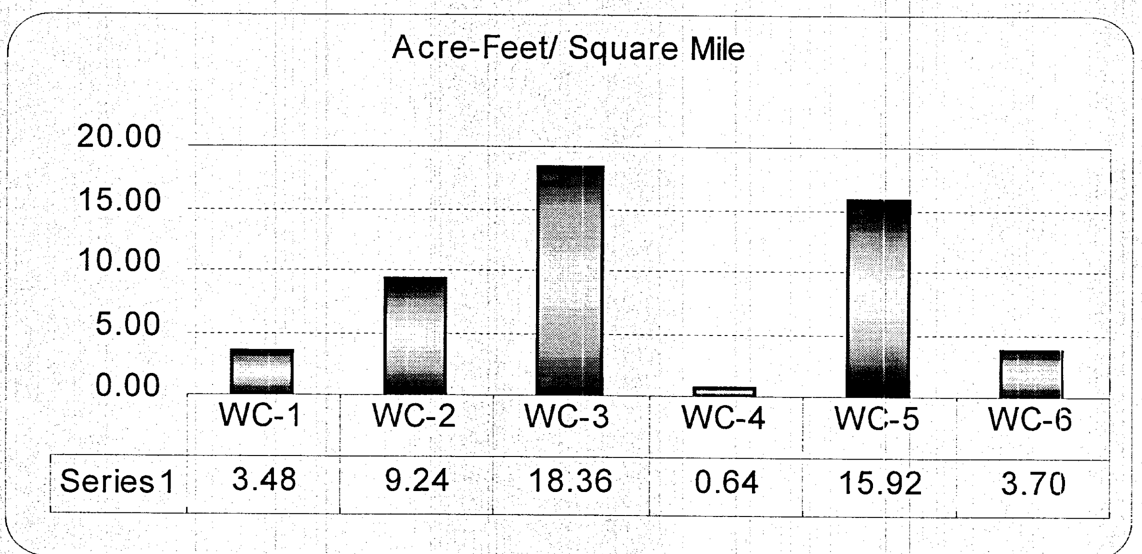


Figure 3. Subwatershed Discharge per Square Mile for the Wolf Creek Watershed

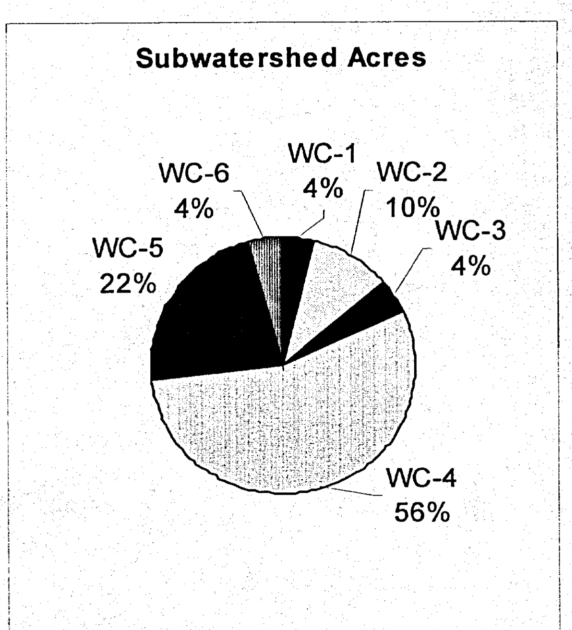
The subwatershed located around the lake itself (WC-6) had runoff volumes similar to those found in the upper reaches of the watershed. There are defined slopes and drainages in this subwatershed, however, the primary land use is not agricultural. Most of the area around the lake is owned and operated by the South Dakota Department of

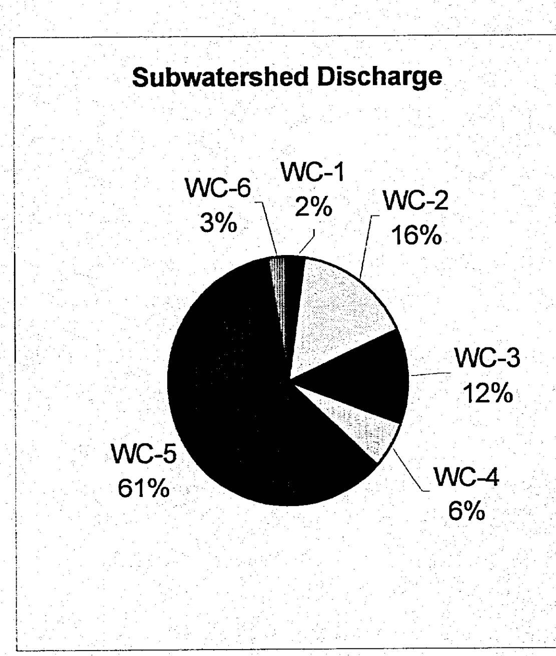
Game, Fish and Parks and its primary uses are hunting and recreational in nature. The range condition is excellent which helps to minimize runoff. There was one animal feeding operation located in this subwatershed.

Subwatershed WC-5 composed 22% of the total watershed acreage immediately above Lake Louise. Most of the discharge (61%) to the lake originated in this subwatershed. Eleven animal feeding operations are located in this subwatershed.

Figure 4 depicts the area of the subwatersheds as well as the percentage of total discharge that originates in each one. While subwatersheds WC-1, WC-6 and WC-4 accounted for over 63% of the total land area in the watershed, they contributed only 11% of the water entering Lake Louise. Figure 4 also depicts the number of acre-feet of discharge that occurred per square mile in each of the subwatersheds during 1999. Subwatersheds WC-2, WC-3, and WC-5 constituted only 36% of the total watershed land area yet contributed 89% of the hydrologic load. For this reason most management efforts should be targeted on these subwatersheds, particularly WC-3 and WC-5, as they have the greatest impact on the condition of Lake Louise. Due to data limitations, WC-1 and WC-3 are omitted as independent watersheds from most of the loading calculations. WC-1 discharges into WC-2 and is accounted for in its loading. WC-3 is accounted for in the same way at site WC-5.

Figure 4. Subwatershed Acreage and Discharge Percentage for the Wolf Creek Watershed





Annual Loading

To calculate the current and future water quality in an impoundment, BATHTUB (Army Corps of Engineers Eutrophication Model) utilizes phosphorus and nitrogen loads entering the impoundment. Found in Table 8, these loads and their standard errors (CV) are calculated through the use of FLUX (Army Corps of Engineers Loading Model) for site WC-5, the inlet to Lake Louise. Sample data collected during this project, an earlier project, as well as by the United States Geological Survey (USGS) were utilized in the calculation of the loads and concentrations.

Table 8. Annual Lake Loadings for Lake Louise

Parameter	Conc. (ppb)	FLUX Load (kg/ Year)	CV
Total Phosphorus	.671	2,129	.017
Total Dissolved Phosphorus	.464	1,482	.364
Total Nitrogen	1.455	4,612	.230
Organic Nitrogen	1.106	3,507	.536
Inorganic Nitrogen	.348	1,104	1.087
Total Alkalinity	178	565,347	.171
Total Suspended Solids	15.9	50,415	.308

Three of the samples collected during 1999 may not be representative of the conditions normally occurring in Wolf Creek. A small amount of flow continued through the summer and into the fall during that sampling year. The source of the flow was an overflowing well located a few hundred meters upstream from site WC-5. Samples taken from this flow had conductivity readings and dissolved solids concentrations that were significantly higher than those recorded during the spring runoff, or in any other sample taken during periods of discharge. Phosphorus and nitrogen concentrations in the well samples were significantly lower than other sample data that was collected at this site. This may all be attributed to the condition of the well water that was discharging into the stream. While these flows were insignificant and did not reach the lake, they were needed to fulfill the minimum data requirement to successfully execute the FLUX program. The low flows associated with these small concentrations have a minimal impact on the overall loading to the lake. Each of the less accurate concentrations were jackknifed (independently removed to determine their affect on the overall load) out during the execution of the modeling program. Load and concentration variations were always less than 5% of the total. The effect that they do have is reflected in slightly reduced total phosphorus and nitrogen loads.

Additional sample data for the inlet to Lake Louise was available from 1993-94, however this data lacked any corresponding flow data making load calculations impossible. However, analysis of this data along with the data collected during the project and by the USGS, offers some additional support for the loads calculated with FLUX. Table 9 contains all the data used for the calculation of the loadings to Lake Louise. Sample data with a measured flow was used to calculate annual loads using the FLUX Model. The first three samples in table 9 collected during August, November and December of 1999 are the samples that may not be considered typical for Wolf Creek.

Table 9. Sample Data at Inlet to Lake Louise

SITE	DATE	Flow (cfs)	SAMPLER	TYPE	SAMPLE DEPTH	Total Phosphorus (ppm)	Total Dissolved Phosphorus (ppm)	Total Nitrogen (ppm)	Organic Nitrogen (ppm)	Inorganic Nitrogen (ppm)
WC-5	8/31/99	0.05	KRUGER	GRAB	SURFACE	0.059	0.145	0.78	0.06	0.72
WC-5	11/9/99	0.05	KRUGER	GRAB	SURFACE	0.026	0.017	0.62	0.11	0.51
WC-5	12/8/99	0.20	SMITH/KRUGER	GRAB	SURFACE	0.191	0.008	0.62	0.06	0.56
WC-5	6/7/99	1.85	NIELSEN/KRUGER	GRAB	SURFACE	0.462	0.403	1.76	0.06	1.70
WC-5	3/18/85	56.00	USGS				0.570			
WC-5	3/29/85	142.00	USGS				0.190			
WC-5	3/18/86	180.00	USGS			0.680	0.620			
WC-5	3/31/86	60.00	USGS			0.670	0.550			
WC-5	4/21/87	0.01	USGS				0.190			
WC-5	8/30/93	2.0	MOERING	GRAB	SURFACE	1.262	1.116	2.16	0.25	1.91
WC-5	4/6/94		MOERING	GRAB	SURFACE	0.393	0.393	1.30	0.21	1.09
WC-5	4/19/94		MOERING	GRAB	SURFACE	0.829		1.36	0.06	1.30
WC-5	4/26/94		MOERING	GRAB	SURFACE	0.693	0.603	1.08	0.07	1.01
WC-5	6/20/94		MOERING	GRAB	SURFACE	1.220	1.140	1.73	0.11	1.62
WC-5	7/18/94		MOERING	GRAB	SURFACE	1.120	1.110	1.72	0.06	1.66

Fecal Coliform Bacteria

Fecal coliform are bacteria that are found in the digestive tract of warm-blooded animals. Some common types of bacteria are *E. coli*, *Salmonella,* and *Streptococcus,* which are associated with livestock, wildlife, and human waste. (Novotny, 1994). Major sources in the Wolf Creek drainage are most likely cattle and possibly wildlife. The human population density is 0.1 to 0.2 people per square mile, making human waste unlikely as a potential source.

Sample data for the Wolf Creek watershed is very limited for fecal coliform. Individual samples reported as 5 colonies/100mL represent samples that were below the detection limit of the State Health Laboratory. Wolf Creek beneficial use standards (above Lake Louise) were not exceeded by any of the samples taken.

Lake Louise is listed for the beneficial use of immersion recreation which requires that no single sample exceed 400 colonies/100mL or the 30-day geometric mean (consisting of 5 samples taken during separate 24 hour periods over 30 days time) be no more then 200 colonies /100mL. This standard was not exceeded in any of the samples collected at the outlet to the lake, WC-6. Grab samples collected during 1993-94 did not indicate any distinct sources of fecal contamination in the watershed. This may not only be the result of limited use of AFOs, but also of untimely collection of samples associated with early spring discharges.

Many of the animal lots in the drainage are used for only a portion of the fall and winter. Early spring snowmelt and rainstorms flush many of these lots out during the first weeks of runoff. The earliest samples were collected on April 6, 1994. During 1994, USGS stream gauging data on the James River indicates that runoff began the second week in March and peaked well before the April samples were collected. Any future sampling efforts should be concentrated during the first weeks of spring runoff. Testing should also include the genetic identification of collected organisms to determine the primary animal host of origin.

Table 10. Fecal Coliform in Wolf Creek

Fecal Coliform (Colonies/100mL)						
Date	Sampler	WC-2	WC-3	WC-4	WC-5	WC-6
06/29/1999	NIELSEN/KRUGER					230
08/30/1993	Moering				100	5
04/06/1994	Moering	5		5		5
04/19/1994	Moering	70		10	380	5
04/26/1994	Moering	580	100	10		180
07/18/1994	Moering	40		190	330	5
Mean		173	100	54	270	72

Alkalinity

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

Alkalinity concentrations in Wolf Creek varied from as high as 210 mg/L to as low as 50 mg/L. Table 11 lists all of the alkalinity samples and the means for each site. Sites WC-1 and WC-3 only had one and two samples, respectively. The two samples collected at site WC-3 had the highest alkalinity recorded on their respective dates when compared with the other subwatersheds. Site WC-5 (inlet) had the highest mean at 140 mg/L of total alkalinity. The state standard for alkalinity is a maximum of 750 mg/L as a geometric mean or 1,313 mg/L in a single sample, which Wolf Creek did not exceed in any of its samples.

Table 11. Total Alkalinity Concentrations (mg/L) for Wolf Creek

		WC-1	WC-2	WC-3	WC-4	WC-5	WC-6
06/07/1999	NIELSEN/KRUGER	143		210		208	124
06/29/1999	NIELSEN/KRUGER						135
08/30/1993	Moering					196	188
04/06/1994	Moering		62		50	61	61
04/19/1994	Moering		92		67		67
04/26/1994	Moering		109	198	69	107	174
06/20/1994	Moering					167	
07/18/1994	Moering		50		54	99	109
Mean		143	78	204	60	140	123

Sites WC-1 and WC-3 had insufficient data to draw any conclusions about the condition of these subwatersheds. Subwatersheds WC-2 and WC-4 had the lowest mean concentrations for total alkalinity when compared to the other sites. The mean concentrations at sites WC-2 and WC-4 are both less then the concentration found at the inlet to the lake. The concentrations at the inlet to Lake Louise are only slightly higher than those collected at the outlet. Site WC-3 has a limited amount of data, however the increased alkalinity concentrations at this site may contribute to the increase in concentration that occurs in subwatershed WC-5. The lower concentration at the outlet indicates an accumulation of alkalinity in the lake.

Macrophyte dominant communities are extremely effective in the uptake of nutrients such as calcium (Wetzel, 1983). Calcium carbonate is a primary contributing species to the alkalinity of surface waters in Hand County (Koch, 1980). The large number of macrophytes are probably responsible for the loss of alkalinity in the lake.

The total alkalinity load at the inlet to the lake was estimated at 565,347 kg/ year. The majority of this load appeared to originate in WC-3 and WC-5 with smaller loads coming from the upper reaches of the watershed, WC-2 and WC-4.

Total Solids

Total solids are the sum of all dissolved and suspended as well as organic and inorganic materials. Dissolved solids are typically found in higher concentrations in groundwater. Wolf Creek samples were typically in excess of 90% to 95% dissolved solids in composition. Table 12 lists all of the total solids concentrations found in Wolf Creek.

Table 12. Total Solids Concentrations (mg/L) for Wolf Creek

		WC-2	WC-3	WC-4	WC-5	WC-6
06/07/1999	NIELSEN/KRUGER		744		965	
06/29/1999	NIELSEN/KRUGER					490
08/30/1993	Moering				707	412
04/06/1994	Moering	315				
04/19/1994	Moering	413		184	319	176
04/26/1994	Moering	435	409	214	369	857
06/20/1994	Moering				771	
07/18/1994	Moering	312		148	253	272
Mean		369	577	182	564	441

Subwatersheds WC-3 and WC-5 appeared to have similar concentrations of total solids. Dissolved species such as calcium carbonate affect the total solids concentration and alkalinity. These two subwatersheds appeared to have similar loads in both alkalinity and total solids. The similarities between these two watersheds suggested a localized difference in the geology that is affecting these subwatersheds.

The outlet to Lake Louise produced a slightly lower mean than the inlet to the lake. This could be the effect of dilution from water with low solids concentrations entering Wolf Creek from the area immediately surrounding Lake Louise. More likely, it is the result of Lake Louise acting as a sink for total solids, accumulating them in its sediments and aquatic macrophytes.

A total solids load was not calculated for the inlet to Lake Louise. This was due to a lack of accurate samples with corresponding discharge measurement. A number of the samples collected were the direct result of an overflowing well. Dissolved solids and total solids concentrations in this water were several magnitudes higher than what were found in other samples collected from this site.

The state standard for dissolved solids is 4,375 mg/L in a single sample or 2,500 mg/L as a geometric mean. The samples that were heavily impacted by the flowing well water had dissolved concentrations that approached, but did not exceed, this standard. Samples collected from runoff that was unaffected by the well water had concentrations that always fell under 1,000 mg/L and were often lower then 500 mg/L.

Suspended Solids

Total suspended solids concentrations in Wolf Creek were lower than would be expected in prairie streams with drainages of comparable size. This is a direct result of the topography and land use. Land slopes in the drainage area are often less then 1%. These low slopes maintain lower water velocities that carry less sediment. While there is some cropping that occurs in the watershed, a vast majority of the land is range and pastureland. As Wolf Creek passes through many of these pastures it is diverted and blocked by stock watering dams. These small impoundments act as settling basins for the suspended solids that the creek is carrying.

Subwatersheds WC-2, WC-5 and WC-6 appeared to be the most impaired for suspended solids concentrations in the Wolf Creek drainage. Each of these subwatersheds had mean concentrations of over 20 mg/L.

Table 13. Suspended Solids Concentrations (mg/L) for Wolf Creek

		WC-1	WC-2	WC-3	WC-4	WC-5	WC-6
06/07/1999	NIELSEN/KRUGER	12		9		4	25
06/29/1999	NIELSEN/KRUGER						14
03/18/1986	USGS					15	
03/31/1986	USGS					23	
08/30/1993	Moering					22	3
04/06/1994	Moering		5				
04/19/1994	Moering		48		8	104	9
04/26/1994	Moering		48	13	8	10	62
06/20/1994	Moering					6	
07/18/1994	Moering		6		3	6	10
Mean		12	27	11	6	24	21

The mean concentration at the inlet to Lake Louise was 23.75 mg/L. The corrected mean concentration from FLUX was 55.6 mg/L. This translated into an average annual load of 50,415 kg (55.6 tons) of sediment moving through the Wolf Creek drainage. This was an average of .239 kg/ acre for the entire watershed.

A comparison between the inlet and outlet to Lake Louise indicated strong similarities in the concentrations. Suspended solids concentrations would normally be expected to drop after passing through an impoundment such as this, however Lake Louise is a long, very narrow water body, which helps maintain water velocities. Consequently, these increased velocities do not allow suspended solids to settle out and the lake discharges nearly the same volume of sediment that enters it. This may be the reason why there is such a small amount of sediment that has accumulated in the basin of the lake.

Nitrogen

Nitrogen is analyzed in four forms: nitrate/ nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these four forms, total, organic, and inorganic nitrogen may be calculated. Nitrogen compounds are major cellular components of organisms. Because its availability may be less than the biological demand, environmental sources may limit productivity in freshwater ecosystems. Nitrogen is difficult to manage because it is highly soluble and very mobile in water.

Sample data collected from Wolf Creek indicated that ammonia and nitrate concentrations were very low to undetectable for a majority of the samples. TKN (the sum of organic nitrogen and ammonia) may be considered a measure of organic nitrogen for samples collected in Wolf Creek due to the near absence of ammonia from most of the samples.

Table 14. Subwatershed Total Nitrogen Concentrations (mg/L) for Wolf Creek

Date	Sampler	WC-1	WC-2	WC-3	WC-4	WC-5	WC-6
06/07/1999	NIELSEN/KRUGER	2.680		1.900		1.710	1.640
06/29/1999	NIELSEN/KRUGER						1.770
08/30/1993	Moering					2.060	1.310
04/06/1994	Moering		1.230		1.150	1.100	1.250
04/19/1994	Moering		1.170		1.010	1.310	1.080
04/26/1994	Moering		2.080	1.830	1.120	1.030	1.550
06/20/1994	Moering					1.630	
07/18/1994	Moering		1.940		1.430	1.670	2.220
	Mean	2.680	1.605	1.865	1.178	1.501	1.546

The FLUX model indicated that the total nitrogen concentration to Lake Louise was 1.36 mg/L. This is only slightly larger then the estimated 1.298 mg/L of organic nitrogen. The inorganic concentration is estimated at .065 mg/L. The annual loads for these three forms of nitrogen are listed in Table 8.

The inlet and outlet to Lake Louise had very similar sample mean concentrations. Mean values were 1.501 and 1.546 mg/L for the inlet and outlet respectively. Since virtually all of the nitrogen entering Lake Louise from Wolf Creek is in the form of unavailable organic nitrogen, it should not be readily consumed. This is reinforced by the similar concentrations discharging from the lake. The near absence of inorganic forms of nitrogen in collected samples does not mean they do not occur in the stream. A more likely explanation is that inorganic nitrogen is quickly consumed by plant life in and along the stream, as it becomes available.

None of the samples collected in the upper reaches of the watershed had significant amounts of inorganic nitrogen (ammonia and nitrate/nitrite). The state standard for nitrates on Wolf Creek is 50 mg/L (mean) or a maximum concentration of 88 mg/L. The highest concentration collected was 2.68 mg/L at site WC-1 on June 7, 1999. No subwatershed appears to be contributing excessive concentrations of nitrogen to Lake Louise.

The similar concentrations found at all of the sites indicated that sites WC-3 and WC-5 were likely contributing the greatest loading per unit area since they discharged the greatest hydrologic load per unit area.

Phosphorus

Phosphorus is one of the macronutrients required for primary production. In comparison to carbon, nitrogen, and oxygen, it is the least abundant in natural systems (Wetzel, 2000). Phosphorus loading to lakes can be of an internal or external nature. External loading refers to surface runoff, dust, and precipitation. Internal loading refers to the transfer of phosphorus from the bottom sediments to the water column of the lake. Total phosphorus is the sum of all attached and dissolved phosphorus in the lake. The attached phosphorus is directly related to the amount of total suspended solids present. An increase in the amount of suspended solids increases the fraction of attached phosphorus.

Total dissolved phosphorus is the unattached portion of the total phosphorus load. It is found in solution, but readily adsorbs to soil particles when they are present. Total dissolved phosphorus, including soluble reactive phosphorus, is more readily available to plant life.

Table 15. Total Phosphorus Concentrations in Wolf Creek (mg/L)

Date	Sampler	WC-1	WC-2	WC-3	WC-4	WC-5	WC-6
06/07/1999	NIELSEN/KRUGER	0.518		0.331		0.462	0.403
06/29/1999	NIELSEN/KRUGER						0.560
03/18/1986	USGS					0.680	
03/31/1986	USGS					0.670	
08/30/1993	Moering					1.262	0.830
04/06/1994	Moering		0.146		0.446	0.393	0.509
04/19/1994	Moering		0.380		0.733	0.829	0.470
04/26/1994	Moering		0.513	0.523	0.676	0.693	1.070
06/20/1994	Moering					1.220	
07/18/1994	Moering		1.550		1.080	1.120	0.574
	Mean	0.518	0.647	0.427	0.734	0.814	0.631

Due to the small number of samples collected during the 1999 to 2000 sampling season, data from USGS as well as an earlier project completed in 1993 to 1994 was utilized. The FLUX estimated load at the inlet to the lake was 2,129 kg/ year with a corrected mean concentration of .671 mg/L for total phosphorus.

Sample data for dissolved phosphorus concentrations was insufficient to compare subwatersheds. Dissolved phosphorus concentrations were consistently between 75% and 85% of the total phosphorus concentration for all of the sites. Subwatershed WC-5 had the highest percentage of dissolved phosphorus at an average of 91%. The outlet to the lake, WC-6, also had a relatively high percentage at 87%. The remainder of the subwatersheds were slightly lower, at the previously stated 75% to 85%.

The total dissolved portion of the phosphorus load was estimated by FLUX to be 1,482 kg per year with a corrected mean concentration of .464 mg/L. The 70% dissolved load creates some disagreement with the 91% dissolved average observed in the mean sample concentration. The reason for this is due to the mean concentrations during high rates of flow. The FLUX load is weighted for higher flows. During these high flows suspended solids concentrations are higher which reduces the percentage of dissolved phosphorus. Since most of the loading to the lake occurs under high flow conditions, the percentage of dissolved phosphorus is weighted to the lower end.

Tributary Site Summary

Wolf Creek nutrient loading to Lake Louise occurs almost exclusively (greater than 95%) during spring snowmelt and rainstorm events. Flows that occur during the summer and fall are small and infrequent in nature. No violations of state standards were ever detected in any of the samples. Fecal coliform, alkalinity, solids, and nitrogen loads were all relatively small when considering the size of the watershed. Inorganic or available nitrogen was consistently lower than detection limits and almost entirely absent from any of the samples. Phosphorus concentrations were extremely high in all of the subwatersheds.

Subwatershed WC-5 was the most impaired of the subwatersheds. It exhibited the highest concentrations for fecal coliform and total phosphorus. A majority of the 2.3 tons of phosphorus that enters the lake on an annual basis originates from this subwatershed. It had the second highest concentrations of alkalinity, total solids, and suspended solids. In addition to producing some of the highest average concentrations of measured parameters, this subwatershed contributed over 60% of the hydrologic load to Lake Louise.

Although subwatershed WC-3 had limited sample data, concentrations of alkalinity and total solids were consistently higher than samples collected from other tributary sites on the same sample dates.

The subwatershed immediately surrounding Lake Louise (WC-6) had similar and often lower concentrations of sediments and nutrients than was found in the rest of the watershed. This is most likely due to accumulation and consumption that is occurring in the lake.

The remainder of the watershed (WC-1, WC-2, and WC-4) had lower concentrations of nutrients, sediments, and did not produce a large enough annual discharge to contribute significant loads to the lake.

Surface Water Chemistry (Lake Louise)

Inlake Sampling Schedule

Sampling began in June, 1999, and was conducted on a monthly basis until the project completion in April, 2000, at the two pre-selected sites. Water samples were filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD. The laboratory then analyzed the following parameters:

Fecal Coliform Bacteria
Total Solids
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus
Alkalinity
Total Dissolved Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Total Volatile Suspended Solids

Personnel conducting the sampling at each of the sites recorded visual observations of the following weather and lake characteristics.

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

Parameters measured in the field by sampling personnel were:

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

South Dakota Water Quality Standards

Every water body within the state of South Dakota has a set of beneficial uses assigned to it. All waters are assigned the use of fish and wildlife propagation, recreation and stock watering. Along with each of these uses are sets of water quality standards that must not be exceeded in order to maintain these uses. Lake Louise has been assigned the beneficial uses of:

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

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

Table 16. State Beneficial Use Standards for Lake Louise

Parameters	mg/L (except where noted)	Beneficial Use Requiring this Standard
Alkalinity *($CaCO_3$)*	<750 *(mean)* <1,313 *(single sample)*	Wildlife Propagation and Stock Watering
Coliform, fecal *(per 100 mL)* May 1 to Sept 30	<200 *(mean)* <400 *(single sample)*	Immersion Recreation
Conductivity *(umhos/cm@25 C)*	<4,000 *(mean)* <7,000 *(single sample)*	Wildlife Propagation and Stock Watering
Nitrogen, unionized ammonia as N	<.04 *(mean)* <1.75 times the applicable limit *(single sample)*	Warmwater Semi-permanent Fish Propagation
Nitrogen, nitrates as N	<50 *(mean)* <88 *(single sample)*	Wildlife Propagation and Stock Watering
Oxygen, dissolved	>5.0	Immersion and Limited Contact recreation
pH *(standard units)*	6.0 - 9.0	Warmwater Semi-permanent Fish Propagation
Solids, suspended	<90 *(mean)* <158 *(single sample)*	Warmwater Semi-permanent Fish Propagation
Solids, total dissolved	<2,500 *(mean)* <4,375 *(single sample)*	Wildlife Propagation and Stock Watering
Temperature	<32.22 C	Warmwater Semi-permanent Fish Propagation

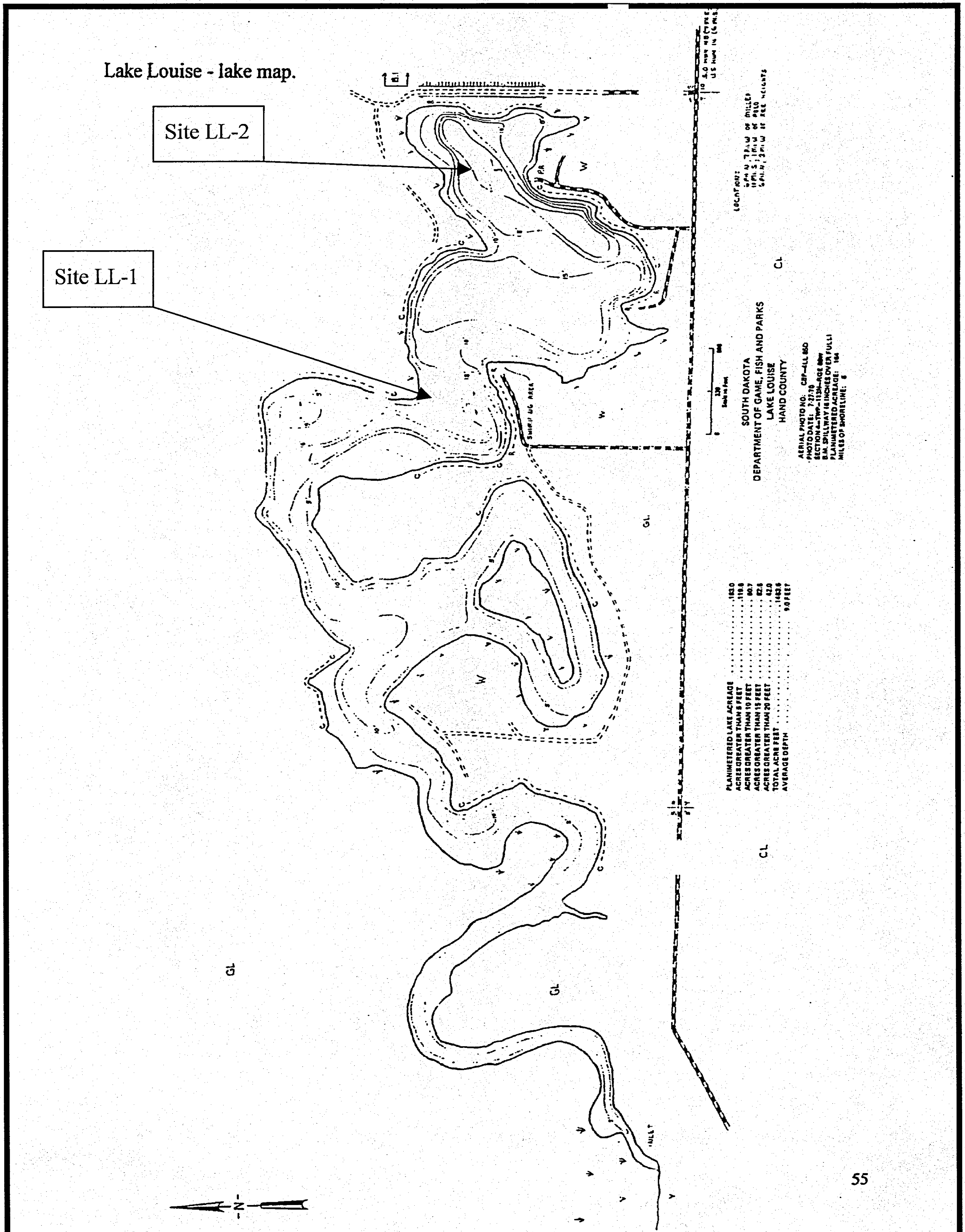


Figure 5. Inlake Sampling Locations for Lake Louise

Inlake Water Quality Parameters

Water Temperature

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

The water temperature in Lake Louise exhibited little variation from site LL-1 to site LL-2. Temperatures showed seasonal variations that are consistent with its geographic location, steadily increasing in the spring and summer and consistently decreasing in the fall and winter. It can be reasonably expected that during most years the inlake temperatures would be within a few degrees of the project data at their respective dates.

The lowest water temperatures were recorded in December, 1999; this was the only sample that was taken while the lake was completely covered in ice. During January and February of 2000, a large portion of the lake, located between the two sample sites, remained open. This may have allowed for some increase in water temperature. The peak annual temperatures were reached during August at 24.5^0 C, which is well below the state standards that require it to maintain a maximum temperature under 32.2^o C.

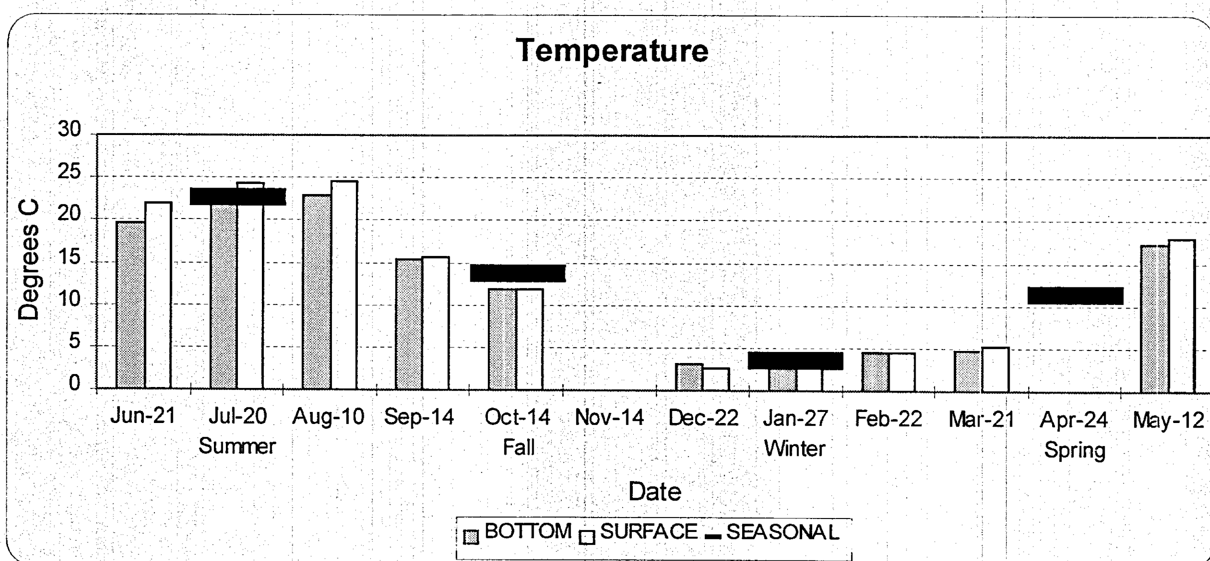


Figure 6. Seasonal and Monthly Temperatures for Lake Louise

Dissolved Oxygen

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

Oxygen levels in Lake Louise were sufficient to maintain the minimum requirement for the local managed fishery. The lowest levels were recorded during the summer months with the exception of August, 1999. The extremely high levels recorded during August, 1999, coincide with a surface blue-green algae bloom that occurred in the lake. It is very likely that high levels of photosynthesis raised the level of oxygen in the upper water layer of the lake (Figure 7). September, 1999, exhibited a dramatic drop in the oxygen concentration. This may be due to the bacterial consumption of the large amounts of plant material, including a collapsed algal bloom, that were present during August, 1999, and presumably died and were undergoing decomposition.

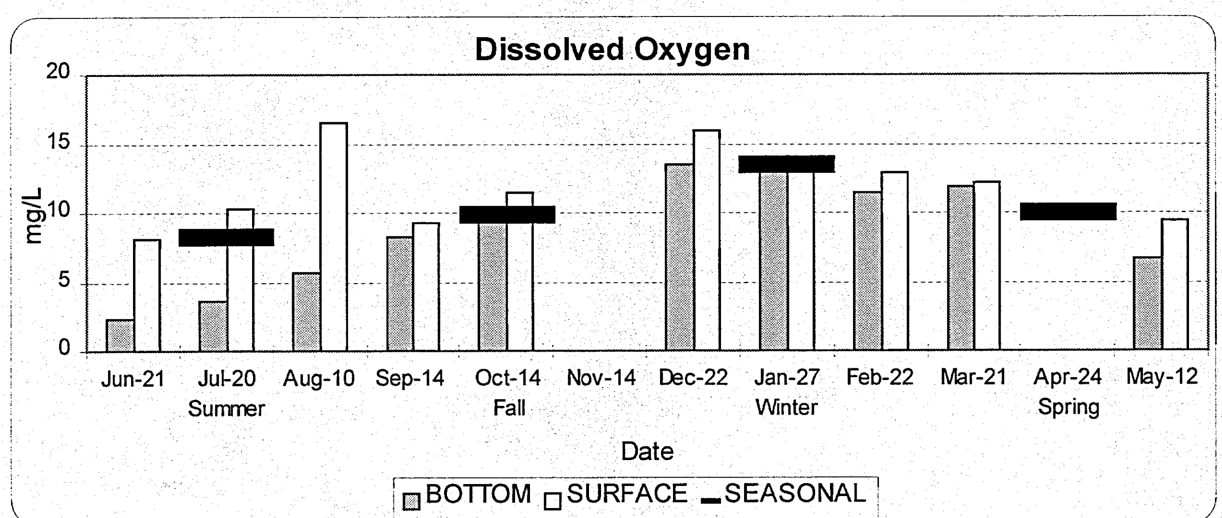


Figure 7. Seasonal and Monthly Dissolved Oxygen Concentrations for Lake Louise

Dissolved Oxygen and Temperature Profiles

Dissolved oxygen and temperature profiles were recorded at one meter intervals in the water column at each of the sites when chemical data was collected. No significant stratification occurred at site LL-1. Stratification had already occurred to some extent when the first profile was recorded at site LL-2 on July 7, 1999. Thermal and oxygen stratification are the most evident in the August, 1999, sample. The September, 1999, profile indicated that mixing in the water column had occurred resulting in no defined stratification of any type. Oxygen depletion in the hypolimnetic zone of a lake may result in anaerobic conditions favoring the release of phosphorus into the water column. This appears to have occurred in Lake Louise during the summer of 1999. Dry conditions resulted in no surface discharge to the lake, however the inlake phosphorus concentrations rose dramatically during July and August. Since each of these months had zones of oxygen depletion, it is likely that internal loading was the mechanism through which the phosphorus entered the water column.

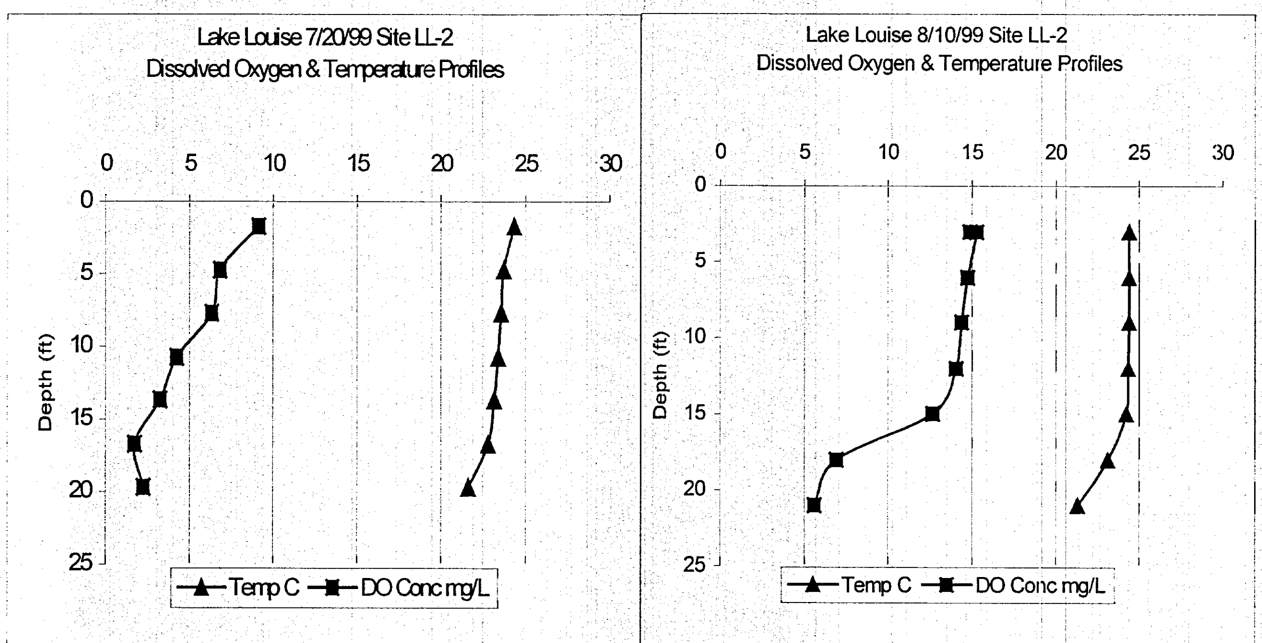


Figure 8. Dissolved Oxygen and Temperature Profiles for Lake Louise

pH

pH is a measure of free hydrogen ions (H+) or potential hydrogen. More simply, it indicates the balance between acids and bases in water. It is measured on a logarithmic scale between 0 and 14 and is recorded as standard units (su). At neutral (pH of 7) acid ions (H+) equal the base ions (OH-). Values less than 7 are considered acidic (more H+ ions) and greater than 7 are basic (more OH- ions). Algal and macrophyte photosynthesis act to increase a lake's pH. The decomposition of organic matter will reduce the pH. The extent to which this occurs is affected by the lakes ability to buffer against changes in pH. The presence of a high alkalinity (>200 mg/L) represents considerable buffering capacity and will reduce the effects of both photosynthesis and decay in producing large fluctuations in pH.

pH values exhibited only small differences between sites LL-1 and LL-2. The greatest differences were produced in August and September of 1999. Considering that these samples also had significant differences in chlorophyll *a* concentrations, the pH shifts may be attributed to this. State standards require that the pH of Lake Louise fall between the values of 6 and 9. The single highest pH recorded of 8.89 was taken during an algae bloom in August, 1999. The lowest pH of 6.96 was taken through the ice in January, 2000. Both of these values fall within the limits set forth by the State of South Dakota. Seasonal pH variations tended to follow the concentrations of the chlorophyll *a* samples. It is possible that during periods of extreme algal blooms (such as in August) that the pH of the lake may temporarily exceed the value of 9.00. This would be expected to occur infrequently and for short durations.

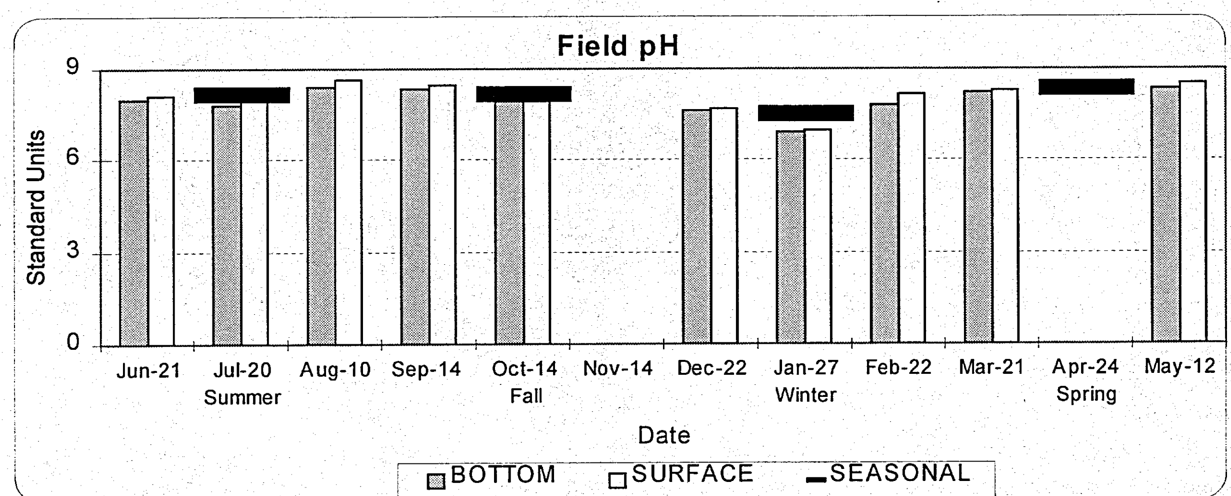


Figure 9. Seasonal and Monthly pH Values for Lake Louise

Conductivity

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

Surface conductivity remained relatively constant during the summer and the fall. The sample collected at site LL-2 in December, 1999, had the lowest conductivity reading recorded at 510 umhos/cm. Samples collected in May of 2000 had the highest conductivity when compared with all of the samples collected, reaching almost 900 umhos/cm. State standards for fish and wildlife propagation require that conductivity does not exceed 4,000 for a 30-day average or 7,000 on any single day. Readings at Lake Louise were consistently within the state standards.

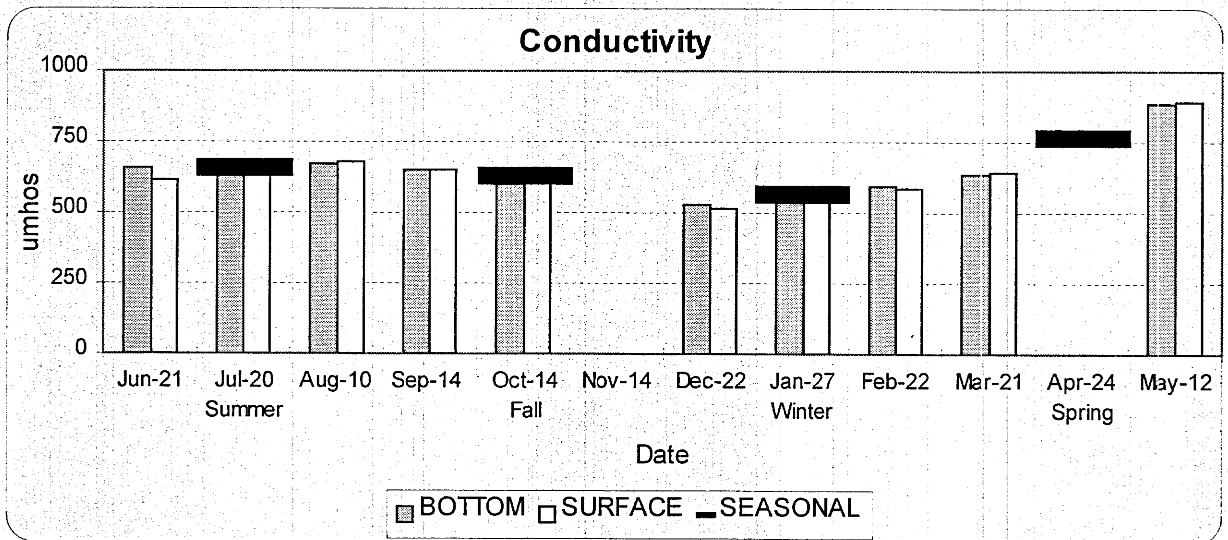


Figure 10. Seasonal and Monthly Conductivity Readings for Lake Louise

Turbidity/ Chlorophyll *a*/ Secchi Depth

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

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

Chlorophyll *a* is the primary photosynthetic pigment found in oxygen producing organisms (Wetzel, 1982). Chlorophyll *a* is a good indicator of a lakes productivity as well as its state of eutrophication. Chlorophyll *a* is also used in the development of lake TSI values.

Lake Louise turbidity is significantly affected by the chlorophyll *a* concentrations. Turbidity is often associated with suspended solids in the water column, however suspended solids in Lake Louise are low most of the year. This is due to the lake's shape, long and narrow with a number of sharp turns, which limits the amount of wind that the lake is exposed to. Suspended solids loads from Wolf Creek were also found to be low reducing their effects in the spring. Figure 11 indicates the significance of chlorophyll *a* and ultimately algal populations on the clarity of Lake Louise.

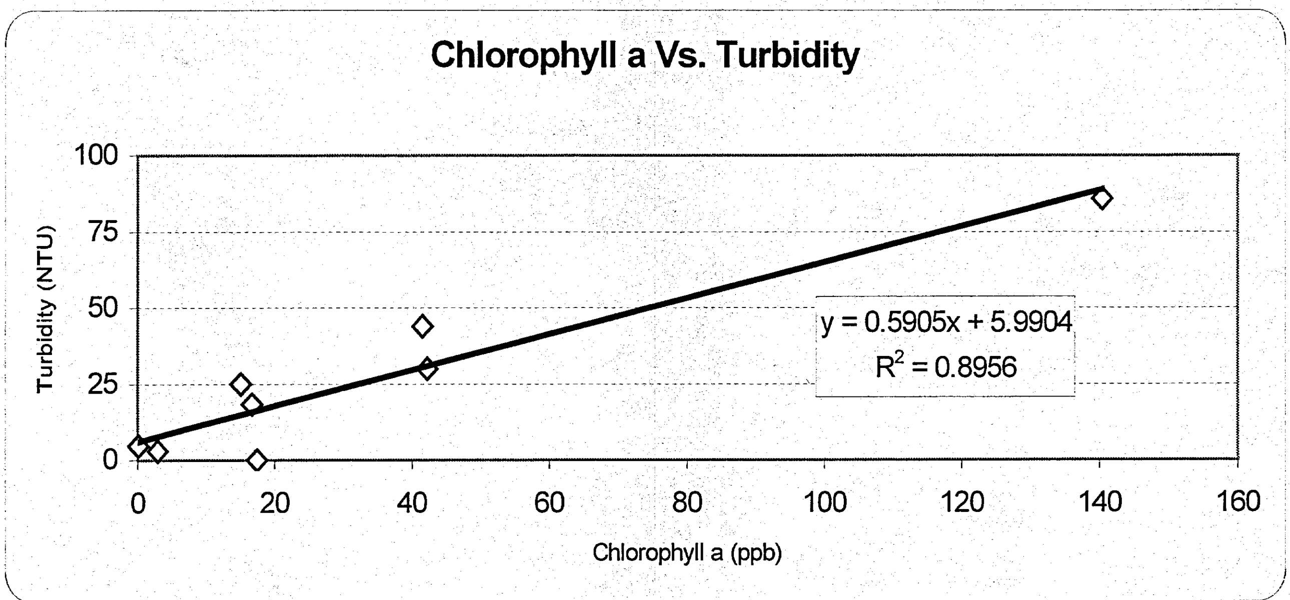


Figure 11. Chlorophyll *a* and Turbidity Correlation's for Lake Louise

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

Secchi depth is used for the development of lake TSI values. In the case of Lake Louise, suspended solids were not a major contributor due to the consistently low concentrations. Chlorophyll *a* significantly affected the turbidity of the lake, but did not have the same impact on the Secchi readings. This is most likely a result of the colored humic substances in the water. Humic substances are chemical compounds released during plant decay. They most likely originate from the grassy areas and organic waste found in the watershed. Recent research has provided evidence that the humic substances released from grasses under aerobic conditions (particularly barley straw) limit the growth of algae in water bodies. This process may be affecting Lake Louise. As water passes through the decaying grasses in the watershed it collects these humic substances that not only stain the water but also limit the algae growth in the lake.

Even with the influence of humic substances, the Secchi readings in Lake Louise were always found to be in excess of 1 meter with the exception of August 1999 when they dropped to 0.6 meter. The average Secchi reading was found to be 1.76 meters with winter samples producing the highest readings. This is due to ice cover limiting algal productivity as well as allowing any suspended solids in the water column to settle out. The mean Secchi reading for most of the growing season (June 1999 through October 1999) was 1.19m.

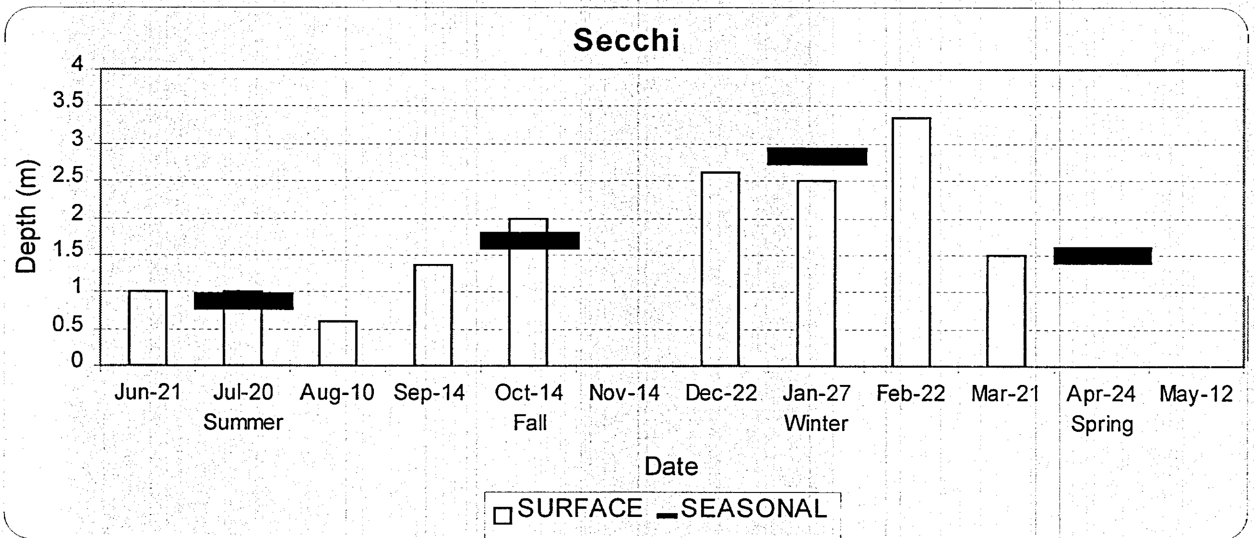


Figure 12. Seasonal and Monthly Secchi Depths for Lake Louise

<u>Alkalinity</u>

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

The alkalinity in Lake Louise varied from a low of 134 mg/L in June of 1999 to a peak value of over 180 mg/L during January and February of 2000. The increase during the winter months may be attributed to the lack of photosynthesis occurring during those months. During the spring and summer, photosynthesis carried on by algae and macrophytes utilized a portion of the alkalinity. The ice cover and cold temperatures reduced this action during the winter months allowing decomposition on the lake bottom to release more carbonates.

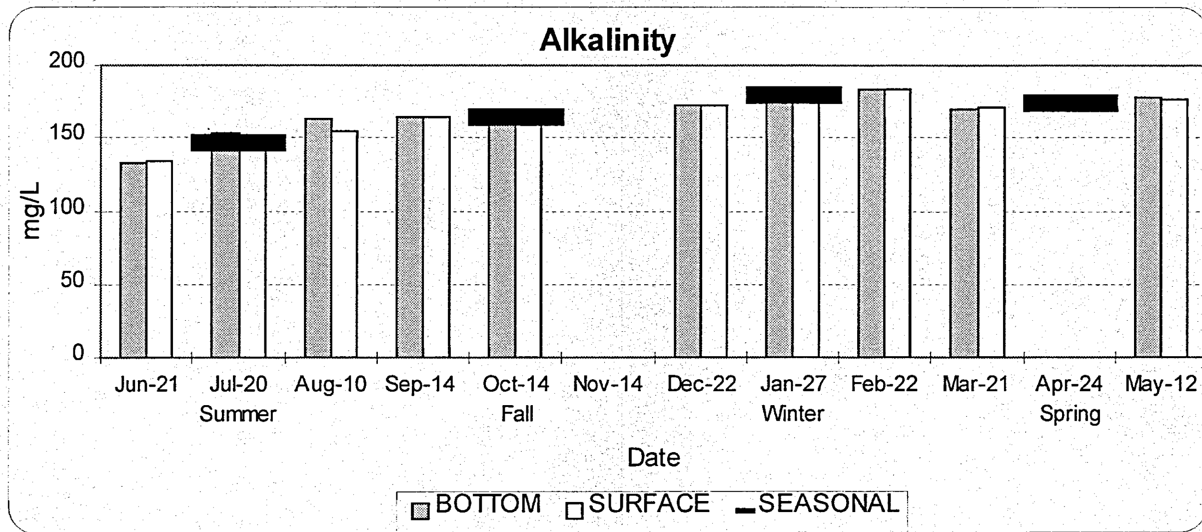


Figure 13. Seasonal and Monthly Alkalinity Concentrations for Lake Louise

Solids

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

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

Lake Louise exhibited very little variation in total solids and dissolved solids concentrations through the course of the year. Peak values were observed during periods of ice cover in January and February of 2000. The lowest values were observed during the early summer samples collected in June of 1999.

Suspended solids concentrations in Lake Louise remained fairly low throughout the course of the year. The lowest concentrations were recorded during ice cover when the effects of wind and wave action had been reduced and algae volumes were at their lowest. Volatile suspended solids followed the same trend as the total suspended solids with increased concentrations during the summer and decreased concentrations during the winter. Most samples were composed of 50% or less organic matter.

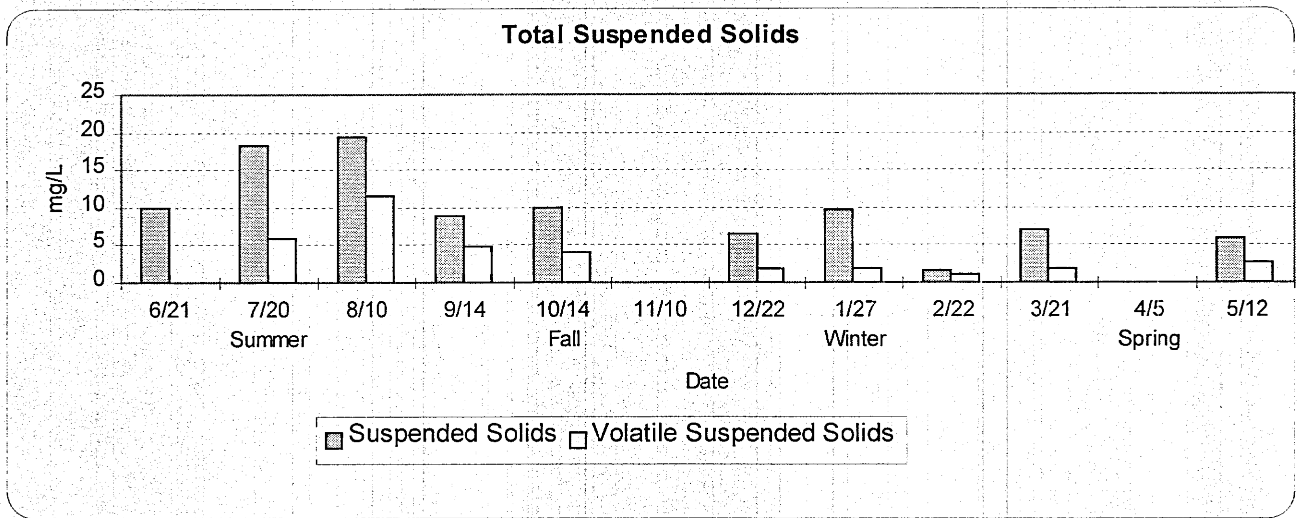


Figure 14. Total Suspended and Volatile Solids Concentrations for Lake Louise

Nitrogen

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

At no time during the project were nitrates/nitrites recorded at or above the detection limit. Ammonia levels were recorded at the detection limit four times, and above the limit twice, in the bottom samples of site WC-2 (deepest site) during periods of anoxic conditions. Ammonia and nitrate/ nitrite are the most readily available forms of nitrogen for plant growth. Lake Louise has an extremely dense population of aquatic macrophytes in its shallow areas. These plants, along with algae, consume almost all of the nitrates and ammonia as fast as they become available. The sum of ammonia and the organic nitrogen present in the water body is measured as TKN. For Lake Louise, it may be assumed that the TKN essentially represents the organic nitrogen in the lake.

Total nitrogen in Lake Louise reached its highest concentrations during the summer months with the peak monthly level being recorded during August of 1999. The single highest sample was collected from the surface at site LL-2 during August of 1999 that had a concentration of 2.5 mg/L. The lowest mean concentrations of total nitrogen were recorded during late winter and early spring. The smallest individual sample concentration was collected on the surface at site LL-1 in May of 2000.

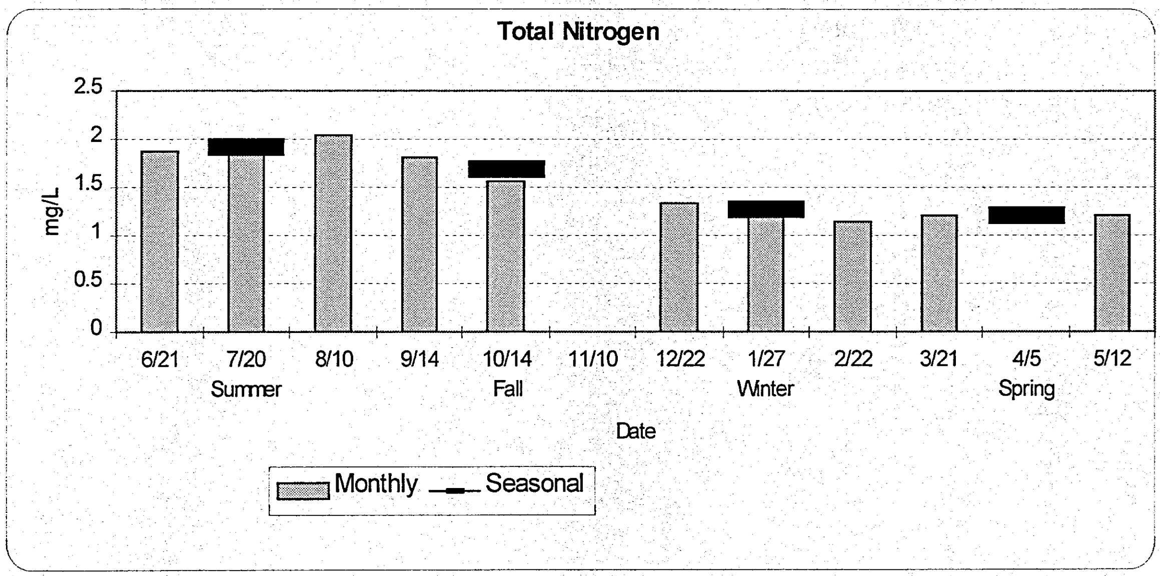


Figure 15. Inlake Total Nitrogen for Lake Louise

Surface and bottom samples had similar concentrations for samples collected on the same day. There was also very little difference in mean concentrations between sites LL-1 and LL-2.

Total Phosphorus

Phosphorus is one of the macronutrients required for primary production. When compared with carbon, nitrogen, and oxygen, it is the least abundant (Wetzel, 2000). Phosphorus loading to lakes can be of an internal or external nature. External loading refers to surface runoff over land, dust, and precipitation. Internal loading refers to the release of phosphorus from the bottom sediments to the water column of the lake. Total phosphorus is the sum of all attached and dissolved phosphorus in the lake. The attached phosphorus is directly related to the amount of total suspended solids present. An increase in the amount of suspended solids increases the fraction of attached phosphorus.

The average in-lake total phosphorus during the assessment was 0.549 mg/L. Algae requires only 0.02 mg/L of dissolved phosphorus to start growing, so Lake Louise averages 27 times the minimal requirements for algal growth. In spite of this over-abundance of phosphorus, algal blooms are not the primary water quality problem in Lake Louise at this time.

Total phosphorus concentrations were greatest in the summer and fall. Winter and spring concentrations were significantly lower and similar in average concentration at approximately 0.2 mg/L. Surface and bottom samples had nearly identical concentrations each month. The one exception to this was the sample collected in July of 1999. The surface sample was significantly smaller than the bottom sample. One possible explanation is that stratification of the lake had created anoxic conditions favorable to the rapid release of phosphorus into the water column. Under aerobic conditions, the exchange equilibria are largely unidirectional toward the sediments. Under anaerobic conditions, inorganic exchange at the sediment-water interface is strongly influenced by redox conditions (Wetzel, 1983). This exchange favors the release of phosphorus from the sediment.

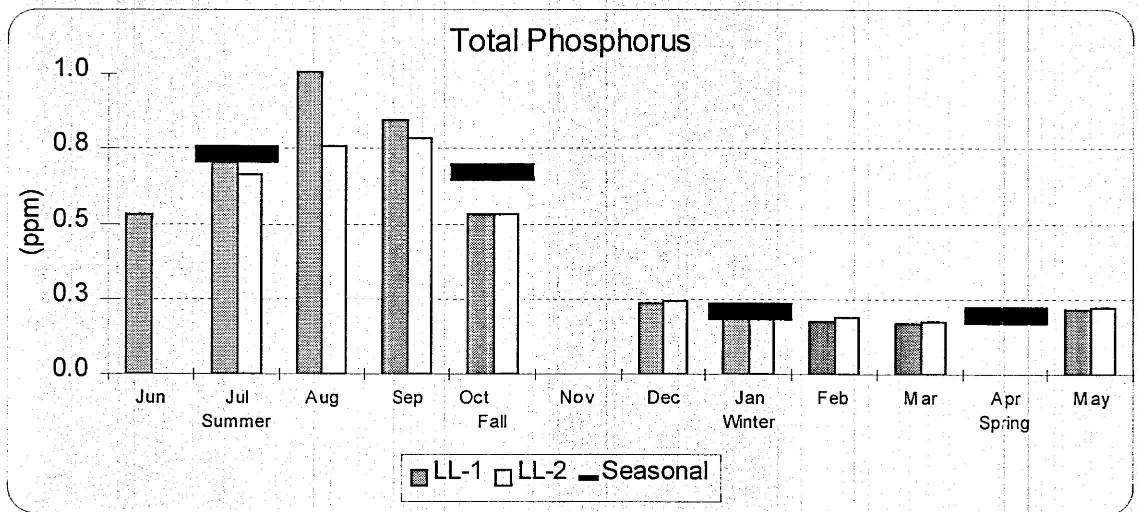


Figure 16. Seasonal and Monthly Total Phosphorus Concentrations for Lake Louise

It appears that during the summer of 1999 these processes occurred in Lake Louise. The loss of oxygen in the spring resulted in the release of phosphorus observed from June through July 1999. After phosphorus concentrations reached their annual peak in August and September 1999 the bottom sediments began to reattach to the phosphorus. This can was observed in the October samples when the bottom samples had considerably lower total phosphorus concentrations than during summer. During the winter months the well-oxygenated water at the sediment interface did not allow for the release of phosphorus into the water column.

The significant drop in phosphorus in the water column was the result of a combination of things. As ice forms, inorganic solids settle out of the water column and some of the phosphorus with them. In much the same way, algae die off and sink to the bottom, removing additional phosphorus. The final method of phosphorus removal is the oxygenation of the water at the sediment interface. As stated earlier, this favors the exchange of phosphorus in the direction of the sediment. Oxygenation of the water column may reduce the intensity of the phosphorus peaks that the lake exhibits during the summer months.

Dissolved Phosphorus

Total dissolved phosphorus is the unattached portion of the total phosphorus load. It is found in solution, but readily binds to soil particles when they are present. Total dissolved phosphorus, including soluble reactive phosphorus, is more readily available to plant life.

Dissolved phosphorus concentrations closely resembled total phosphorus concentrations in Lake Louise. Most surface and bottom samples had very little variation. The exceptions to this are seen in July and August of 1999. These months had the highest total phosphorus concentrations that were observed during the sampling season and had the greatest difference in surface and bottom dissolved concentrations. This corresponds with a mid to late summer algae bloom. The algae most likely tied up large amounts of the dissolved phosphorus.

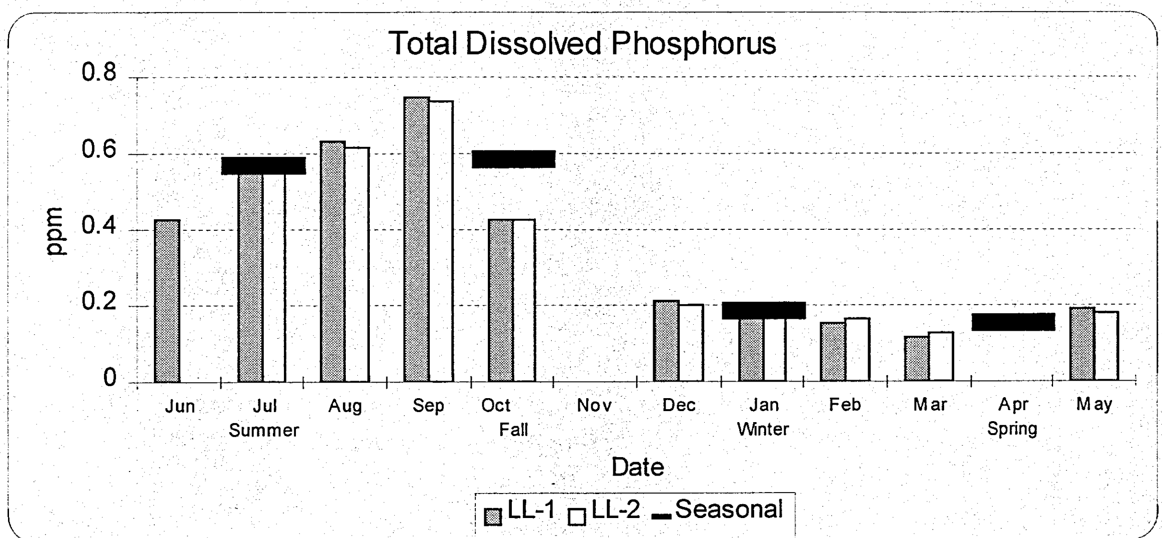


Figure 17. Seasonal and Monthly Dissolved Phosphorus Concentrations for Lake Louise

August samples also exhibited the greatest variation in percentage of dissolved phosphorus between the surface and bottom samples. The bottom sample consisted almost entirely of dissolved phosphorus while the surface sample was only 70% dissolved, one of the lowest percentages of dissolved phosphorus measured. This was probably the result of the blue-green algae bloom that occurred at the same time the August samples were collected. Most samples consisted of 80% to 90% dissolved phosphorus. The dissolved portion varied little from season to season. The greatest differences were observed in August, 1999, and March, 2000. March, 2000, surface and bottom samples were nearly identical and both contained approximately 70% dissolved phosphorus.

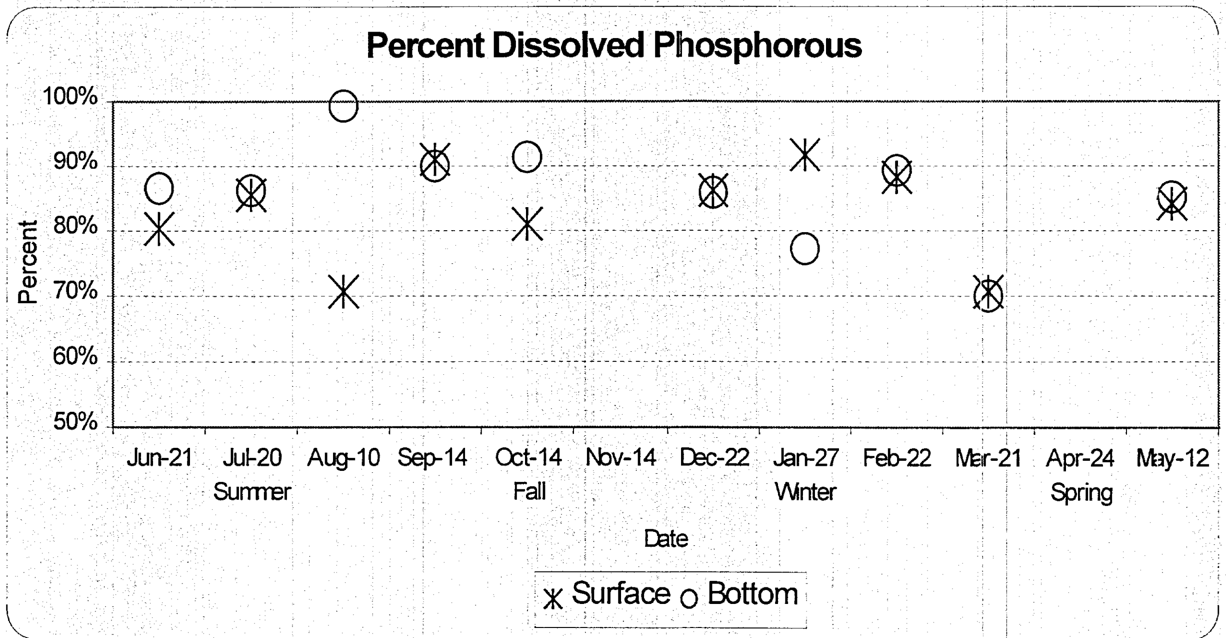


Figure 18. Monthly Dissolved Phosphorus Percentages for Lake Louise

Fecal Coliform Bacteria

Lake Louise is listed for the beneficial use of immersion recreation which requires that no single sample exceed 400 colonies/100mL or the 30 day geometric mean (consisting of at least 5 samples) be no more then 200 colonies /100mL. No exceedences of the state standards were observed during the project. Samples collected and analyzed by the State Health Lab for fecal coliform were consistently below the detection limit of 10 colonies per 100 mL. The only samples collected that indicated the presence of fecal coliform were collected on October 14, 1999. Samples collected at each of the sites produced concentrations of 20 colonies per 100 mL on this date.

Of the over 100 samples collected at the beach from 1992 through 2000, only two during 1996 were high enough to warrant beach closure advisories. These samples were collected on July 30 and August 19 of that year and were 2700 colonies/ 100 mL each. These exceedences constitute less than 2 % of all fecal samples which indicates that this is not a recurring problem and that the beneficial uses to the lake are affected only minimally.

Limiting Nutrients

Two primary nutrients are required for cellular growth in organisms, phosphorus and nitrogen. Nitrogen is difficult to limit in aquatic environments due to its highly soluble nature. Phosphorus is easier to control, making it the primary nutrient targeted for reduction when attempting to control lake eutrophication. The ideal ratio of nitrogen to phosphorus for aquatic plant growth is 10:1 (EPA, 1990). Ratios higher than 10 indicate a phosphorus-limited system. Those that are less than 10:1 represent nitrogen-limited systems.

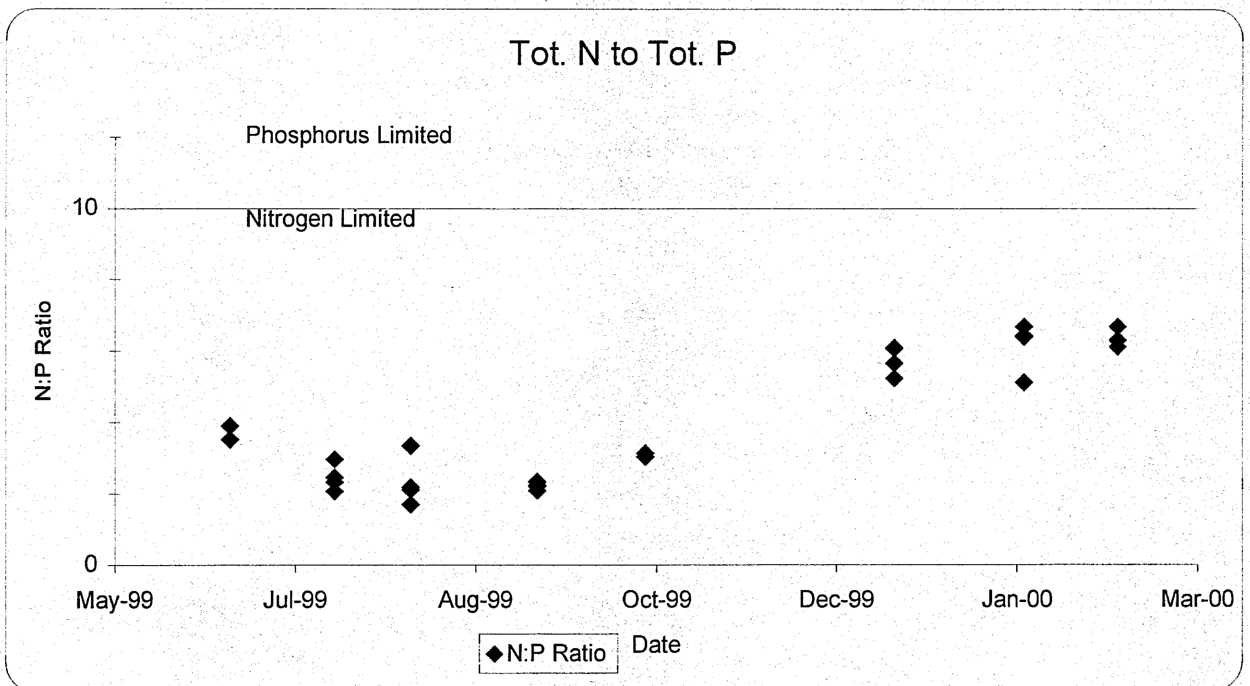


Figure 19. Limiting Nutrients for Lake Louise

The average nitrogen to phosphorus ratio for Lake Louise was 4.5:1. Surface and bottom samples had nearly identical ratios to the lakes overall average. The greatest difference was seen between summer and winter ratios. Summer samples dropped to 2.7 parts of nitrogen to each part of phosphorus, which is heavily nitrogen limited. Winter samples climbed to 6.1:1. Both phosphorus and nitrogen concentrations decreased during the winter months. Phosphorus concentrations dropped to 20% of the summer concentration while nitrogen concentrations dropped to 60% of their mean summer concentrations. An important fact to note is that the nitrogen concentrations are typical of most central South Dakota lakes, the super abundance of phosphorus is the primary cause of the lakes nitrogen limitation.

During the winter the lake was still nitrogen limited, however it was significantly closer to a phosphorus limited system. Oxygenation of the water column during the summer should move the ratio closer to phosphorus limited.

Trophic State

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

Lakes with TSI values less than 35 are generally considered to be oligotrophic and contain very small amounts of nutrients, little plant life, and are generally very clear. Lakes that obtain a score of 35 to 50 are considered to be mesotrophic and have more nutrients and primary production than oligotrophic lakes. Eutrophic lakes have a score between 50 and 65 and are subject to algal blooms and have large amounts of primary production. Hyper-eutrophic lakes receive scores greater than 65 and are subject to frequent and massive blooms of algae that severely impair their beneficial use and aesthetic beauty.

Table 17. Trophic State Ranges

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

Lake Louise is located in the Northern Glaciated Plains (a Level III ecoregion). As determined in "Ecoregion Targeting for Impaired Lakes in South Dakota" (Stueven et al., 2000) reservoirs in this region should have a mean TSI value of 65.0 or less to fully support their beneficial uses. Partial support of these uses is reached at TSI values between 65.0 and 75.0. Lakes that do not support these uses had TSI values greater than 75.0. Lake Louise is listed as non-supporting in the report with a mean TSI value slightly greater than 80.

During the study the average trophic state for Lake Louise during 1999 and 2000 was 64.4, placing it within the eutrophic lake category. This varied from a seasonal low of 49.6 during the winter of 2000 to a maximum of 76.4 during the summer of 1999.

TSI values are normally compared for only the growing season. The mean TSI during the growing season (summer and fall 1999, spring 2000) increased to 70.6. The variation during this time span ranged from 64.3 during the spring of 2000 to 76.3 during the summer of 1999. The mean growing season Trophic State Index (TSI) values for Lake Louise during the assessment period were 92.3 (hypereutrophic) for phosphorus, 56.5 (eutrophic) for Secchi disk measurements, and 63.0 (hypereutrophic) for chlorophyll *a*.

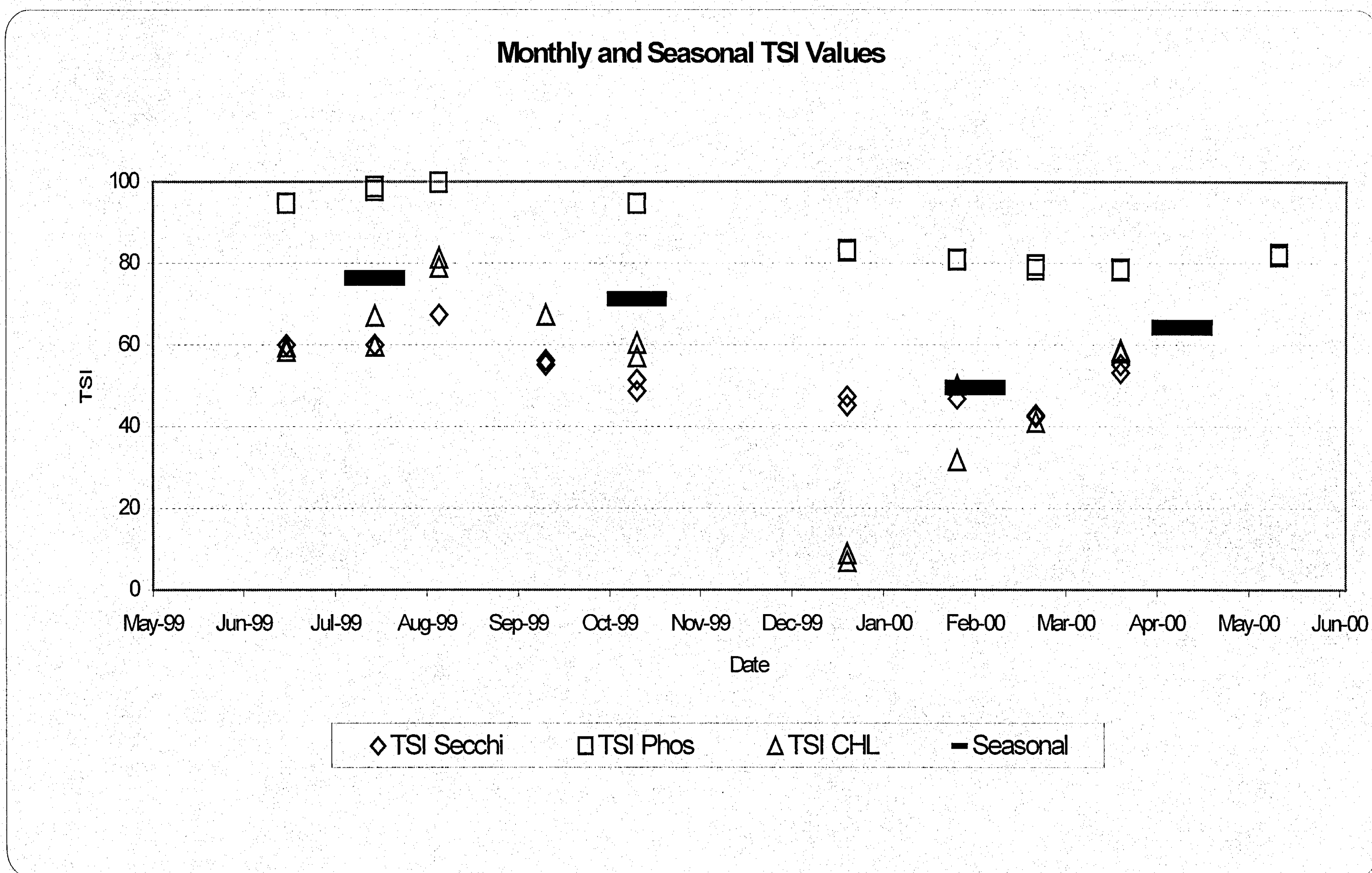


Figure 20. Monthly and Seasonal TSI Values for Lake Louise

Reduction Response Modeling

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

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

BATHTUB not only predicts the inlake concentrations of nutrients; it also produces a number of diagnostic variables that help to explain the lake responses. Table 18 shows the response to reductions in the phosphorus load. The observed and predicted water quality is listed in the first two columns. The observed and predicted trophic states are 72.6 and 72.8 respectively, less than 1% difference between them.

The variables (N-150)/P and INORGANIC N/P are both indicators of phosphorus and nitrogen limitation. The first, (N-150)/P, is a ratio of total nitrogen to total phosphorus. Values less than 10 are indicators of a nitrogen-limited system. The second variable, INORGANIC N/P, is an inorganic nitrogen to ortho-phophorus ratio. Values less than 7 are nitrogen-limited. The current state of Lake Louise is nitrogen-limited. Phosphorus limitation would only be possible through 90% or greater reduction in the total phosphorus load from the watershed.

The variables FREQ (CHL-a)% represent the predicted algal nuisance frequencies or bloom frequencies. Blooms are often associated with concentrations of 30 to 40ppb of total phosphorus. These frequencies are the percentage of days during the growing season that algal concentrations may be expected to exceed the respective values. Very little change is observed with reductions of less than 90% reductions in the phosphorus load to the lake.

TSI responses to the reductions in phosphorus load to the lake exhibited substantial variation. The TSI phosphorus value showed consistent positive responses to the reductions. The chlorophyll *a* and Secchi responses were much less significant. Each showed very little response to the reductions until they reached 90% or greater. The limited responses are a result of the limited nitrogen supply and excessive phosphorus concentrations. The model predicted a mean TSI value reduction to less than 70 with aeration and less than 65 with aeration and a reduction in phosphorus loading of 51% or greater.

Responses to reductions may be enhanced through aeration of the water column during the growing season. This may inhibit the release of phosphorus from bottom sediments, maintaining concentrations similar to those observed during the winter months. This, in combination with reductions in phosphorus loads, may further reduce TSI values for chlorophyll *a* and Secchi depth.

Table 18. BATHTUB Calculations for Lake Louise

		Aerated	Aerated	Aerated	Aerated	Aerated	Aerated	Aerated	Aerated	Aerated
Phosphorus Reduction on Wolf Creek-->		0%	10%	20%	30%	50%	70%	90%	95%	99%
VARIABLE	Present Condition	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED
TOTAL P MG/M3	620.37	436.45	393.37	350.93	308.49	223.61	138.72	53.84	32.3	15.65
TOTAL N MG/M3	1549.29	1244.56	1244.56	1244.56	1244.56	1244.56	1244.56	1244.56	1244.56	1244.56
CHL-A MG/M3	56.24	41.17	40.92	40.59	40.12	38.4	33.78	18.15	10.73	4.58
SECCHI M	1.68	2.25	2.27	2.28	2.31	2.4	2.7	4.68	7.18	12.85
ORGANIC N MG/M3	1445.38	1101.65	1096.03	1088.48	1077.87	1038.65	933.17	576.82	407.67	267.53
ANTILOG PC-1	1575.46	904.84	895.29	882.53	864.77	800.5	639.02	219.86	92.73	25.4
ANTILOG PC-2	28.07	27.79	27.79	27.78	27.77	27.72	27.58	26.69	25.56	22.64
(N - 150) / P	2.26	2.51	2.78	3.12	3.55	4.9	7.89	20.33	33.88	69.96
INORGANIC N / P	0.2	0.39	0.46	0.56	0.7	1.31	3.85	28.13	54.31	100.82
FREQ(CHL-a>10) %	99.33	97.57	97.52	97.44	97.33	96.86	95.09	74.26	42.21	5.84
FREQ(CHL-a>20) %	91.27	80.36	80.09	79.72	79.19	77.11	70.38	32.03	9.43	0.36
FREQ(CHL-a>30) %	75.92	57.95	57.57	57.06	56.33	53.53	45.27	13.12	2.45	0.04
FREQ(CHL-a>40) %	59.48	39.6	39.23	38.72	38.01	35.35	28	5.65	0.75	0.01
FREQ(CHL-a>50) %	45.21	26.64	26.33	25.9	25.3	23.1	17.29	2.59	0.26	0
FREQ(CHL-a>60) %	33.93	17.94	17.69	17.35	16.88	15.16	10.81	1.26	0.1	0
CARLSON TSI-P	96.88	91.8	90.31	88.66	86.8	82.16	75.28	61.63	54.26	43.81
CARLSON TSI-CHLA	70.13	67.07	67.01	66.93	66.82	66.39	65.13	59.04	53.88	45.54
CARLSON TSI-SEC	52.5	48.29	48.21	48.1	47.95	47.36	45.66	37.75	31.6	23.21
Mean TSI	73.2	69.1	68.5	67.9	67.2	65.0	62.0	52.8	46.6	37.5

Table 19. BATHTUB Calculations Legend

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

Long-Term Trends

Lake Louise is listed on the state's 303(d) list as an impaired waterbody with a declining trend in water quality as a result of nutrients, sediment, and algal growth. This is also supported in the 1995 South Dakota Lakes Assessment Final Report. Data from this report is included in Figure 21 together with TSI values collected during the 1999 and 2000 growing seasons. The TSI value of Lake Louise is considerably higher than calculated from the first samples collected in 1979. This trend would appear to be reaching a plateau with a mean TSI value of approximately 75 to 80. These values are too high to fully or partially support the designated beneficial uses for Lake Louise.

Reductions in nutrient and sediment load to the lake may help to reverse this trend. To shift its trophic state to eutrophic, Lake Louise needs a TSI value of 65 or less. This was the condition of the lake in 1979 when the first samples were collected. To reverse a change this large (> 10 TSI Units) is not a good short-term improvement target. Achieving a stable TSI value of less than 75 would restore its beneficial uses and is a more reasonable goal for a water quality improvement project.

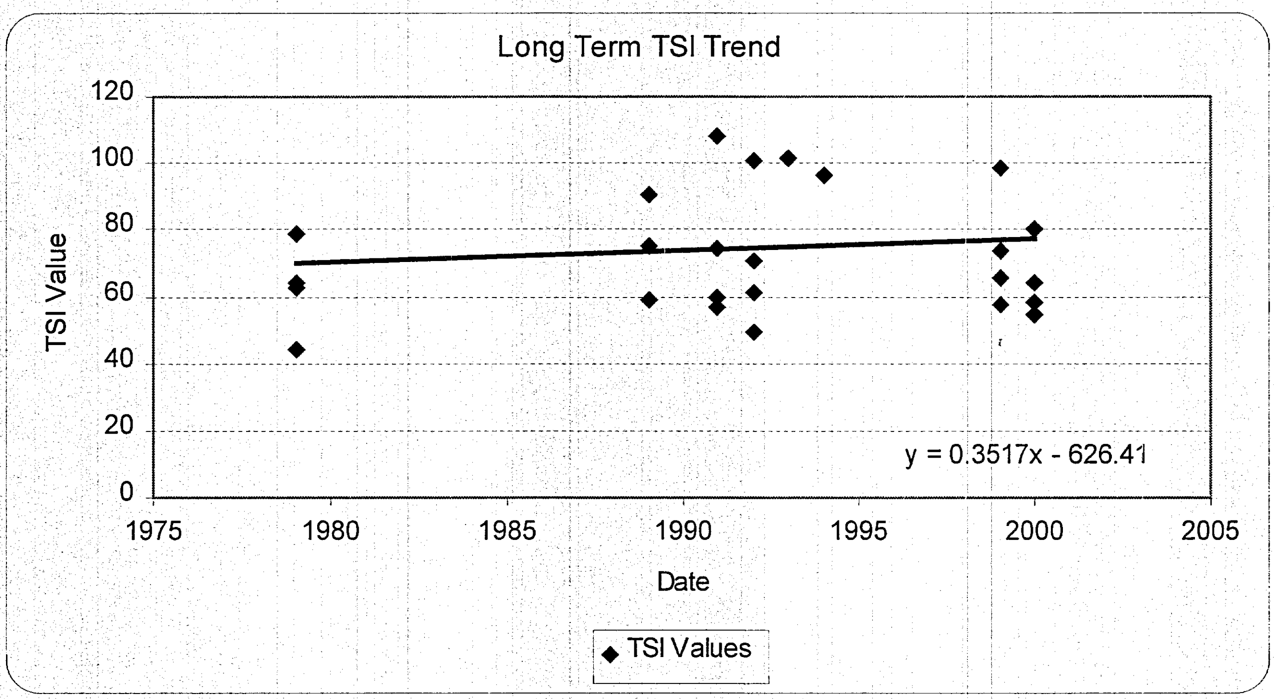


Figure 21. Long Term TSI Trends for Lake Louise

Biological Monitoring

Fishery

The complete fisheries report produced from Lake Louise surveys may be found in Appendix D. The following account is a brief summary of what may be found in that report. Lake Louise may be considered Hand County's best fishery. The combination of excellent facilities and quality fishery helped to contribute to the approximately 10,000 angler hours spent at the lake from May through August of 1997 and 1998.

The fish community in Lake Louise was sampled in 1997 and 1998 using the following methods. Largemouth bass and panfish populations were sampled by electro-fishing. Scale samples were collected from weighed and measured fish to conduct growth analysis. In addition to electro-fishing, passive sampling was conducted with gill and frame nets. Fish collected with the passive methods were also weighed, measured and scale sampled.

Sample analysis indicated a fish community resembling that of a lake managed under the panfish option. Largemouth bass populations were high and composed primarily of age 4 and younger individuals. Bluegill size structure was high. Bluegill also composed the majority of fishes collected during the survey. Yellow perch were also identified as an abundant species in Lake Louise. Black bullhead populations were present in the survey, but did not compose a significant portion of the fish community. The low number of bullheads may be attributed to the high largemouth bass density. Walleye populations were also present, but in very small numbers with only seven individuals collected in 1998.

South Dakota Department of Game Fish and Parks (SDGF&P) recommendations include monitoring of bluegill and largemouth bass populations. Possible bluegill limit restrictions were also suggested. The practice of stocking walleye in Lake Louise needs to be "critically evaluated" as stated by the author of the report. This is primarily due to the small number of walleye caught in the survey as well as the limited angler harvest.

Threatened and Endangered Species

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

Phytoplankton

Surface samples of planktonic algae collected monthly from June to October 1999 and December 1999 to March 2000 at two inlake sites in Lake Louise (Figure 5) consisted of 78 taxa including two unidentified categories (Table 20). Green algae (Chlorophyta) were the most diverse group with 28 taxa (including two motile genera, *Chlamydomonas* sp. and *Pandorina morum)* followed by diatoms (Bacillariophyceae) with 21 taxa. Blue-green algae (Cyanophyta) were less well represented with only 6 taxa. Twenty-three taxa of motile (flagellated) algae made up nearly 30% of total algae identified. Yellow-brown algae (Chrysophyta) consisted of 9 taxa followed by cryptomonads (Cryptophyta) and dinoflagellates (Pyrrhophyta: Dinophyceae) with 5 taxa apiece. The euglenoids (Euglenophyta) and motile green algae (Chlorophyta) represented the least diverse algal groups in Lake Louise with two taxa each.

Table 20. Algae Species List for Lake Louise

Taxa	Algal Type	Taxa	Algal Type
Anabaena circinalis	Blue Green Algae	*Mallomonas sp.*	Flagellated Algae
Anabaena flos-aquae	Blue Green Algae	*Mallomonas tonsurata*	Flagellated Algae
Ankistrodesmus falcatus	Green Algae	*Melosira granulata*	Diatoms
Ankistrodesmus sp.	Green Algae	*Melosira sp.*	Diatoms
Aphanizomenon flos-aquae	Blue Green Algae	*Microcystis aeruginosa*	Blue Green Algae
Asterionella formosa	Diatoms	*Navicula capitata*	Diatoms
Ceratium hirundinella	Dinoflagellates	*Nephrocytium sp.*	Green Algae
Chlamydomonas sp.	Flagellated Algae	*Nitzschia acicularis*	Diatoms
Chlorella sp.	Green Algae	*Nitzschia hungarica*	Diatoms
Chromulina sp.	Flagellated Algae	*Nitzschia sp.*	Diatoms
Chroococcus minimus	Blue Green Algae	*Ochromonas sp.*	Flagellated Algae
Chroomonas sp.	Flagellated Algae	*Oocystis lacustris*	Green Algae
Chrysochromulina sp.	Flagellated Algae	*Oocystis parva*	Green Algae
Chrysosphaerella sp.	Flagellated Algae	*Oocystis pusilla*	Green Algae
Closteriopsis longissima	Green Algae	*Oscillatoria sp.*	Blue Green Algae
Closterium aciculare	Green Algae	*Pandorina morum*	Flagellated Algae
Cocconeis sp.	Diatoms	*Pediastrum duplex*	Green Algae
Coelastrum sp.	Green Algae	*Peridinium cinctum*	Dinoflagellates
Crucigenia crucifera	Green Algae	*Phacus sp.*	Flagellated Algae
Crucigenia quadrata	Green Algae	*Rhodomonas minuta*	Flagellated Algae
Crucigenia tetrapedia	Green Algae	*Scenedesmus bijuga*	Green Algae
Cryptomonas erosa	Flagellated Algae	*Scenedesmus opoliensis*	Green Algae
Cryptomonas ovata	Flagellated Algae	*Scenedesmus quadricauda*	Green Algae
Cryptomonas sp.	Flagellated Algae	*Selenastrum minutum*	Green Algae
Cyclotella meneghiniana	Diatoms	*Sphaerocystis schroeteri*	Green Algae
Cyclotella stelligera	Diatoms	*Staurastrum sp.*	Green Algae
Dictyosphaerium pulchellum	Green Algae	*Stephanodiscus astraea*	Diatoms
Dinobryon sertularia	Flagellated Algae	*Stephanodiscus astraea minutula*	Diatoms
Elakatothrix viridis	Green Algae	*Stephanodiscus hantzschii*	Diatoms
Euglena sp.	Flagellated Algae	*Stephanodiscus niagarae*	Diatoms
Fragilaria capucina v. mesolepta	Diatoms	*Surirella angusta*	Diatoms
Fragilaria construens	Diatoms	*Synedra acus*	Diatoms
Glenodinium gymnodinium	Dinoflagellates	*Synedra cyclopum*	Diatoms
Glenodinium quadridens	Dinoflagellates	*Synedra ulna*	Diatoms
Glenodinium sp.	Dinoflagellates	*Synura uvella*	Flagellated Algae
Gloeocystic gigas	Green Algae	*Tetraedron sp.*	Green Algae
Gloeocystis ampla	Green Algae	*Unidentified algae*	Unidentified algae
Kirchneriella sp.	Green Algae	*Unidentified flagellates*	Flagellated Algae
Mallomonas akrokomos	Flagellated Algae	*Unidentified pennate diatoms*	Diatoms

The seasonal pattern of algal abundance in Lake Louise during this study was characterized by a single high peak in August, 1999, due to a blue-green algae bloom, that was preceded and followed by comparatively small populations in the other months of this survey (Figure 22). This rather unusual algal distribution may have resulted owing to the lack of sampling in April and May which are normally the months of the spring algal maximum in many of the state lakes. Figure 22 shows what may be the start of such a spring algal increase in late March 2000.

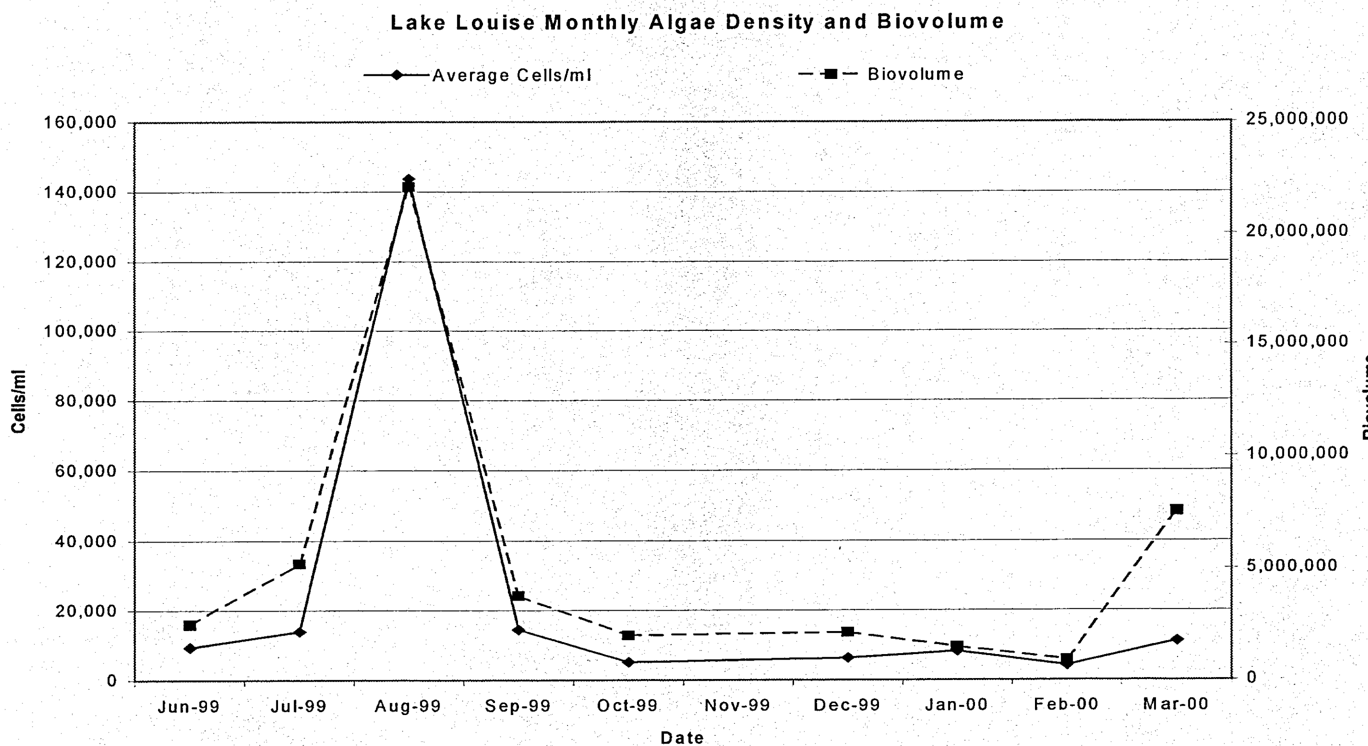


Figure 22. Monthly Algae Density and Biovolume for Lake Louise

Blue-green algae, mainly *Aphanizomenon flos-aquae*, numerically dominated the lake plankton for three months of the survey, from August to October. They were sub-dominant during July 1999 (Figure 23). Blue-green dominance in terms of biovolume was observed only in August when *Aphanizomenon* increased to its annual maximum density. Blue-greens were sub-dominant by volume in September and October 1999 (Figure 24). In late June, diatoms and flagellated algae, primarily *Rhodomonas minuta* (*Chroomonas* sp. Butcher) and *Cryptomonas erosa*, exceeded blue-greens in volume and abundance. By late July, non-motile green algae, mainly *Gloeocystis ampla*, had replaced diatoms and flagellates as the most abundant group in the summer plankton. During the cold months, December 1999 to March 2000, diatoms and flagellated algae were alternately dominant (Figures 23 and 24). Flagellated (motile) algae belonging to several phyla were somewhat more diverse and abundant in Lake Louise than usually encountered in other monitored state lakes. Why this should be so is not evident at this time. Perhaps, it may be due to some pond-like characteristics of the lake, such as the smaller and narrow wind-sheltered basin, greater water clarity (little sediment turbidity), tannins and lignins in the water, extensive macrophyte coverage, and superabundant phosphorus. The seasonal abundance of major flagellated taxa is shown in Appendix E.

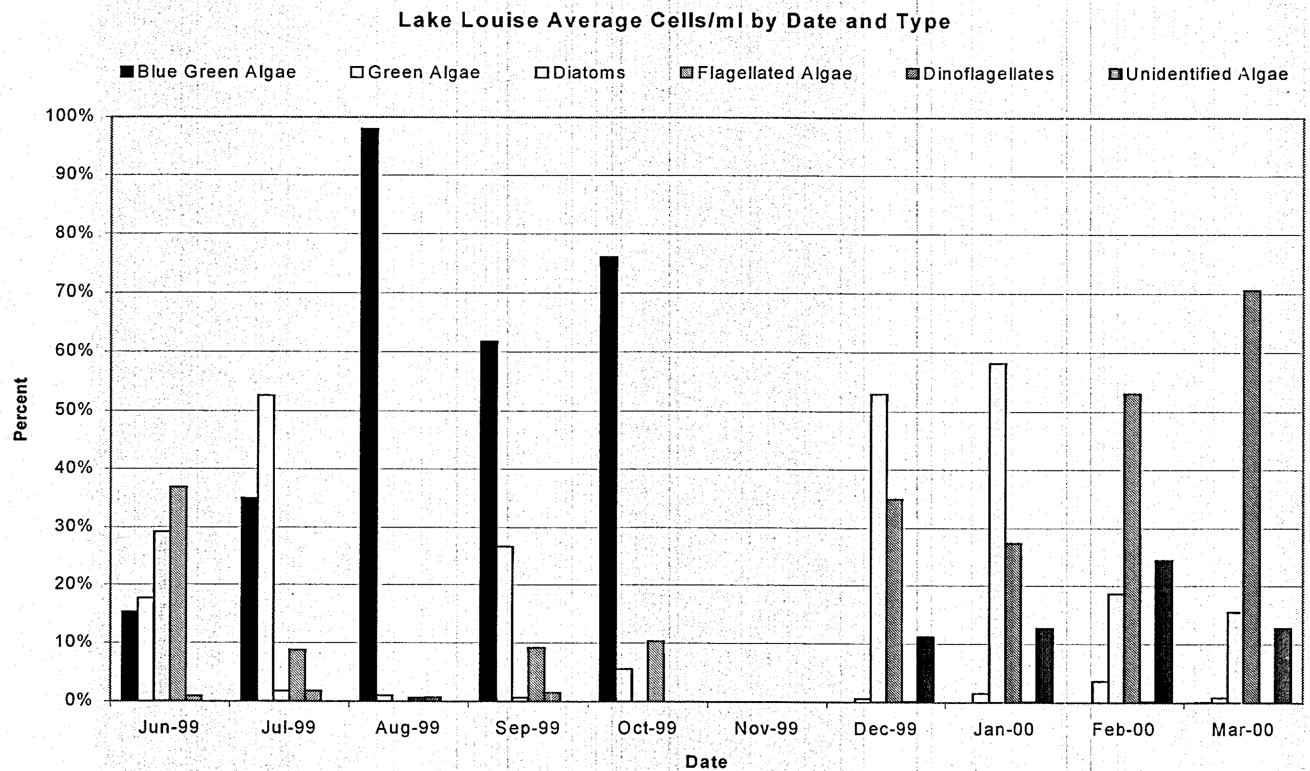


Figure 23. Average Cells/ mL by Date and Type for Lake Louise

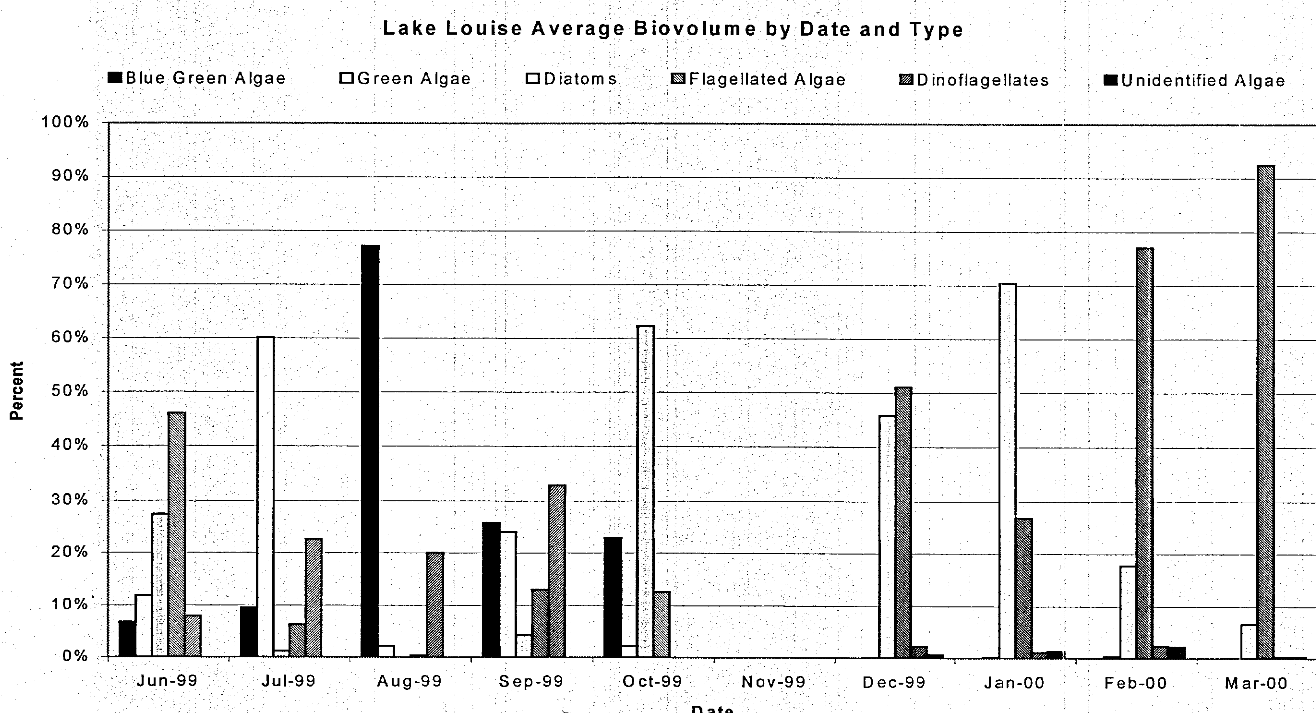


Figure 24. Average Biovolume by Date and Type for Lake Louise

Phytoplankton mean density and biovolume ranged from 4,257 cells/mL and 0.923ul/l (= 923,000 um^3/ mL x 10^{-6}) in February 2000 to 143,801 cells/mL and 22.114 ul/l in August 1999 (Tables 21 and 22). Average monthly density and biovolume for the study period amounted to 24,134 cells/mL and 5.307 ul/l, respectively. Algae density and biovolume was generally similar at the two sites on most sampling dates, with algae populations at site LL-2 being somewhat larger in August and March (Figures 25 and 26). In flow-through reservoirs such as Lake Louise, larger plankton populations would be expected in the lower reaches near the dam (site LL-2) due to accumulation of nutrients, transport of organisms from upstream, and greater in-place production due to longer water retention time (less current). However, there was no inflow detected from Wolf Creek after June 1999. The similarity in the algal populations of sites LL-1 and LL-2 was fairly high from June to October 1999 according to a trophic state index developed by Sweet (1986).

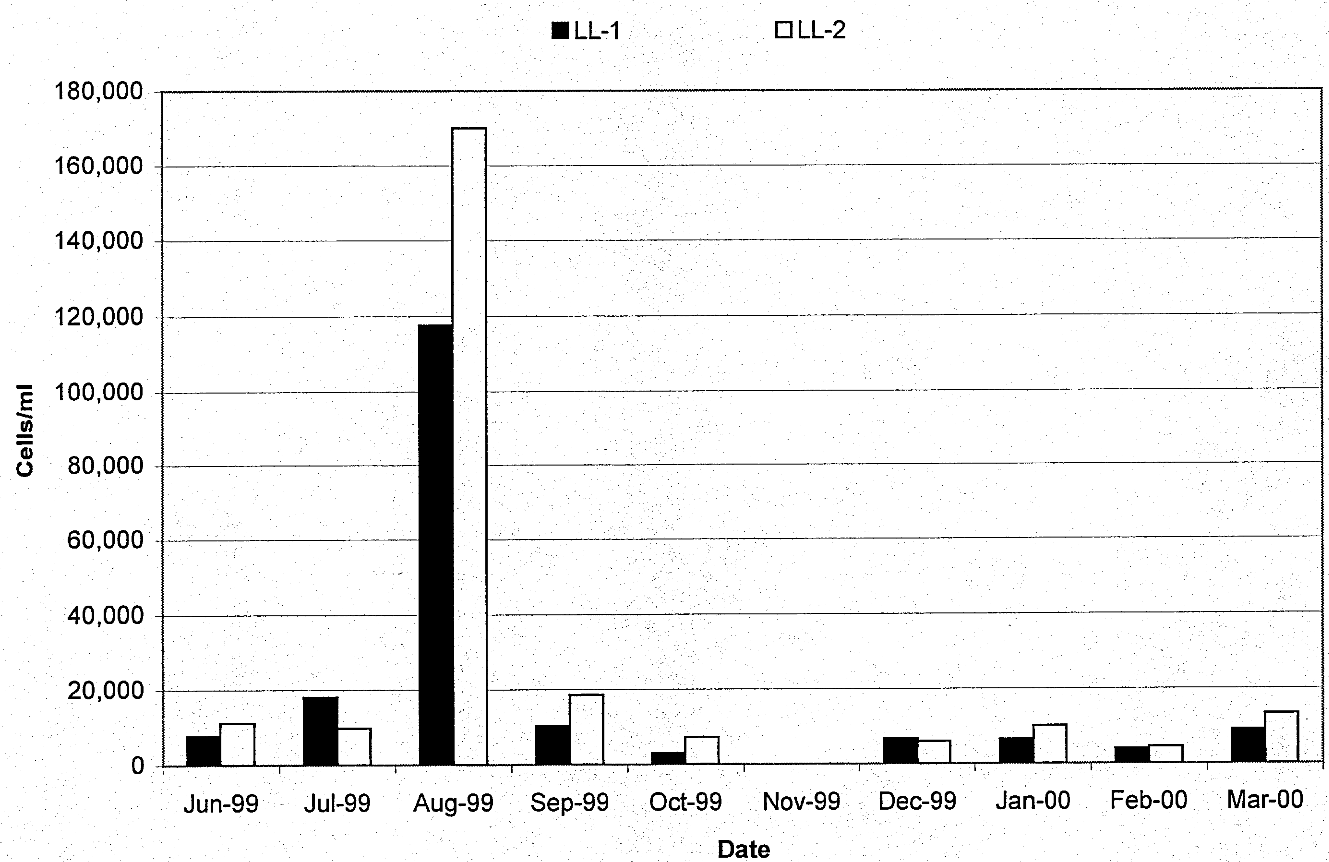


Figure 25. Total Algal Cells/ mL by Date for Lake Louise

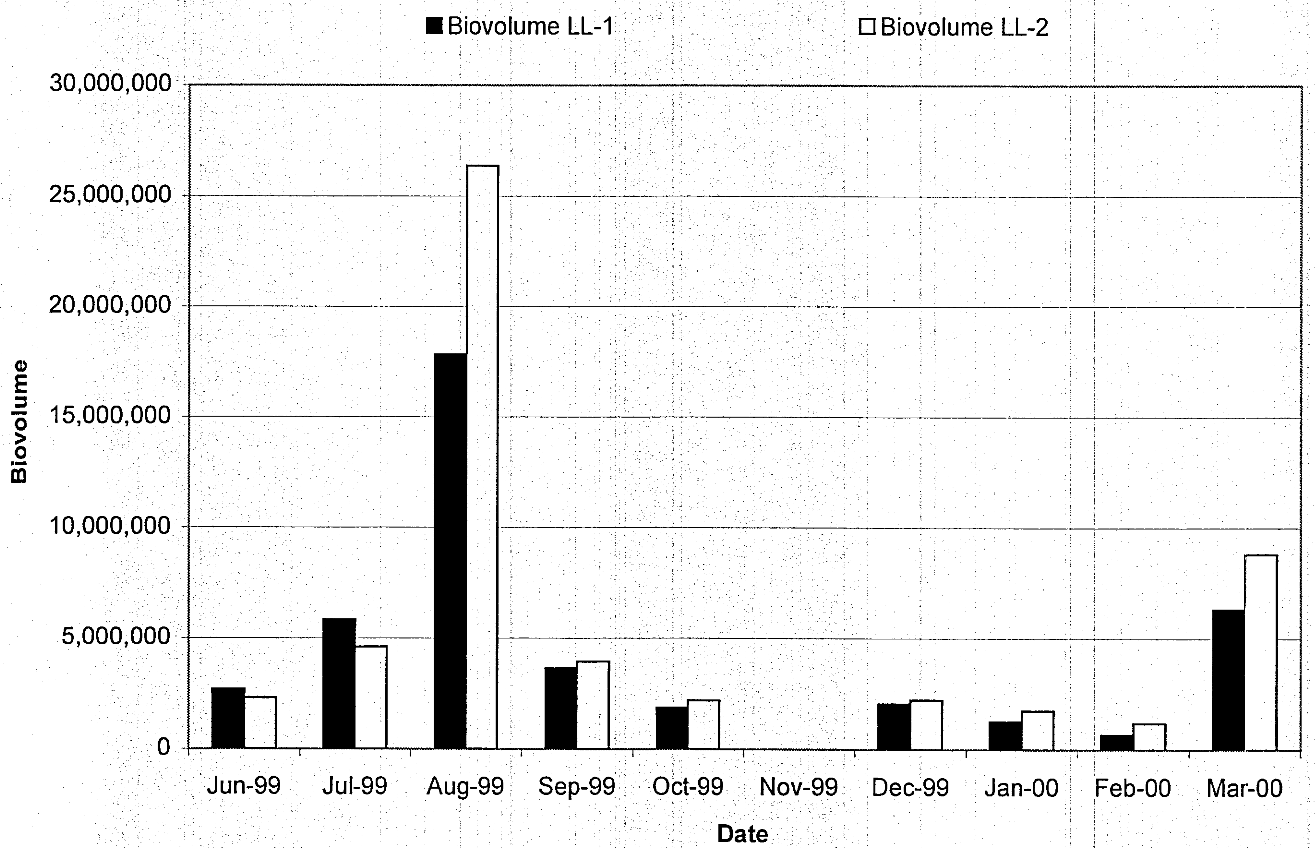


Figure 26. Total Algal Biovolume by Date for Lake Louise

The initial samples of this survey were collected at the beginning of summer on June 21,1999. Sample analysis for the two sites (Figure 5) indicated a mean algae population of 9,490 cells/mL. Thirty-one percent of this total was comprised of a diverse assemblage of flagellated (motile) algae, mainly *Cryptomonas erosa* and *Rhodomonas minuta*. Diatoms, primarily *Asterionella formosa* and *Fragilaria capucina*, made up nearly 27% of total algae. Flagellated algae and diatoms also accounted for nearly 77% of total biovolume in late June (Tables 21 and 22). *Aphanizomenon* was the only blue-green alga collected in June at an average density of 1,454 cells/mL.

Table 21. Algal Abundance (Density) in Cells/mL for Lake Louise

Sum of Cells/mL		Site Number				
Date	Algal Type2	LL-1	LL-2	Grand Total	Avg	Percent
21-Jun-99	Blue Green Algae		2907	2907	1454	15.3%
	Diatoms	1919	3622	5541	2771	29.2%
	Dinoflagellates	80	85	165	83	0.9%
	Flagellated Algae	3638	3374	7012	3506	36.9%
	Green Algae	2160	1195	3355	1678	17.7%
21-Jun-99 Total		7797	11183	18980	9490	
20-Jul-99	Blue Green Algae	7538	2250	9788	4894	35.0%
	Diatoms	508		508	254	1.8%
	Dinoflagellates	203	303	506	253	1.8%
	Flagellated Algae	1067	1389	2456	1228	8.8%
	Green Algae	8807	5894	14701	7351	52.6%
20-Jul-99 Total		18123	9836	27959	13980	
10-Aug-99	Blue Green Algae	114946	166776	281722	140861	98.0%
	Dinoflagellates	752	1366	2118	1059	0.7%
	Flagellated Algae	517	205	722	361	0.3%
	Green Algae	1400	1640	3040	1520	1.1%
10-Aug-99 Total		117615	169987	287602	143801	
14-Sep-99	Blue Green Algae	4845	13109	17954	8977	61.8%
	Diatoms	132	81	213	107	0.7%
	Dinoflagellates	211	239	450	225	1.5%
	Flagellated Algae	1633	1036	2669	1335	9.2%
	Green Algae	3676	4085	7761	3881	26.7%
14-Sep-99 Total		10497	18550	29047	14524	
14-Oct-99	Blue Green Algae	1683	6239	7922	3961	76.2%
	Diatoms	428	404	832	416	8.0%
	Flagellated Algae	725	348	1073	537	10.3%
	Green Algae	214	362	576	288	5.5%
14-Oct-99 Total		3050	7353	10403	5202	
22-Dec-99	Diatoms	3722	3070	6792	3396	53.0%
	Dinoflagellates	13	11	24	12	0.2%
	Flagellated Algae	2218	2270	4488	2244	35.0%
	Green Algae	48	34	82	41	0.6%
	Unidentified algae	840	600	1440	720	11.2%
22-Dec-99 Total		6841	5985	12826	6413	
26-Jan-00	Diatoms	3578	6075	9653	4827	58.2%
	Dinoflagellates	14	10	24	12	0.1%
	Flagellated Algae	1981	2565	4546	2273	27.4%
	Green Algae	60	188	248	124	1.5%
	Unidentified algae	900	1210	2110	1055	12.7%
26-Jan-00 Total		6533	10048	16581	8291	
22-Feb-00	Diatoms	792	797	1589	795	18.7%
	Dinoflagellates	6	9	15	8	0.2%
	Flagellated Algae	2127	2393	4520	2260	53.1%
	Green Algae	171	138	309	155	3.6%
	Unidentified algae	880	1200	2080	1040	24.4%
22-Feb-00 Total		3976	4537	8513	4257	
21-Mar-00	Blue Green Algae		13	13	7	0.1%
	Diatoms	1689	1804	3493	1747	15.5%
	Dinoflagellates	12	7	19	10	0.1%
	Flagellated Algae	6440	9460	15900	7950	70.7%
	Green Algae	86	110	196	98	0.9%
	Unidentified algae	870	2010	2880	1440	12.8%
21-Mar-00 Total		9097	13404	22501	11251	
Grand Total		183529	250883	434412		

Table 22. Algal Abundance (Biovolume) um^3/ mL for Lake Louise

Sum of Bio Volume		Site Number				
Date	Algal Type2	LL-1	LL-2	Grand Total	Avg	Percent
21-Jun-99	Blue Green Algae		340119	340119	170060	6.8%
	Diatoms	542420	823935	1366355	683178	27.3%
	Dinoflagellates	336000	59500	395500	197750	7.9%
	Flagellated Algae	1346238	954296	2300534	1150267	46.0%
	Green Algae	460800	132744	593544	296772	11.9%
21-Jun-99 Total		2685458	2310594	4996052	2498026	
20-Jul-99	Blue Green Algae	721987	281213	1003200	501600	9.6%
	Diatoms	129540		129540	64770	1.2%
	Dinoflagellates	245000	176400	421400	210700	4.0%
	Flagellated Algae	1079239	1528002	2607241	1303621	25.0%
	Green Algae	3669075	2612291	6281366	3140683	60.2%
20-Jul-99 Total		5844841	4597906	10442747	5221374	
10-Aug-99	Blue Green Algae	14201262	19964124	34165386	17082693	77.2%
	Dinoflagellates	1579200	2868600	4447800	2223900	10.1%
	Flagellated Algae	1740504	2881540	4622044	2311022	10.5%
	Green Algae	333305	658611	991916	495958	2.2%
10-Aug-99 Total		17854271	26372875	44227146	22113573	
14-Sep-99	Blue Green Algae	566865	1387071	1953936	976968	25.8%
	Diatoms	219563	108702	328265	164133	4.3%
	Dinoflagellates	1183000	1300600	2483600	1241800	32.8%
	Flagellated Algae	575023	411802	986825	493413	13.0%
	Green Algae	1099493	720159	1819652	909826	24.0%
14-Sep-99 Total		3643944	3928334	7572278	3786139	
14-Oct-99	Blue Green Algae	196911	729963	926874	463437	23.0%
	Diatoms	1257518	1254208	2511726	1255863	62.3%
	Flagellated Algae	373431	133720	507151	253576	12.6%
	Green Algae	16504	70814	87318	43659	2.2%
14-Oct-99 Total		1844364	2188705	4033069	2016535	
22-Dec-99	Diatoms	1005080	956360	1961440	980720	45.8%
	Dinoflagellates	49978	46278	96256	48128	2.2%
	Flagellated Algae	980851	1206583	2187434	1093717	51.1%
	Green Algae	1194	3808	5002	2501	0.1%
	Unidentified algae	16800	12000	28800	14400	0.7%
22-Dec-99 Total		2053903	2225029	4278932	2139466	
26-Jan-00	Diatoms	795500	1317780	2113280	1056640	70.4%
	Dinoflagellates	23600	11600	35200	17600	1.2%
	Flagellated Algae	422458	380792	803250	401625	26.8%
	Green Algae	1500	5066	6566	3283	0.2%
	Unidentified algae	18000	24200	42200	21100	1.4%
26-Jan-00 Total		1261058	1739438	3000496	1500248	
22-Feb-00	Diatoms	158440	169520	327960	163980	17.8%
	Dinoflagellates	18000	27000	45000	22500	2.4%
	Flagellated Algae	467790	955162	1422952	711476	77.1%
	Green Algae	5000	3586	8586	4293	0.5%
	Unidentified algae	17600	24000	41600	20800	2.3%
22-Feb-00 Total		666830	1179268	1846098	923049	
21-Mar-00	Blue Green Algae		273	273	137	0.0%
	Diatoms	531670	469580	1001250	500625	6.6%
	Dinoflagellates	31400	21000	52400	26200	0.3%
	Flagellated Algae	5743959	8261238	14005197	7002599	92.5%
	Green Algae	5874	13693	19567	9784	0.1%
	Unidentified algae	17400	40200	57600	28800	0.4%
21-Mar-00 Total		6330303	8805984	15136287	7568144	
Grand Total		42184972	53348133	95533105		

The next samples collected on July 20,1999, indicated a 53% increase in algal density to a mean of 16,130 cells/mL. This increase was due mainly to greater numbers of green algae (Chlorophyta) which comprised nearly 53% of July algal density and 60% of biovolume. The major green alga, *Gloeocystis ampla*, was present as 5,017 cells/mL or 31% of the total algae. Blue-green algae also became more common and diverse in July, *Aphanizomenon*, for example, more than doubled in density to 3,256 cells/mL (Figure 23). Diatoms and flagellated algae declined sharply at the same time. Diatoms decreased from 2,771 cells/mL in June to 254 cells/mL in July and flagellated algae, principally the cryptomonads *Rhodomonas* and *Cryptomonas*, declined less severely from 3,546 cells/mL to 1,460 cells/mL. Both of those latter groups remained at reduced monthly densities until December. Diatoms remained at less than 450 cells/mL and flagellates below 1,510 cells/mL for the rest of the summer. Increases in blue-green algae and a decline in diatoms by late spring are typical for these algal groups. While cryptomonad flagellates are often seen in greater numbers during the cooler months of the year, they appear to have no typical seasonality (Hutchinson 1967).

August samples indicated a 9-fold increase in summer algal densities due mainly to the presence of a substantial bloom of *Aphanizomenon flos-aquae* estimated at a mean density of 90,321 cells/mL. Other common blue-greens in August included *Anabaena circinalis* at 38,624 cells/mL and *Anabaena flos-aquae* 11,916 cells/mL. Those three blue-green species made up 98% of total plankton density and 77% of the biovolume in August 1999. In addition to decreases in diatoms and flagellated algae mentioned in the previous paragraph, green algae, also declined sharply in August to 1,520 cells/mL. from a yearly maximum of 7,351 cells/mL in July. Along with the increase in blue-greens, numbers of the large-sized dinoflagellate *Peridinium cinctum* (probably *Glenodinium gymnodinium*) increased from 232 cells/mL in July to its annual maximum of 530 cells/mL in August when it made up less than 1% of algal density but accounted for 20% of monthly biovolume. In September, mean density of *Peridinium* fell to 225 cells/mL, but this small number comprised nearly 33% of monthly biovolume due to the smaller algae populations in that month. *Peridinium* was not collected during the remainder of the study but other dinoflagellate species, notably *Glenodinium* sp., occurred in trace densities during the winter months (Appendix E).

Mid-September samples indicated a steep decline in blue-green densities and a substantial rise in green algae density and biovolume (Tables 21 and 22). Blue-green mean density (primarily *Aphanizomenon*) fell to 8,977 cells/mL while that of green algae more than doubled from 1,520 cells/mL in August to 3,881 cells/mL in September. While blue-greens still made up nearly 62% of total algae density, in terms of biovolume they were subordinate to dinoflagellates and only slightly higher than green algae (Figures 23 and 24). The predominant green alga was *Scenedesmus quadricauda*, present as 2,030 cells/mL and comprising 52% of the green algae population in September. In succeeding months non-motile green algae declined to an average of 104 cells/mL from December to March.

Decreasing seasonal water temperature in October probably resulted in a further decline of the Lake Louise summer algae population from 14,524 cells/mL in September to 5,202 cells/mL in mid-October. This decrease was due to the seasonal decline in blue-greens, mainly *Aphanizomenon*. Blue-greens are usually abundant only during the warm months of the year (Smith 1950). However, numerically, blue-greens (*Aphanizomenon*) still comprised 76% of the total algae, whereas a small autumnal increase of a large-sized centric diatom *Stephanodiscus niagarae* to 356 cells/mL represented nearly 57% of the algal biovolume but barely 7% of the density in October. This example serves to illustrate how algal density and biovolume can present different views on algal abundance. Both are usually required for a more detailed description of an algae community (Figures 23 and 24).

Interestingly, winter algae numbers in Lake Louise showed significant increases over autumn levels, from 5,202 cells/mL in October to 6,413 cells/mL in December and 8,291 cells/mL in late January before declining to 4,257 cells/mL in late February 2000 (No sampling was conducted in November 1999 due to thin-ice conditions). For the same period, algal biovolume increased moderately from 2.016 ul/l in October to 2.139 ul/l in December and then declined to 1.500 ul/l and 0.923 ul/l in January and February, respectively (Figure 22). A dip in the abundance of the flagellate *Synura uvella* was responsible for the January decline and a collapse of the winter population of *Asterionella formosa* in February contributed to the lower biovolume for that month.

The Lake Louise phytoplankton community during the first half of winter (December and January) was characterized by an increase in flagellated algae over autumn levels and moderate blooms of two species of diatoms, *Asterionella formosa* and *Stephanodiscus hantzschii*, apparently under ice cover. During this period, diatoms can be described as the dominant algal group in terms of density and/or biovolume, even though the biovolume of flagellates was slightly higher in December (Figures 23 and 24). *A. formosa* was present as 2,818 cells/mL in December and 2,809 cells/mL in January. Since *Asterionella* was not collected in October, those densities may be considered to represent a late fall / winter diatom bloom. Moreover, numbers of a small centric diatom, *Stephanodiscus hantzschii*, increased to a winter and yearly maximum of 2,010 cells/mL in late January.

At first sight, the above diatom increases under ice present a puzzling phenomenon, since under ice cover there is typically no water turbulence, and diatoms as well as most other algae, being slightly heavier than water, depend on turbulence to remain suspended in the water column. There is no possibility of flotation under still conditions (ice cover) despite the stratagems algae employ to retard sinking, such as oil droplets contained within algal cells (diatoms), a large surface to volume ratio, spines, and other means (Round 1965).

This apparent contradiction may have been resolved upon the examination of the field record for the Lake Louise project. The mild winter of 1999-2000 caused an open-water area of several acres to develop between the sampling sites in December that remained relatively ice-free for most of the winter. It was hypothesized that this expanse of open water was sufficient to produce enough water turbulence in the vicinity of the sampling sites for diatoms and other algae to remain in suspension until breakup of ice cover in the spring.

Flagellated (motile) algae were under no such constraints and developed as usual. Major identified taxa in December and January were *Chromulina* spp., *Synura uvella*, and *Chroomonas* sp., in order of abundance. Flagellates, including unidentified taxa, maintained consistent monthly densities from December through February that ranged from 2,244 to 2,273 cells/mL. For those months, flagellated algae comprised from 27% to 53% of the total algae (Table 21).

By late February, diatoms were replaced by flagellates as the dominant algal group in the winter plankton. This was not due to an increase in flagellate numbers over January densities, but the result of a steep decline in the diatom species *Stephanodiscus hantzschii* and particularly *Asterionella formosa* which dropped from 2,809 cells/mL in January to 9 cells/mL on February 22, 2000, to increase slightly to 58 cells/mL on the last sampling date. In February, a diverse assemblage of flagellated algae constituted 53% of total algae density and 77% of the biovolume. A yellow-brown colonial flagellate, *Synura uvella*, made up nearly 64% of this volume in a small late winter algae population.

The last sampling date of this survey in late March indicated a substantial increase in the algal population from an annual minimum of 4,257 cells/mL in February to a mean of 11,251 cells/mL on March 21, 2000. Nearly 71% of this total and 92% of the biovolume was composed of flagellated algae, primarily *Synura uvella*, which was present as a bloom of 4,992 cells/mL, accounting for 44% and 86% of the March algal density and biovolume, respectively. *Synura* appears to be a cold-water form with an optimum growth temperature of around 5C and high phosphorus requirements (Hutchinson 1967). Diatoms, primarily *Stephanodiscus hantzschii* at 1,620 cells/mL, comprised approximately 16% of total algal density and 7% of the biovolume in late March.

Aquatic Macrophyte Survey

The Project Coordinator and SD DENR Staff conducted an aquatic plant survey on August 17 and 18 of 1999. Submerged and floating vegetation was dense throughout most of the lake, while emergent vegetation was also abundant and covered approximately 95 % of the shoreline. Plant species identified and their habitat can be found in the following table.

Table 23. Aquatic Plant Species for Lake Louise

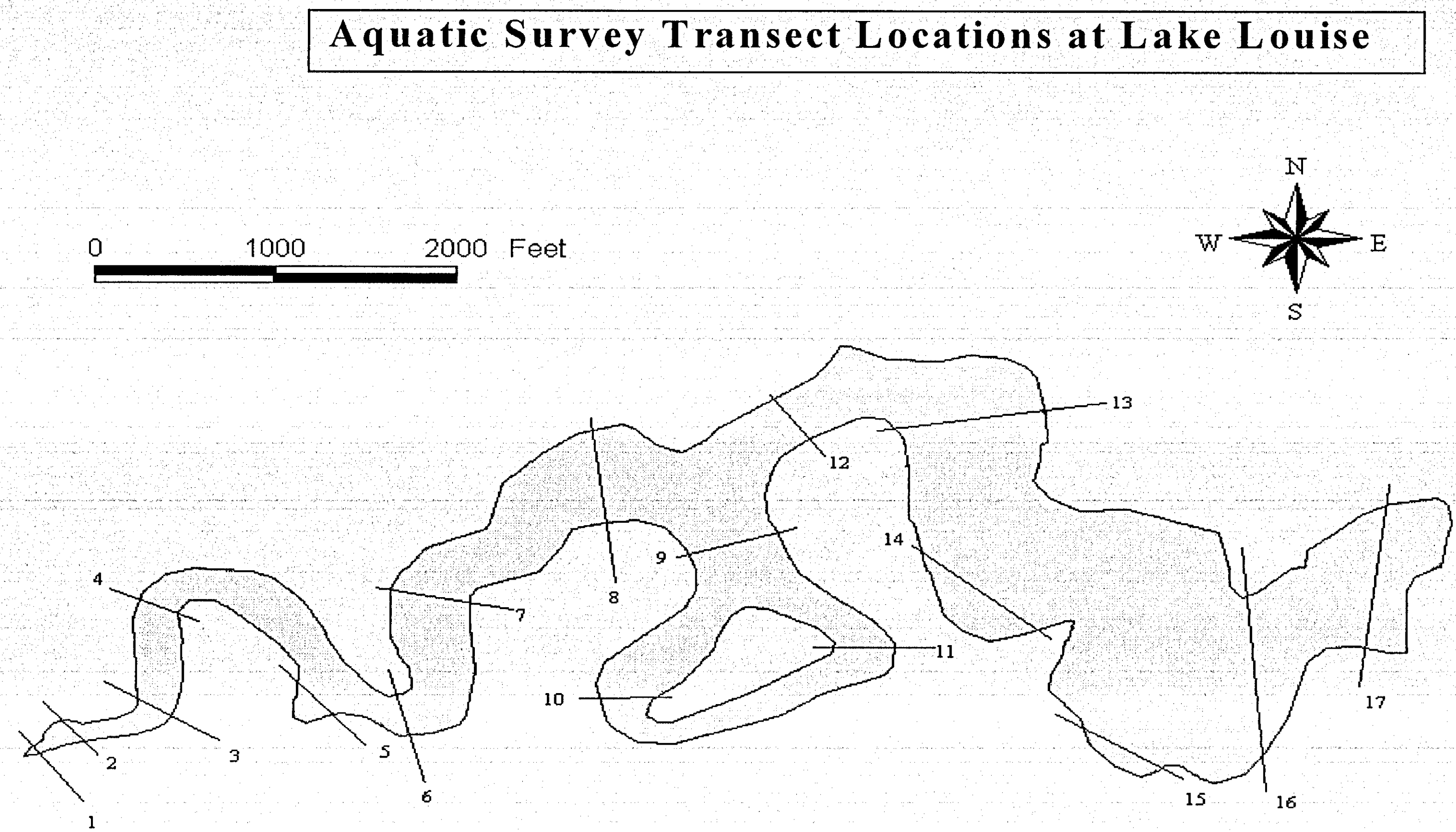
Common Name	Genus	Species	Habitat
Arrowhead	*Sagittaria*	*latifolia*	Emergent
Common Reed	*Phragmites*	*australis*	Emergent
Coontail	*Ceratophyllum*	*demersum*	Floating/ Submergent
Dull-leaf Indigo	*Amorpha*	*fruiticosa*	Emergent
Flat-Stem Pondweed	*Potamogeton*	*zosteriformis*	Submergent
Floating-Leaved Pondweed	*Potamogeton*	*natans*	Floating/ Submergent
Swamp Milkweed	*Asclepias*	*incarnata*	Emergent
Flowering Rush	*Butomus*	*umbellatus*	Emergent
Green Bulrush	*Scirpus*	*atrovirens*	Emergent
Lesser Duckweed	*Lemna*	*minor*	Floating/ Submergent
Narrow-Leaved Cattails	*Typha*	*angustifolia*	Emergent
Prairie Cord Grass	*Spartina*	*pectinata*	Emergent
Reed Canarygrass	*Phalaris*	*arundinacea*	Emergent
River Bulrush	*Scirpus*	*fluviatilis*	Emergent
Sago Pondweed	*Potamogeton*	*pectinatus*	Submergent
Sand Bar Willow	*Salix*	*exigua*	Emergent
Sedge	*Carex*	*spp.*	Emergent
Strawcolored Nutsedge	*Cyperus*	*strigosus*	Emergent
Smartweed	*Polygonum*	*Pennsylvanicum*	Emergent
Swamp Smartweed	*Polygonum*	*coccineum*	Emergent

Due to the narrow width of the lake and extensive vegetation coverage, all transects were completed from shoreline to shoreline. Samples were pulled at approximately 50 meter intervals along each transect. The most abundant submerged plants were coontail, flat-stem pondweed, and sago pondweed. Table 24 lists the density rating of each plant species along with the lake depth and Secchi reading at each position. The density was rated according to the number of times that the plant was recovered at each position by means of a plant grapple thrown four different directions. A density of "5" rates the species as dense while a "1" indicates that it was present but sparse at that location. Figure 27 contains a map indicating the location of each transect. The sampling positions begin at the northwest end of each line, labeled "A". Subsequent samples along the same transect proceed along it to the south and east.

Table 24. Aquatic Macrophyte Sampling Transects for Lake Louise

Transect	Position	Secchi	Depth	Coontail	Flat-Stem Pondweed	Sago Pondweed
1	A	2.1	6	4	-	-
2	B	2	10	3	2	-
2	A	2	6	3	-	-
3	B	1.8	7	2	1	-
3	A	1.6	6	4	2	1
4	A	1.3	5	5	1	2
4	B	1.8	8	-	-	-
5	A	1.7	4	4	-	2
6	C	1.4	10	1	-	-
6	A	1.2	4	4	3	4
6	B	1.5	4	-	-	-
7	B	1.5	4	5	3	3
7	A	1.7	4	5	3	-
7	C	1.8	10	-	1	-
8	A	2	12	1	1	-
8	B	2	10	1	-	-
8	C	2	5	3	2	2
9	C	2	7	1	1	-
9	A	2	10	1	-	-
9	D	1.9	6	2	-	1
9	B	2	10	-	-	-
10	A	2.4	5	5	1	1
11	B	1.9	8	1	2	1
11	A	1.7	6	2	3	-
12	A	2.3	16	1	-	-
12	B	2.4	8	2	-	-
13	D	2	15	2	1	-
13	A	2.1	4	5	-	-
13	B	2	8	-	-	-
13	C	2.2	9	-	-	-
14	A	2.1	12	-	-	-
14	B	2	11	-	-	-
14	C	2.2	18	-	-	-
14	D	2	15	-	-	-
15	A	2.6	5	3	2	-
16	A	2.6	9	-	-	-
16	B	2	12	-	-	-
16	C	2.4	15	-	-	-
17	B	2.6	23	1	-	-
17	D	2.8	7	3	2	-
17	A	2.7	14	-	-	-
17	C	2.4	17	-	-	-

Figure 27. Aquatic Macrophyte Survey Transects for Lake Louise



The results of the aquatic survey indicate that coontail was the most abundant species consisting of 51% of the plant material recovered. Flat-stem pondweed and sago pondweed comprised 32% and 16% respectively. The remaining percentage was comprised of observed species that were not collected such as floating-leaf pondweed and duckweed.

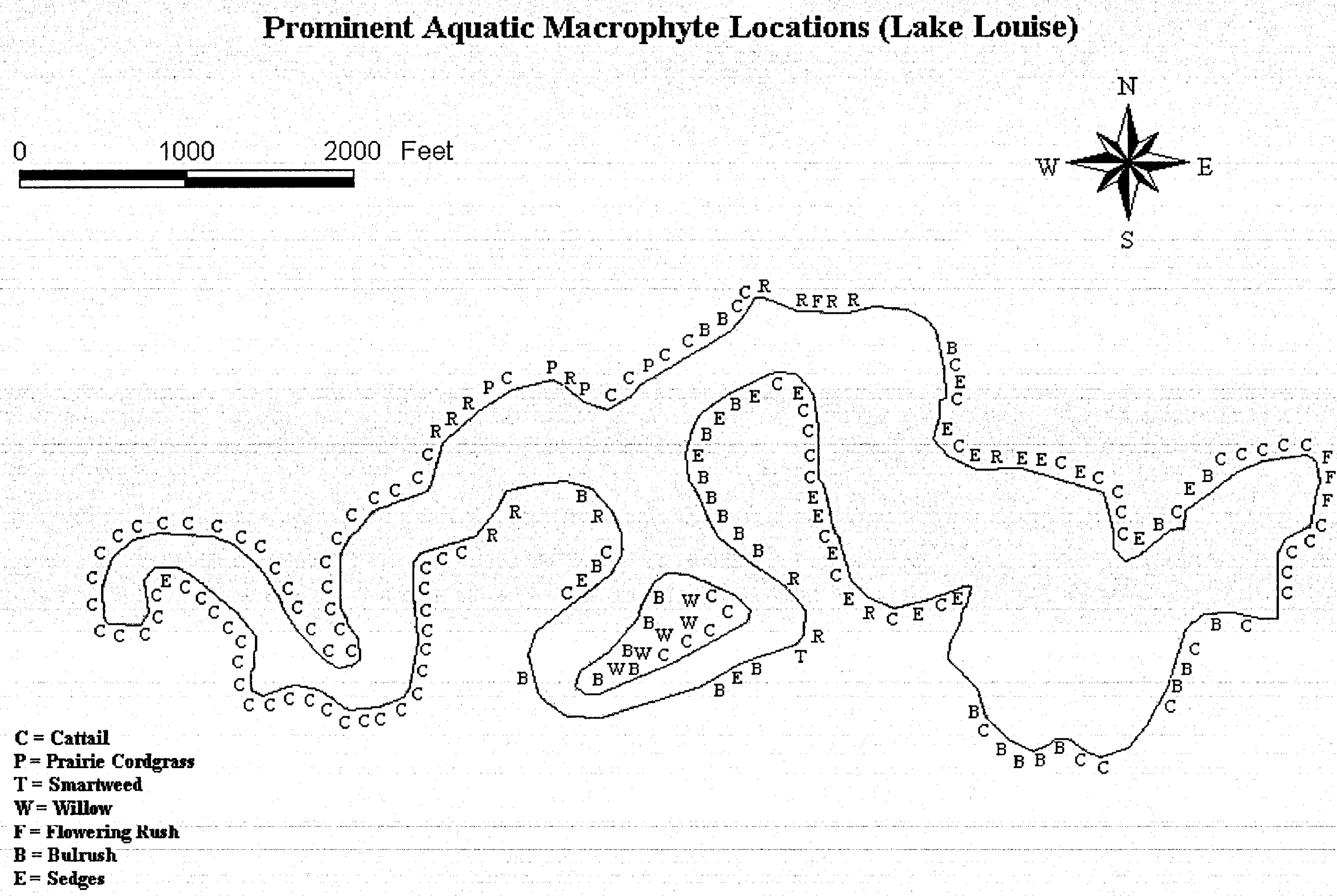
The emergent vegetation that line the shoreline of the lake consisted of a variety of species with the major ones consisting of narrow-leaved cattail, sedge, bulrush, and arrowhead. A variety of other less common species included prairie cord grass, sandbar willow, common reed, and flowering rush that also inhabited the shoreline.

The flowering rush had previously been documented only at Lake Faulkton in South Dakota. A small number of these exotics have become established at Lake Louise and are thriving. Originating from Europe, it was introduced to the Midwest as an ornamental plant. It can grow as an emergent in shallow areas of a lake or as a submersed form in depths up to 10 feet. It often crowds out native species such as bulrush. (Canadian Wildlife Service, 1999) Flowering rush is spread over long distances primarily by people who plant it as an ornamental. When initially established in a watershed, it spreads locally by rhizomes and root pieces that break off and form new plants. Muskrats use parts of the plant to build houses and contribute to its local spread. Boaters may transport flowering rush on their equipment. Flowering rush does produce seeds but studies conducted by Bemidji State University indicate that seed viability is very low. (University of Minnesota, 1998)

Shore fishing access is limited by the dense stands of cattails and bulrushes as well as the large amount of submerged vegetation lining the shoreline. The coontail, sago pondweed, and flat-stem pondweed have limited boating and fishing. During mid to late summer, dense stands of these plants virtually close off access to sections of the lake.

The locations of the primary emergent species observed during the survey can be found in Figure 28 on the following page.

Figure 28. Prominent Shoreline Aquatic Macrophytes for Lake Louise



Other Monitoring

Pacific Southwest Inter-Agency Committee Model (PSIAC)

The PSIAC model is an assessment tool designed to determine sediment loadings in large watersheds that contain more than 50% grass and rangeland. The model is based on characteristics such as land use, cropping practices, soil types, local climate, and stream characteristics. A multidisciplinary team consisting of local and regional NRCS personnel, staff from the Water Resources Assistance Program, and local coordinators, conducts the evaluation. NRCS personnel in the South Dakota state office then generate the report. The complete PSIAC report may be found in Appendix A.

PSIAC bases reduction estimates on expected participation rates of BMP application. These rates are broken down into three classes for low, moderate, and high involvement. Low participation rates expect Best Management Practices (BMP) on 20% of the rangeland and 10% of the cropland in the watershed. Moderate participation is based on 30% for rangelands and 15% for croplands. High participation is based on 40% for rangeland and 20% for cropland. These percentages are based on the improvement of range condition by a factor of one class, for example, from fair to good range condition. Cropland percentages are based on improving crop residue as well as the addition of buffer strips and other BMPs. Table 25 indicates the number of acres that could be expected to be involved in BMPs to attain the level of participation indicated.

Table 25. Acres in BMP to Achieve Participation Rates

Land Use	Total Acres	Acres in BMP		
		Low	Moderate	High
Range	173,785	34,757	52,135	69,514
Cropland	26,947	2,694	4,042	5,389
Hay/Crop	12,154	0	0	0
Other	4,345	0	0	0
Acre sum	217,231	37,451	56,177	74,903

PSIAC deals exclusively with sediment (suspended solids loads) but phosphorus loads may be linked to these loads. Phosphorus loads may be found in two primary forms, attached and dissolved. Attached loads are calculated by subtracting the dissolved portion of the load from the total phosphorus load.

Equation 1. Attached Phosphorus Calculation

Total Phosphorus – Dissolved Phosphorus = Attached Phosphorus

***2129 kg – 1482 kg** = 647 kg of Attached Phosphorus*

Medicine Creek delivers a total load of 2129 kg of phosphorus to Lake Louise annually. Of this, 647 kg (30%) is attached to suspended solids. The annual suspended solids load is 50,415 kg. Attached phosphorus (AP) loads were linked to suspended sediment loads on Lake Lanier in Georgia and in the Chattahoochee River (Rasmussen, 2000). Loading ratios of AP: TSS for Lake Lanier in Georgia ranged from .0025 to as high as .009, while the Chattahoochee River had a value of .004. The attached phosphorus (AP) to suspended sediment (TSS) ratio for Lake Louise is AP=.012TSS.

Equation 2. Attached Phosphorus Ratio

$$\frac{TotalAttachedPhosphorus}{TotalSuspendedSolids} = \frac{647kg}{50{,}415kg} = .012$$

Reducing the suspended solids load will reduce the attached phosphorus load by an equal percentage. The total phosphorus load will be reduced by a smaller percentage, because the sediment reduction will not affect the dissolved portion of the load. When this ratio is used with the reduced solids loads predicted by PSIAC, reduction estimates can be calculated. Table 26 indicates the phosphorus reductions that can be expected when the participation rates are met. Solids reductions vary from 4.1% to 7.3% for the highest participation rate. Phosphorus reductions from rangeland and cropland BMP range from 3.1% to 4.0%.

Table 26. PSIAC Phosphorus Reductions

Participation Rate	Low	Moderate	High
% Sediment Reduction	4.1%	5.5%	7.3%
Current Suspended Solids Load	50,415	50,415	50,415
Predicted SS with Reduction	48,348	47,642	46,735
Ratio of Attached Phosphorus to SS	0.012	0.012	0.012
Current Total Phosphorus Load	2,129	2,129	2,129
Attached P after Reduction	580	572	561
Total P after Reduction	2,062	2,054	2,043
% TP Reduction	3.1%	3.5%	4.0%

Agricultural Non-Point Source Model (AGNPS)

In order to objectively assess the impact of the animal feeding operations located within the watershed, the AGNPS feedlot assessment subroutine was employed. A complete evaluation was conducted on all animal-feeding areas with a defined drainage to Wolf Creek. Animal lots with drainages confined to small areas and no defined discharges were not rated during the assessment. Lots that were rated were assessed for a 25-year, 24-hour storm event in the drainage area. This is the largest event that waste systems in the area are designed to handle.

The Lake Louise and Wolf Creek drainage area consists of a very high percentage of range and pastureland (86%) mixed with very little cropland (12%). Due to the high percentage of grassland, a complete AGNPS model was not completed on the entire watershed. The PSIAC model was used to assess rangeland and cropland conditions and estimate sediment delivery rates. The subwatersheds contained a small number of animal feeding operations (AFOs) that PSIAC was not capable of assessing. The AGNPS Animal Feeding Operation Subroutine was used to assess each of those AFOs. Each feedlot was numbered, linked to a subwatershed, and then assessed to obtain an AGNPS ranking number. The model was completed with a 25-year, 24-hour storm event simulation, which is the equivalent of a 4.1-inch rainfall event for this area. This event was selected because it is used as the design event for constructing animal waste systems in the area.

There were 25 potential feeding areas that were identified from a visual survey conducted during the summer of 1999. Many of the animal lots targeted for assessment were used for only a small portion of the year, often as holding lots for calves prior to sale. Of the 25 lots, a complete assessment was completed on 24. Access to a single lot was not permitted and no data was obtained for it. There were 7 lots which received a rating of 0 for a variety of reasons; some were no longer being used, some did not receive enough use to rate them, and in a few instances the lots were in a closed drainage system with no discharge to the stream system. The remaining lots received rankings from 14 to 62. Table 27 indicates the predicted phosphorus load originating from AFOs in each of the subwatersheds that could be expected to discharge during a 4.1-inch rainfall event. The predicted total phosphorus discharge from Wolf Creek is 735 pounds or 333 kg.

Table 27. AGNPS Predicted Phosphorus Load

Subwatershed	AGNPS Predicted Phosphorus Load (Kg)
WC-2	96.6
WC-3	22.7
WC-4	12.2
WC-5	201.8

A majority of the AFO phosphorus load appears to be originating from subwatershed WC-5. Of the estimated 735 pounds of phosphorus, approximately 60% of it originates from this watershed. Table 28 represents each of the AFOs, their respective AGNPS rankings, subwatershed location, and predicted phosphorus discharge. They are listed according to their predicted phosphorus discharges. The five AFOs with rankings greater than 40, that are also located in subwatershed MC-5, represent 47% of the AFO predicted load. Reducing the phosphorus discharge from those five AFOs would provide the greatest benefit to the watershed if the phosphorus discharge from them is reduced.

Typically, in South Dakota, AFOs with rankings of 40 or greater contribute from 1% to 1.5% of the total phosphorus load. With this in consideration, it may be assumed that the five AFOs previously mentioned contribute 5% to 7% of the total phosphorus load.

Table 28. Feedlot Phosphorus Discharge in the Wolf Creek Watershed

Lot ID #	AGNPS Rating	Sub- watershed	P mass @ Discharge	% of Total P mass
8	62	5	146.12	20%
13	52	2	80.85	11%
12	47	5	62.93	9%
9	46	2	59.2	8%
4	47	5	49.02	7%
3	45	5	44.18	6%
20	43	5	44.01	6%
5 West	37	5	40.16	5%
11	42	2	38.12	5%
18 East	0	5	37.89	5%
15 East	0	3	27.15	4%
22	37	4	26.97	4%
15 West	33	3	22.93	3%
7	30	2	19.48	3%
14	27	2	15.58	2%
5 East	23	5	14.98	2%
18 West	14	5	5.81	1%
2	0	4	0	0%
6	29	5	0	0%
21	0	5	0	0%
1	0	4	0	0%
19	0	5	0	0%
16	0	3	0	0%
17	0	5	0	0%
10	Not Rated	6	0	0%

Sediment Survey

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

Due to a very short duration in the ice cover on Lake Louise, the sediment survey was conducted from a boat. A total of 87 water and sediment depth measurements were recorded. A spatial analysis could not be completed on the lake due to an inadequate number of data points in the lake. The sediment depths varied from 0.15 m to a maximum of 2.3 m. The mean sediment depth was .97m with the 95% confidence intervals between .85m and 1.07m. Water depths collected at each of these sites had a mean depth of 2.8 m. The SD GF&P estimate for mean depth in the lake to be 2.7 m, indicating that a representative cross section of water depths was sampled. Lake Louise had a total volume of 639,847m3 of accumulated sediment (Figure 29). There is a very small amount of sediment moving through the watershed. The flux estimates calculated that the annual load to the lake is only 50,415 kg, or 30 m3 of sediment. The majority of the sediment that has accumulated is a result of shoreline that collapsed as a result of creating the lake.

Elutriate samples were completed with a Petite Ponar and shipped to the State Health Lab for analysis. In addition to sediment, a volume of 3 gallons of water was collected at each of the testing sites as well and was analyzed for the same chemicals as the sediment. The results of the elutriate test completed on the lake were all negative. Table 29 indicates the various toxins that were tested for in the elutriate sample.

Results from the elutriate and receiving water tests yielded results below the detection limit for all of the parameters that were tested for with the exception of lead, which was detected at 0.1 ppb. The elutriate tests were conducted during the early part of a spring with no runoff from the watershed. Some of the chemicals tested for have half lives that are sufficient to maintain detectable levels throughout the year, while others are relatively short lived and will persist in detectable quantities for only a few weeks. Late season testing provides too much time for these short-lived chemicals to break down, making detection difficult to impossible. Future tests may best be collected during the spring or early part of the summer after a runoff event has occurred.

Table 29. Elutriate Test Toxins for Lake Louise

Elutriate Test Toxins (none detected)		
ALACHLOR	DIAZINON	ALDRIN
CHLORDANE	DDD	DIEDRIN
ENDRIN	DDT	PCB
HEPTACHLOR	DDE	ALPHA BHC
HEPTACHLOR EPOXIDE	BETA BHC	MERCURY
TOXAPHENE	HAMMA BHC	LEAD

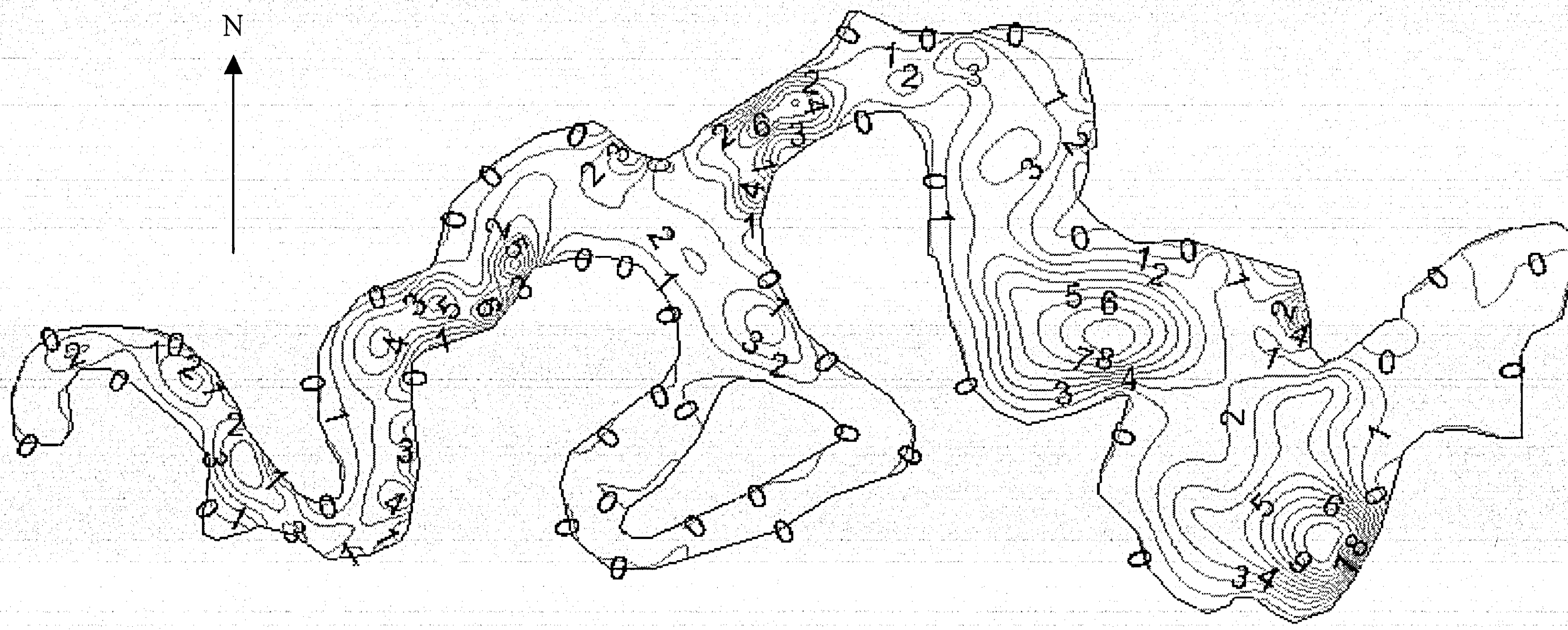


Figure 29. Lake Louise Sediment Map (Contours Expressed as Feet)

Quality Assurance Reporting

Quality Assurance/ Quality Control (QA/QC) samples were collected for 10% of the inlake and tributary samples taken. A total of 40 lake samples were collected along with four sets of duplicates and blanks. The eight tributary samples had one duplicate and blank collected with them. Complete test results for duplicates and blanks may be found in the following table.

The tributary duplicate produced very similar results to the sample itself with the only notable exceptions being fecal coliform counts and total suspended solids concentrations. The total suspended solids consistently produced high percent differences for the inlake samples. This may be attributed to the low concentrations (<10 mg/L) often found in the samples.

Field blanks taken during 1999 consistently registered detectable limits of nutrients and sediments. This may be due to inadequate rinsing of bottles. Another source of the problem may have been the quality of distilled water. The local supplier changed brands after the first of the year. This new supply of water may have been superior in quality.

Table 30. Field Duplicates and Blanks

SITE	DATE	Type	DEPTH	TALKA	TSOL	TDSOL	TSSOL	AMMO	NIT	TKN	TPO4	TDPO4	FEC
LL-9	14-Oct-99	Blank	SURFACE	7	6	4	1	0.02	0.10	0.14	0.002	0.004	10
LL-11	14-Oct-99	Duplicate	SURFACE	162	542	510	6	0.01	0.05	1.70	0.508	0.425	10
LL-1	14-Oct-99	Sample	SURFACE	165	553	510	14	0.01	0.05	1.56	0.528	0.427	20
				2%	2%	0%	80%	0%	0%	9%	4%	0%	67%
WC-9	09-Nov-99	Blank	SURFACE	<7	4	<4	<1	<.02	0.1	<.14	0.002	0.009	<10
WC-15	09-Nov-99	Duplicate	SURFACE	136	2373	2303	8	0.01	0.05	0.67	0.059	0.018	20
WC-5	09-Nov-99	Sample	SURFACE	138	2377	2311	9	0.01	0.05	0.73	0.059	0.017	30
				1%	0%	0%	12%	0%	0%	9%	0%	6%	40%
LL-9	22-Feb-00	Blank	SURFACE	<6	<5	<4	<1	<.02	0.10	<.21	<.002	<.002	<2
LL-11	22-Feb-00	Duplicate	SURFACE	184	608	577	1	0.01	0.05	1.02	0.179	0.157	1
LL-1	22-Feb-00	Sample	SURFACE	184	616	581	0.5	0.01	0.05	1.03	0.172	0.154	1
				0%	1%	1%	67%	0%	0%	1%	4%	2%	0%
LL-9	21-Mar-00	Blank	SURFACE	<6	9	9	<1	<.02	0.10	<.21	<.002	<.002	<2
LL-12	21-Mar-00	Duplicate	SURFACE	169	567	531	8	0.01	0.05	1.05	0.176	0.12	5
LL-2	21-Mar-00	Sample	SURFACE	171	569	538	9	0.01	0.10	1.06	0.173	0.126	5
				1%	0%	1%	12%	0%	67%	1%	2%	5%	0%
LL-9	12-May-00	Blank	BOTTOM	<6	<6	8	<1	<.02	0.10	<.21	<.002	0.006	<2
LL-11	12-May-00	Duplicate	BOTTOM	177	560	540	7	0.01	0.10	1.20	0.233	0.185	
LL-1	12-May-00	Sample	BOTTOM	178	566	542	6	0.01	0.05	1.00	0.238	0.206	
				1%	1%	0%	15%	0%	67%	18%	2%	11%	
	Average Percent Differnce			1%	1%	1%	37%	0%	27%	7%	2%	5%	

Public Involvement and Coordination

State Agencies

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

The South Dakota Department of Game, Fish and Parks aided in the completion of the assessment by providing use of their boat at Lake Louise. They also provided historical information on the park and a complete report on the condition of the fishery in Lake Louise.

Federal Agencies

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

Historical stream flow data for the watershed was provided by the United States Geological Survey (USGS). Sample data collected by USGS was also used in the final report for the assessment.

The Natural Resource Conservation Service (NRCS) provided technical assistance and completed the PSIAC portion of the assessment.

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

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

The Hand and Hyde County Conservation Districts provided work space, financial assistance, and aided in the completion of the PSIAC report.

Public involvement consisted of individual meetings with landowners that provided a great deal of historic perspective on the watershed. A meeting with the local Kiwanis club provided many of the area business owners with an opportunity to learn more about the project and the water quality of the lake.

Other Sources of Funds

Matching funds came from several groups to complete the project at Lake Louise. Table 31 depicts the funding sources, the proposed budget from each of these sources, total expenditures, and the percentage of the proposed budget that was utilized. In-kind match came from a variety of sources such as office rent, boat use, supplies, and volunteer labor assisting in the collection of samples.

Table 31. Funding Sources and Funds Utilization

	Budget	Cash	In-Kind	% utilized
Federal EPA 319	$ 101,420.00	$ 87,673.43		86.4%
Conservation Commission	$ 33,400.00	$ 32,372.17		96.9%
Central Plains Water Development District	$ 12,430.00	$ 13,625.00	$ 1,400.00	120.9%
Cottonwood Lake Association	$ 9,091.00	$ 5,850.00	$ 559.48	70.5%
Conservation Districts	$ 12,691.00	$ 6,875.00	$ 6,069.00	102.0%

Aspects of the Project that did Not Work Well

All of the objectives proposed for the project were met in an acceptable fashion and in a reasonable time frame. The number of tributary samples collected during the project was considerably less than proposed. This was due to an unavoidable period of drought that persisted throughout the project period.

Completion of the restoration alternatives and final report for Lake Louise and Wolf Creek in Hand and Hyde Counties was delayed until the completion of the final report for an additional lake and watershed that was completed under the same grant.

Future Activity Recommendations

A number of future activities and concerns need to be addressed in the Wolf Creek and Lake Louise watershed. The high concentrations of phosphorus and periodic discharge nature of the stream make it difficult to achieve the reductions that are required to adjust the trophic state of the lake to full support of its beneficial uses. Initial steps towards achievement of this goal should be taken in subwatersheds WC-3 and WC-5 only.

Management steps taken here should include the BMPs listed below on 1,400 acres of cropland and BMPs on 18,000 acres of rangeland in subwatersheds WC-5 and WC-3. Additionally, construction of five animal waste management systems for the highest ranking AFOs, in subwatershed WC-5 only, should be completed. Accompanying these practices informational and educational materials and meetings should be held to inform the public of improvements and benefits of the program. As a margin of safety, BMPs should be implemented on 280 acres of cropland and 3,600 acres of rangeland in subwatersheds WC-1, WC-2, WC-6, and those portions of WC-4 located downstream from Lake Mitchell. Following is a list of potential steps

1. Animal Waste Management Systems
2. Rangeland BMP
    a. Grazing and Rangeland Management
    b. Alternative Livestock Watering Sources
    c. Windbreak/ Shelterbelt Establishment
3. Cropland BMP
    a. Grassed Waterways
    b. Crop Residue Management
    c. Filter Strips
    d. Integrated Crop Management
    e. Conservation Crop Rotation
4. Information/ Education Program

Range and cropland BMPs will result in a 7.3% reduction in sediment and a 4.0% reduction in phosphorus to Lake Louise. Further steps towards the improvement of Lake Louise would include the installation of aeration equipment. BATHTUB predictions estimate that a 29% reduction in ambient phosphorus concentrations can be achieved with aeration of the lake to the sediment interface.

The end result from these reductions will be a decrease in phosphorus loading from Wolf Creek by approximately 10% and a reduction in ambient phosphorus concentrations in the lake by 36%. The resulting trophic state will be sufficiently low enough to partially support the beneficial uses of the lake.

Future sampling activities should include collection of fecal coliform samples at the start of spring runoff as well as the genetic identification of their host animals of origin (livestock, wildlife, or human). Sediment sampling times should be critically evaluated for this lake and possibly moved to a date during or immediately following spring runoff.

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SEDIMENT ASSESSMENT AND EVALUATION STUDY

FOR

LAKE LOUISE AND COTTONWOOD LAKE

HAND, HYDE, FAULK, AND SPINK COUNTIES SOUTH DAKOTA

United States Department of Agriculture
Natural Resources Conservation Service
South Dakota

In Cooperation with

South Dakota Department of Environment and Natural Resources
And
Hand County Conservation District

MAY 2000

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INTRODUCTION

The Lake Louise – Cottonwood Lake Watershed Assessment Project is the initial phase of a proposed watershed-wide restoration project. Agricultural non-point source pollution, specifically sediment and nutrients, have been identified as sources of water quality impairment in the watersheds of Lake Louise and Cottonwood Lake. The South Dakota Department of Environment and Natural Resources (DENR) has previously relied on computer simulation to analyze non-point source pollution in agricultural watersheds. In South Dakota the most commonly used tool to assess agricultural non-point sources of pollution has been the Agricultural Nonpoint Source (AGNPS) model. AGNPS results have proved to be useful in watersheds that are predominantly cropland, however, it is not well adapted for evaluating watersheds that are primarily rangeland, hayland and/or pastureland.

Rangeland, hayland, and pastureland account for approximately 70 percent of the total land use in the study area. The Pacific Southwest Interagency Committee (PSIAC) sediment evaluation method was determined to be the most effective tool to use in an effort to determine total sediment loads and the sediment contributions from each of the different agricultural land uses. PSIAC is presently the only method available that is recognized as an evaluation tool capable of assessing sediment loads from watersheds with a large percentage of rangeland.

Phosphorus evaluations have been based on water quality monitoring data that was collected during the 1999 water year. Total and dissolved phosphorus loads were measured at various points throughout the Lake Louise and Cottonwood Lake watersheds, at the point of discharge into the lakes, and at the outlet of the lakes. The values for the dissolved fraction of the total phosphorus delivered to Lake Louise and Cottonwood Lake were 64 percent of the total phosphorus and 87 percent of the total phosphorus respectively. The remaining portions of the total phosphorus loads would be considered attached or sediment associated. The values for the attached portion of the phosphorus concentrations were compared to the PSIAC sediment values. The phosphorus concentrations associated with sediment were based on an average of the chemical analyses of phosphorus concentrations found in the major soil associations.

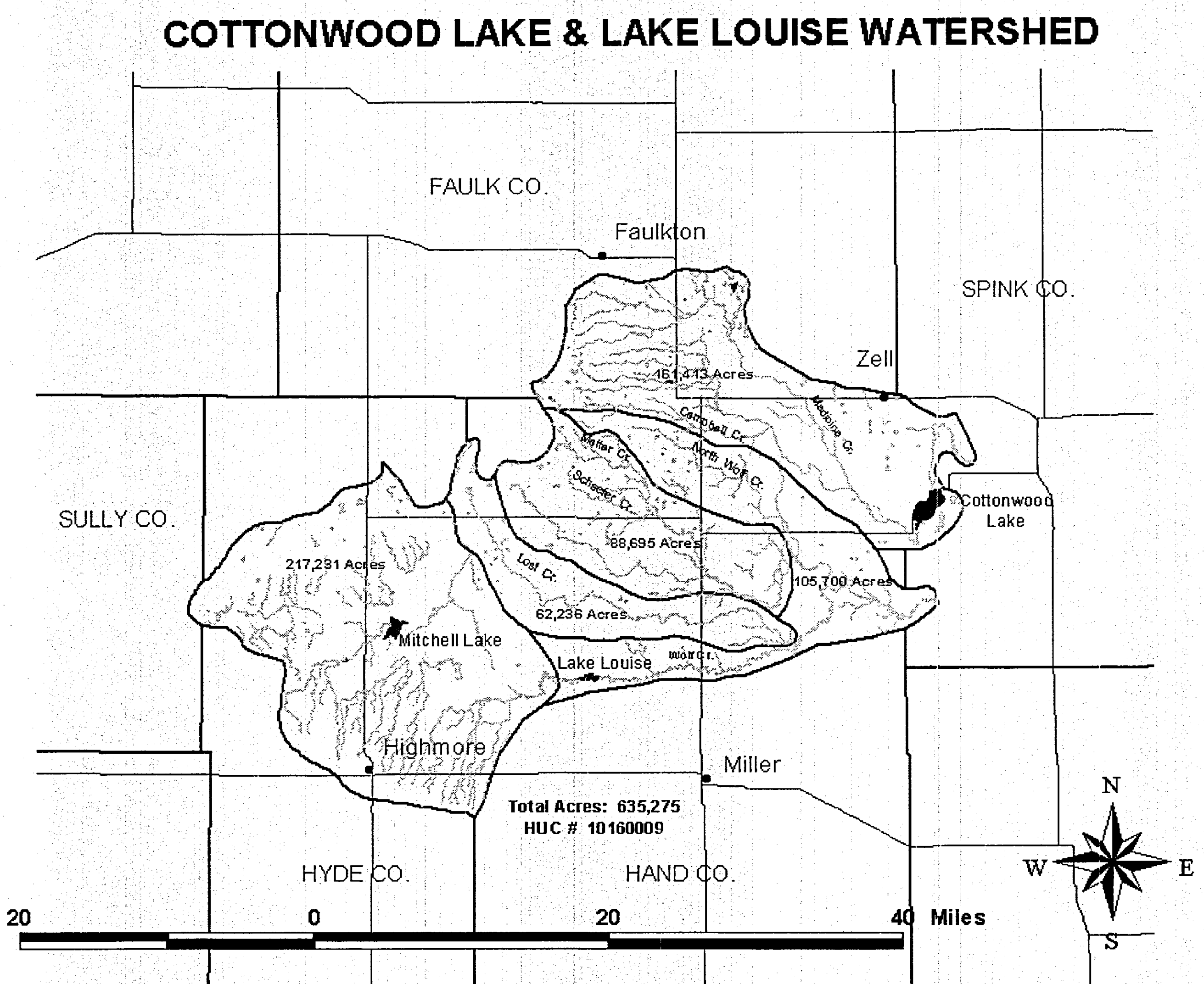
Phosphorus fertilization is not a common practice in the study area and was determined to be insignificant when compared to the naturally occurring phosphorus concentrations in the soil. The ratio of dissolved phosphorus to total phosphorus indicates that sediment associated phosphorus is not the major source of the phosphorus reaching the lakes. Further assessment of the watersheds is needed to identify other possible sources of phosphorus.

PROJECT SETTING

The Lake Louise — Cottonwood Lake Watershed Assessment study area is located in central South Dakota (Figure 1) and is part of the James River Lowlands in the Central Lowland physiographic division. The Central Lowlands region in eastern South Dakota is an area profoundly influenced by the most recent glaciation. Natural drainage systems are poorly developed, and numerous lakes and wetlands occur on the landscape. The large number of "pothole" wetlands typical of the Prairie Pothole Region characterizes the northeastern part of South Dakota. The study area is located in the western extent of this region. Typically, major streams flow from north to south. Very flat slopes characterize the low-lying areas of the James River Lowland.

The study area is located in two Major Land Resource Areas (MLRA) 53C and 55C. The Watershed Assessment project covers 635,275 acres of drainage area in four counties, Hand, Hyde, Faulk, and Spink (Figure 1). Lake Louise is located in Hand County and Cottonwood Lake is located in Spink County, South Dakota. The sediment and nutrient loads from agricultural non-point sources in the study area have been identified as the major sources contributing to the impairment of the designated beneficial uses of the lakes.

FIGURE 1



WATERSHED ASSESSMENT

The Lake Louise and Cottonwood Lake Watershed Assessment study area was divided into sub-watersheds to determine relative contributions of sediment delivered from each area. Five sub-watersheds were identified and named for the major tributary stream in the respective 11-digit hydrologic unit (Figure 1). Water quality samples were collected in only the Medicine Creek (Cottonwood Lake) and Upper Wolf Creek (Lake Louise) sub-watersheds. The sub-watershed boundaries and acreage were determined using existing Geographic Information System (GIS) data (Table 1).

Medicine Creek drains the 161,413-acre Cottonwood Lake watershed. The creek begins in Faulk County, travels east through the northeast part of Hand County and discharges into Cottonwood Lake in Spink County. The Cottonwood Lake watershed includes 63,387 acres in Hand County, 78,366 acres in Faulk County, and 19,660 acres in Spink County.

Upper Wolf Creek is the major tributary in the drainage network of the Lake Louise watershed. It originates in the hills of Ree Heights in eastern Hyde County. There are 217,231 acres in the Lake Louise watershed: 181,605 acres in Hyde County, 34,279 acres in Hand County, and 1,347 acres in Sully County.

Lost Creek, Schaefer Creek, Lower Wolf Creek and North Wolf Creek drainages converge below Lake Louise. This 256,631 acre drainage area does not directly contribute to either Lake Louise or Cottonwood Lake; however, it has been included in this watershed inventory and evaluation as part of a more comprehensive assessment of resources in Hand County.

TABLE 1

Cottonwood Lake and Lake Louise Watershed Assessment Study Area

GIS Acrages Generated from 1:250,000 11-Digit Hydrologic Unit Data

08/17/99

Medicine and Campbell Creeks	**161,413 acres**
(Cottonwood Lake)	
Faulk County	78,366 acres

Hand County	63,387 acres
Spink County	19,660 acres
Upper Wolf Creek	**217,231 acres**
(Lake Louise)	
Hand County	34,279 acres
Hyde County	181,605 acres
Sully County	1,347 acres
North Wolf and Lower Wolf Creeks	**105,700 acres**
Hand County	103,163 acres
Spink County	2,537 acres
Schaefer and Matter Creeks	**88,695 acres**
Hand County	88,695
Lost Creek	**62,236 acres**
Hand County	58,409 acres
Hyde County	3,827 acres

LAND USE

Agriculture is the principal economic activity in the study area. Production of small grains, corn, sunflowers, soybeans, hay, and raising beef cattle are the major enterprises in the watershed.

Approximately 69.6 percent of the study area has some type of permanent vegetative cover. Large acreages of rangeland and interspersed tracts of pasture, hayland, and Conservation Reserve Program (CRP) occur throughout the study area.

Cropland comprises about 28.4 percent of the area. The most common cropping sequence is a rotation of corn, soybeans and small grains. Approximately 70 percent of the cropland acres have some form of residue management (greater than 15 percent ground cover after planting), or are managed using minimum till or no-till conservation tillage systems. Only a small percentage of the cropland is designated as Highly Erodible Land (HEL). Wind erosion is the predominant type of erosion associated with cropland in the study area. Water erosion is a minor resource concern due to the flat slopes and relatively low amount of annual precipitation. Any significant water erosion is associated with the infrequent, localized, thunderstorms that are of high intensity but short duration.

TABLE 2

LAND USE

SUBWATERSHED	TOTAL ACRES	(Acres) RANGELAND	CROPLAND	HAY/CRP	OTHER
Medicine Creek (Cottonwood Lake)	161,413	80,707	52,703	24,773	3,230
Upper Wolf Creek (Lake Louise)	217,231	173,785	26,947	12,154	4,345
North Wolf Creek	105,700	42,280	52,109	9,196	2,115
Schaefer Creek	88,695	53,217	28,648	5,055	1,775
Lost Creek	62,236	37,342	19,824	3,825	1,245
TOTAL	**635,275**	**387,331**	**180,231**	**55,003**	**12,710**

OTHER includes roads, railroad-right-of-way, farmsteads, and urban areas.

EVALUATION METHODS

Sediment

The Pacific Southwest Interagency Committee (PSIAC) sediment evaluation method was developed as the result of an interagency cooperative effort to assess the average annual sediment yield from watersheds larger than ten square miles. PSIAC evaluations quantify and characterize the watershed sediment yield at a downstream delivery point based on nine physical features within the watershed. It is a method intended for use as an aid to develop and support broad-based resource planning strategies. No other method is currently available to use as a rapid assessment tool for evaluating sediment yield at the watershed level. Sediment surveys and monitoring studies would require more intensive, long term, and costly investigation procedures.

The Natural Resources Conservation Service (NRCS - formerly Soil Conservation Service) Midwest National Technical Center sedimentation geologist approved the use of the PSIAC method of sediment yield evaluation in South Dakota (1993). PSIAC evaluations correlate well with measured results from historic sediment surveys, United States Geological Survey (USGS) gage station data and other sediment data previously collected by various agencies in South Dakota. NRCS has used PSIAC to evaluate sediment yield from agricultural sources for the purpose of broad-based resource planning in river basin studies, watershed plans, and resource assessment reports.

PSIAC has previously been used in South Dakota by NRCS to evaluate sediment loads for the following projects:

Little Minnesota River - Big Stone Lake Watershed Project (1995).

Lower Bad River — River Basin Study (1994).

Upper Bad River — River Basin Study (1998).

Upper Big Sioux — River Basin Study (1999).

Medicine Creek Watershed Assessment Report (1999).

Bear Butte Creek Watershed Assessment Report (1999).

Grand River Watershed Assessment Report (1999).

Phosphorus

The PSIAC sediment evaluations included three sub-watersheds that are not located in the drainage areas of Cottonwood Lake or Lake Louise. These sub-watersheds (North Wolf, Schaefer, and Lost Creeks) were included in the sediment evaluations, however, no water quality sampling was done in these sub-watersheds. Phosphorus concentrations were identified as a resource concern for only the watersheds of Lake Louise and Cottonwood Lake.

Seven water quality-monitoring sites were established along Medicine Creek in the Cottonwood Lake watershed and six sites were located on Upper Wolf Creek in the Lake Louise watershed (Figures 2 and 3). Water quality samples were taken during the 1999 water year and analyzed for various physical and chemical properties, which included total and dissolved phosphorus.

Phosphorus concentrations in soil exist as both organic and inorganic chemical compounds. The amount of phosphorus present varies depending on the soil parent material, texture, and/or management factors such as rates of phosphorus fertilization and cultivation practices. Soil samples taken from the major soil associations in the study area have an average phosphorus concentration of 1.8 pounds of total phosphorus per ton of soil.

Phosphorus transportation, both dissolved and attached, is similar to sediment transport. Phosphorus is either dissolved or in particulate form attached to soil particles. Phosphorus losses are associated with surface runoff and soil erosion. Very little phosphorus is removed from the system through the process of leaching and none through volatilization. Phosphorus measurements taken at the inlet of each lake were compared to the respective PSIAC values for sediment delivered from the watershed. The ratios of "attached to dissolved" phosphorus were determined from the chemical analyses of the water samples collected for each of the sub-watersheds. These measured concentrations reflect the total phosphorus delivery from the watershed.

PSIAC EVALUATION

Each sub-watershed was evaluated separately to determine the average annual sediment yield delivered to the downstream point of discharge into Lake Louise, Cottonwood Lake, or another watershed. An interdisciplinary planning team (Appendix A) evaluated the nine factors used in the PSIAC method to determine sediment yield. The physical features evaluated are: surface geology, soils, climate, runoff, topography, ground cover, land use and management, upland erosion, and channel development and sediment transport. The sediment yield characteristics of each factor are evaluated and then assigned a numerical value representing the relative significance in the sediment yield rating. The sediment yield rating is a sum of the values for each of the nine factors.

Each of the nine factors has a "paired influence" with the exception of topography. **Surface geology and soils** are directly related; that is, the "parent material" (the geologic formation in which the soil formed) determines the soil characteristics. The other factors that influence each other are **climate and runoff; ground cover and land use;** and **upland erosion and channel development**. Ground cover and land use can have a negative influence on sediment production. The ground cover and/or land use impact on sediment yield is therefore indicated as a negative value when affording better protection than average.

Land treatment measures used for erosion and sediment control will affect the following factors: runoff, land use and management, ground cover, upland erosion, and channel development and sediment transport. The other factors are related to the physical characteristics of the geographical area and do not change with land use or treatment.

Efforts to reduce erosion and sediment production can be measured on a watershed basis by comparing the existing conditions against the expected changes in one or more of the PSIAC factors that relate to the proposed land treatment. An example would be the changes expected when 20 percent of the present rangeland condition is improved by one condition class. This action would reduce runoff, improve ground cover, improve the level of land use and management, and can affect upland erosion and channel development. The total effect is measured as a percent reduction of delivered sediment in the present condition compared to the expected change in sediment delivered after the identified conservation measures are implemented.

PSIAC EVALUATION FACTORS

Surface Geology

The general geology of MLRA (Major Land Resource Area) 53C and MLRA 55C is a result of the different periods of glaciation that occurred during the Pleistocene. The surface geology of the study area is glacial till with isolated areas of sand and gravel deposits.

Soils

The majority of the soils in the study area are nearly level to gently sloping or undulating loamy soils formed in glacial till or melt-water deposits. Rolling to hilly soils formed in mixed materials are present in significant amounts in the Medicine Creek sub-watershed, but occur only as a minor component in the rest of the sub-watersheds.

Climate

The climate of central South Dakota is sub-humid and continental, characterized by large seasonal fluctuations in temperature, moderate to high relative humidity, and frequent high winds. Recurring periods of drought or near drought conditions are common. Less frequent periods of short duration can yield higher than normal amounts of precipitation. The average annual precipitation is 18.6 inches with 75 percent occurring during the period April to September, which is the growing season for most of the crops raised in this area. The growing season ranges from 115 days to 130 days. The average last killing frost occurs in mid-May and the first killing frost generally occurs in mid-September. Seasonal fluctuations in temperatures range from well below zero in winter to 100 + degree-days in July or August. Many freeze-thaw events occur in the fall and early spring.

Runoff

Precipitation and runoff rates in South Dakota differ annually and with season and location. Storms are generally of moderate intensity and short duration, and localized thunderstorms of high intensity and short duration are common. Approximately 70 percent of runoff occurs as a result of snowmelt and rainfall in the spring and early summer. The study area is located in an area that the U.S. Geological Survey has designated as Hydrologic sub-region B which has a moderate rating for runoff. There are scattered wetlands throughout the study area. Upper Wolf Creek is the only sub-watershed that has significant wetlands affecting runoff.

Topography

The study area lies in the James River Lowland section of the Central Lowland Physiographic Division. The generally flat slopes of the prairie characterize the topography of the study area with little local relief in the low rolling hills and stream channels. Elevations range from 2,000 feet mean sea level (msl) in the Ree Hills of the Upper Wolf Creek sub-watershed to about 1,350 feet msl in the Medicine Creek sub-watershed.

Ground Cover

Ground cover is described as anything on or above the surface of the ground, which alters the effect of precipitation on the soil surface and soil profile. Included in this factor are vegetation, litter, and rock fragments. A good ground cover acts to dissipate the energy of rainfall before it strikes the soil surface, deliver water to the soil at a relatively uniform rate, impede the overland flow of water, and promote infiltration by the action of roots within the soil. Conversely, the absence of ground cover, whether through natural growth habits or the effects of overgrazing, tillage, or fire, leaves the land surface open to the worst effects of storms.

Differences in vegetative type have a variable effect on erosion and sediment yield, even though percentages of total ground cover may be the same. For instance, the sod forming short grasses can have vastly different rates of runoff from the same range sites when compared to the intermediate/tall grasses. The sod forming grasses, which have a shallow, dense root system, have a lower rate of infiltration and therefore higher rates of runoff. The intermediate/tall grasses have a deeper root system that promotes a greater rate of infiltration and less runoff. Even though the ground cover is effective at both sites, there is the potential to impact sediment yield off-site due to the differences in amount of runoff and infiltration.

Land Use and Management

The use of land has a widely variable impact on sediment yield, depending largely on the susceptibility of the soil and rock to erosion, the amount of stress exerted by climatic factors and the type and intensity of use. In almost all instances, the land use either removes or reduces the amount of natural vegetative cover, which in turn affects the varied relationships within the environment. In certain instances, the loss or deterioration of vegetative cover may have little noticeable on-site impact but may increase off-site erosion, an effect of a higher volume and an acceleration of runoff.

Upland Erosion

Upland erosion occurs on sloping watershed lands beyond the confines of valleys. Sheet erosion, which involves the removal of a thin layer of soil over an extensive area, is usually not visible to the eye. This erosion type is evidenced by the formation of rills. Experience indicates that soil loss from sheet and rill erosion can be seen if it amounts to about five tons or more per acre.

A gully is defined as a small channel with steep sides caused by erosion from concentrated but intermittent flow of water usually during and immediately following heavy rains or after ice/snow melt. Significant gully erosion contributing to sediment loads is evidenced by the presence of numerous raw cuts along the hill slopes or areas of concentrated flow and sediment deposition in gently sloping or nearly level cropland areas. Deep soils on moderately steep to steep slopes usually provide an environment for gully development.

Downslope soil movement due to slumping or mass wasting can be an important factor in sediment yield on steep slopes that are underlain by unstable geologic formations.

Wind erosion from upland slopes and the deposition of the eroded material in stream channels can be a significant factor. The material deposited in channels is readily moved by subsequent runoff. Wind erosion is the major source of sediment from cropland in the study area.

Channel Erosion and Sediment Transport

Channel erosion and sediment transport are a function of the drainage network that has developed within the watershed. A healthy, well-developed drainage network will efficiently transport "normal" sediment loads. Networks that are healthy will transport runoff and sediment loads with no adverse effects from incised channels or floodplain degradation. Drainage networks that are unstable have channels that are down cutting and producing sediment loads that cannot be handled by the channel system. Poorly developed drainage networks characterize areas that serve as natural sediment retention basins.

PSIAC RESULTS

The inventoried sub-watersheds had a sediment production range of 0.48 tons per acre for the Upper Wolf Creek sub-watershed (Lake Louise) to 0.87 tons per acre in the Medicine Creek (Cottonwood Lake) sub-watershed. The three other sub-watersheds have approximately a 0.6 tons per acre sediment delivery rate. The lower sediment delivery rate of the Upper Wolf Creek sub-watershed can be attributed to the large number of ponds, wetlands, and water spreading-dike systems within the drainage area that act as sediment traps. Lake Mitchell is also located in the watershed and influences the amount of runoff from the upper third of the Upper Wolf Creek drainage area.

TABLE 3

PSIAC SEDIMENT DELIVERY RATE

(Tons/Acres)

SUBWATERSHED	TOTAL ACRES	TONS/ACRE	TONS
Medicine Creek (Cottonwood Lake)	161,413	0.87	140,430
Upper Wolf Creek (Lake Louise)	217,231	0.48	104,270
North Wolf Creek	105,700	0.63	66,590
Schaefer Creek	88,695	0.6	53,220
Lost Creek	62,236	0.6	37,340
TOTAL	**635,275**		**401,850**

The PSIAC sediment delivery rates for the study area compare well with a 1969 SCS (NRCS) sediment survey completed on Richmond Lake in Brown County, South Dakota. Richmond Lake is located approximately 65 miles north of Cottonwood Lake and has a drainage area of 73.5 square miles (47,040 acres). The Richmond Lake watershed and Cottonwood Lake watershed have similar geology, soils, climate, topography, hydrology, and land use. During the 32-year interval from 1937 to 1969 measured sediment accumulations in the lake amounted to an average annual 1.1 tons per acre of sediment delivered from the Richmond Lake watershed. This correlates closely to the PSIAC sediment delivery rate of 0.87 tons per acre in the Cottonwood Lake watershed.

SEDIMENT EVALUATIONS

PSIAC evaluations of the sub-watersheds estimate the sediment yield from all sources delivered to the mouth of the drainage area. Additional analysis is needed in order to apportion the sediment load among the different land use types and to develop land treatment strategies. Each sub-watershed was inventoried for the land use (Table 2, **Page 5)** and sediment contributions were determined for each type of land use (Table 4).

TABLE 4

PRESENT CONDITION SEDIMENT

SUBWATERSHED	ACRES	RANGELAND (TONS)	CROPLAND (TONS)	HAY/CRP (TONS)
Medicine Creek (Cottonwood Lake)	161,413	62,780	70,070	7,585
Upper Wolf Creek (Lake Louise)	217,231	79,920	20,110	4,235
North Wolf Creek	105,700	20,160	44,265	2,165
Schaefer Creek	88,695	25,630	26,280	1,310
Lost Creek	62,236	18,190	18,175	975
TOTAL	635,275	206,680	178,900	16,270

TOTAL SEDIMENT	**401,850 TONS**

In each sub-watershed, the acres of rangeland were divided into four condition classes; excellent, good, fair, and poor in order to assess reduction in sediment yield with improved range condition (Table 5). Rangeland in excellent condition has 76 to 100 percent of the original native vegetation consisting of the most desirable perennial forage plants. Native legumes and other desirable forbs are usually present. Good condition rangeland has a 51 to 75 percent mixture of original native vegetation. Some legumes and forbs may be present. Fair condition rangeland is characterized by a 26 to 50 percent mixture of original native vegetation, some legumes may be present, but most of the forbs that occur are the less desirable increasers or invaders. Overall vegetation appearance is shorter and the amount of bare ground generally is increasing. Poor condition rangeland vegetation has less than 25 percent of the highly palatable, desirable perennial plants. Invaders and increasers comprise the majority of the vegetation.

TABLE 5

PRESENT CONDITION RANGELAND
(ACRES)

SUBWATERSHED	RANGELAND ACRES	RANGE CONDITION CLASS (ACRES) POOR (Acres)	FAIR (Acres)	GOOD (Acres)	EXCELLENT (Acres)
Medicine Creek (Cottonwood Lake)	80,707	40,353	32,282	4,036	4,036
Upper Wolf Creek (Lake Louise)	173,785	34,757	95,582	26,068	17,387
North Wolf Creek	42,280	12,684	23,254	4,228	2,114
Schaefer Creek	53,217	10,111	30,866	7,983	4,257
Lost Creek	37,342	7,468	22,405	3,734	3,734
TOTAL	**387,331**	**105,373**	**204,389**	**46,049**	**31,528**

The sediment production from the different range condition classes was determined for each of the sub-watersheds based on standard NRCS procedures from the Engineering Field Manual for South Dakota, Chapter 11, Amendment 15 (Table 6).

TABLE 6

PRESENT CONDITION RANGELAND SEDIMENT
(TONS)

SUBWATERSHED	RANGELAND ACRES	RANGE CONDITION CLASS (TONS) POOR (Tons)	FAIR (Tons)	GOOD (Tons)	EXCELLENT (Tons)
Medicine Creek	80,707	37,360	21,910	2,010	1,210

(Cottonwood Lake)					
Upper Wolf Creek (Lake Louise)	173,785	20,220	45,480	9,670	4,345
North Wolf Creek	42,280	7,780	10,465	1,390	635
Schaefer Creek	53.217	6,690	14,990	2,820	1,275
Lost Creek	37,342	4,960	10.915	1,325	1,120
TOTAL	**387,331**	**77,010**	**103,760**	**17,215**	**8,705**

TOTAL SEDIMENT FROM RANGELAND **206,680 TONS**

The cropland was divided into four categories based on residue after planting: less than 15 percent; greater than 15 percent but less than 30 percent; greater than 30 percent but less than 70 percent; and greater than 70 percent. The county averages for the different residue management systems were used to prorate the acres for each category in the sub-watersheds (Table 7).

TABLE 7

PRESENT CONDITION

CROPLAND		PERCENT RESIDUE (ACRES)			
SUBWATERSHED	ACRES	<15 % (Acres)	>15 % <30 % (Acres)	>30 % <70 % (Acres)	>70 % (Acres)
Medicine Creek (Cottonwood Lake)	52,703	17,333	15,621	11,646	8,103
Upper Wolf Creek (Lake Louise)	26,947	6,591	7,073	8,476	4,807
North Wolf Creek	52,109	14,643	15,200	14,267	7,999
Schaefer Creek	28,648	8,050	8,357	7,844	4,397
Lost Creek	19,824	5,527	5,747	5,477	3,073
TOTAL	**180,231**	**52,144**	**51,998**	**47,710**	**28,379**

Using the Revised Universal Soil Loss Equation (RUSLE), erosion rates were calculated for each of the residue management levels. Sediment yields were calculated using standard NRCS procedures from the Engineering Field Manual for South Dakota, Chapter 11, Amendment 15 (Table 8).

TABLE 8

PRESENT CONDITION CROPLAND SEDIMENT
(TONS)

SUBWATERSHED	CROPLAND ACRES	PERCENT RESIDUE < 15% (Tons)	>15% < 30% (Tons)	>30% < 70% (Tons)	> 70% (Tons)
Medicine Creek (Cottonwood Lake)	52,703	26,000	18,745	8,735	4,005
Upper Wolf Creek (Lake Louise)	26,947	6,590	5,660	5,085	1,780
North Wolf Creek	52,109	21,965	18,240	10,700	2,610
Schaefer Creek	28,648	12,075	10,030	5,885	1,550
Lost Creek	19,824	8,290	6,895	4,110	1,090
TOTAL	**180,231**	**75,070**	**59,030**	**33,770**	**11,035**

TOTAL SEDIMENT FROM CROPLAND 178,905 TONS

STRATEGIES FOR SEDIMENT REDUCTION

There are numerous combinations of conservation practices that can be used to reduce sediment. The measures that are used for erosion and sediment control in South Dakota may be classified by purpose into several groups: 1.) To intercept and/or conserve moisture; 2.) To increase infiltration capacity; 3.) To reduce or eliminate stress on existing cover; 4.) To preserve existing cover regarded as adequate or in the process of becoming adequate with time; 5.) To increase the protection of the soil by a change in the type as well as density of vegetation.

As part of the assessment for the Lake Louise – Cottonwood Lake study area, four different levels of resource management practice application were assessed. The first level considered was the continuation of present conditions with no additional special projects or funding for sediment and erosion control conservation practices (Tables 3,4,5,6,and 7). Three other levels of consideration (low, moderate, high) were based on an increase in the total number of acres with improved rangeland grazing management and/or cropland residue management for erosion and sediment control. The low, moderate, and high levels of participation were selected to represent a reasonable expectation of change if there were an attempt to increase the level of resource management application. A comparison between the different levels of landowner participation provides a guide to the expected decrease in sediment versus the number of acres that would need to be treated to achieve any goals set for sediment reduction.

PRESENT CONDITION

If there are no significant changes in the present land use and on-going conservation programs remain funded at the present level there will be no significant changes in the amount of sediment produced in the watershed. Range condition will probably remain as is, with no long term trend either up or down. Presently 30 percent of the rangeland is under some type of range management. Crop residue management trends indicate that there is an annual increase of approximately two-percent in the number of acres that change to a higher level of residue use. Approximately 70 percent of the cropland acres have some level of residue management at this time. Since the majority of the land use is rangeland, the increase in residue management will not significantly affect reductions in total sediment.

LOW PARTICIPATION RATE

The low level of participation is an estimate of sediment reduction that can be expected if 20 percent of the rangeland in the watershed is managed to improve these acres one condition class. Typical range management practices would include grazing distribution, proper grazing use, and prescribed grazing systems. The sediment reduction in the Medicine Creek sub-watershed (Cottonwood Lake) would be 5.2 percent from rangeland (Table 9) or 2.3 percent of the total sediment load. The Upper Wolf Creek sub-watershed (Lake Louise) would have a sediment reduction of 4.7 percent from the rangeland (Table 9), a reduction in the total sediment of 3.6 percent.

Sediment reduction from the cropland acres was based on 10 percent of the cropland acres increasing residue management by one level. Typical conservation practices that could be used are changes from conventional tillage to minimum or no-till, changing cropping sequence, or establishing a permanent vegetative cover. The Medicine Creek sub-watershed (Cottonwood Lake) would have 4.0 percent reduction in sediment from the cropland (Table 10) and a 2.0 percent total reduction of sediment. In the Upper Wolf Creek sub-watershed

(Lake Louise) there would be a 2.6 percent reduction of sediment from cropland (Table 10) with an overall reduction of 0.5 percent.

MODERATE PARTICIPATION RATE

The moderate participation for rangeland was assumed to be increased management on 30 percent of the acres resulting in an improvement in the range condition one condition class. Medicine Creek (Cottonwood Lake) would have a 7.8 percent decrease from rangeland (Table 9) and a 3.5 percent total reduction. The Upper Wolf Creek sub-watershed (Lake Louise) would have a 6.2 percent reduction (Table 9) or an overall sediment reduction of 4.8 percent.

A 15 percent increase of one residue management level was assumed for the cropland acres. The Medicine Creek sub-watershed (Cottonwood Lake) would have a 4.3 percent decrease from cropland (Table 10) and an overall reduction of 2.1 percent. Upper Wolf Creek (Lake Louise) would have a 3.8 percent reduction of sediment from cropland (Table 10) or a 0.7 percent total reduction.

HIGH PARTICIPATION RATE

Forty percent was used for the high participation rate for rangeland. Sediment reductions were based on 40 percent of the rangeland acres with improved management to achieve an improvement of one condition class. There would be a 10.5 percent reduction from rangeland sediment (Table 9) or a total reduction of 4.7 percent in the Medicine Creek sub-watershed (Cottonwood Lake). The Upper Wolf Creek sub-watershed (Lake Louise) would have an 8.3 percent reduction in rangeland sediment (Table 9) or a total reduction of 6.3 percent. A 20 percent participation rate was used for the cropland. The Medicine Creek sub-watershed (Cottonwood Lake) would have a 5.7 percent decrease in sediment from cropland (Table 10) and an overall reduction of 2.9 percent. The Upper Wolf Creek sub-watershed (Lake Louise) would have a 5.1 percent reduction of cropland sediment (Table 10) and a total reduction of 1.0 percent.

TABLE 9

RANGELAND SEDIMENT
(TONS)

			SEDIMENT REDUCTIONS					
			PARTICIPATION RATES					
SUBWATERSHED	RANGELAND ACRES	PRESENT SEDIMENT (Tons)	LOW (Tons)	% CHANGE	MODERATE (Tons)	% CHANGE	HIGH (Tons)	% CHANGE

Medicine Creek (Cottonwood Lake)	80,707	62,785	59,520	5.2	57,890	7.8	56,195	10.5
Upper Wolf Creek (Lake Louise)	173,785	79,925	76,170	4.7	74,970	6.2	73,290	8.3
North Wolf Creek	42,280	20,160	19,110	5.2	18,590	7.8	18,045	10.5
Schaefer Creek	53,217	25,630	24,325	5.1	23,655	7.7	23,015	10.2
Lost Creek	37,342	18,190	17,260	5.1	16,790	7.7	16,790	11.3
TOTAL	**387,331**	**206,690**	**196,385**		**191,895**		**186,680**	
PERCENT REDUDCTION				**5.0**		**7.2**		**9.7**

TABLE 10

CROPLAND SEDIMENT
(TONS)

SUBWATERSHED	CROPLAND ACRES	PRESENT SEDIMENT (Tons)	SEDIMENT REDUCTIONS / PARTICIPATION RATE: LOW (Tons)	% CHANGE	MODERATE (Tons)	% CHANGE	HIGH (Tons)	% CHANGE
Medicine Creek (Cottonwood Lake)	52,700	70,075	67,200	4.1	67,060	4.3	66,080	5.7
Upper Wolf Creek (Lake Louise)	26,947	20,110	19,590	2.6	19,345	3.8	19,085	5.1
North Wolf Creek	52,109	44,265	42,940	3.0	42,275	4.5	41,610	6.0
Schaefer Creek	28,648	26,280	25,490	3.0	25,100	4.5	24,705	6.0
Lost Creek	19,824	18,175	17,630	3.0	17,360	4.5	17,085	6.0
TOTAL	**180,231**	**178,905**	**172,850**		**171,140**		**168,565**	
PERCENT REDUCTION					**3.4**			**4.4**
5.8								

The estimated reductions in sediment based on the Low, Moderate, or High participation rates are very conservative. This would be the minimum amount of reduction that could be expected. The changes for the different participation rates were prorated by percentage of existing land use and condition for each sub-watershed. This means that rangeland or cropland acres already managed at the higher levels were included when sediment reductions were calculated. There was no allowance for improving conditions by more than one class, (i.e. poor range condition was assumed to only improve to fair condition and not good or excellent). Neither was there any attempt to consider changes related to land use. The results reflect a generalized "across the board" type of change.

Additional conservation practices used in conjunction with rangeland or cropland management would greatly enhance the overall reduction of sediment from the study area. An example would be the use of buffer or filter strips along with improved residue management, or fencing riparian areas for dormant season grazing. It was beyond the scope of this assessment to evaluate individual, site-specific conservation practices.

A more detailed evaluation would need to be made to assess additional reductions based on other assumptions. This would be appropriate if there is a specific project or study proposed for a sub-watershed. Based on recent NRCS River Basin studies (Lower Bad River, 1994, Upper Bad River, 1998) significant sediment reductions can be expected from implementing a combination of conservation practices in addition to management systems. The Little Minnesota River-Big Stone Lake Watershed Project (NRCS, 1995) also projected significant reductions in phosphorus and sediment based on the implementation of conservation practices and land management treatment at various levels. The recommended plans had a favorable cost-benefit ratio and projected reductions up to 36 percent (Little Minnesota-Big Stone Lake Watershed Project).

PHOSPHORUS EVALUATION

The results from the water quality monitoring sites indicate that the ratio of dissolved phosphorus to total phosphorus is quite high (Table 11). The sediment attached portion of the measured phosphorus levels is not the most significant source of phosphorus delivered to Cottonwood Lake and Lake Louise. Additional evaluations of the watersheds should be completed to identify the possible sources of phosphorus that are not predominantly related to sediment.

TABLE 11

WATER YEAR 1999

PRESENT CONDITION PHOSPHORUS LOADINGS (POUNDS)

SUBWATERSHED	SITE	WATER VOLUME (GALLONS)	TOTAL PHOSPHORUS (POUNDS)	TOTAL DISSOLVED PHOSPHORUS (POUNDS)	RATIO DISSOLVED/ TOTAL (%)
Medicine Creek (Cottonwood Lake)	MC 1	469,030,233	4,061	3,722	92
	MC 2	594,237,738	5,688	5,294	93
	MC 3	131,099,041	371	345	93
	MC 4	719,165,762	4,682	3,435	73
	MC 5	862,689,875	7,011	6,004	86
	MC 6	2,175,568,064	11,467	7,391	64
Outlet	MC 7	2,816,783,468	5,344	2,820	53

TOTAL PHOSPHORUS DELIVERED TO COTTONWOOD LAKE 11,467 POUNDS

SUBWATERSHED	SITE	WATER VOLUME (GALLONS)	TOTAL PHOSPHORUS (POUNDS)	TOTAL DISSOLVED PHOSPHORUS (POUNDS)	RATIO DISSOLVED/ TOTAL (%)
Upper Wolf Creek (Lake Louise)	WC 1	489,952	2.118	1.582	75
	WC 2	2,932,468	0	0	
	WC 3	1,671,824	4.618	4.004	87
	WC 4	2,374,526	0	0	
	WC 5	33,400,924	128.788	112.341	87
Outlet	WC 6	43,098,794	173.196	142.262	82

TOTAL PHOSPHORUS DELIVERED TO LAKE LOUISE 128.8 POUNDS

WATER YEAR SPRING 2000

PRESENT CONDITION PHOSPHORUS LOADINGS (POUNDS)

SUBWATERSHED	SITE	WATER VOLUME (GALLONS)	TOTAL PHOSPHORUS (POUNDS)	TOTAL DISSOLVED PHOSPHORUS (POUNDS)	RATIO DISSOLVED/ TOTAL (%)
Medicine Creek (Cottonwood Lake)	MC 1	469,030,233	1,637	1,470	90
	MC 2	594,237,738	2,121	1,927	91
	MC 3	131,099,041	171	159	93
	MC 4	719,165,762	1,544	619	40
	MC 5	862,689,875	1,459	1,142	78
	MC 6	2,175,568,064	5,894	3,468	59
Outlet	MC 7	2,816,783,468	2,901	1,385	47

TOTAL PHOSPHORUS DELIVERED TO COTTONWOOD LAKE 5,894 POUNDS

CONCLUSIONS

The PSIAC sediment evaluations for the study area can provide a baseline for developing conservation practice implementation strategies for sediment reduction. In order to achieve a more substantial reduction in sediment delivered to Lake Louise, Cottonwood Lake, or other downstream watersheds, it will take more than cropland residue or grazing management. Other conservation practices for sediment and erosion control in combination with proper management are needed to effectively change sediment yield. Total Resource Management Systems or Progressive Conservation Planning in conjunction with the implementation of Best Management Practices would help to achieve the desired sediment reduction.

Water quality data indicate that the major sources of phosphorus in the watersheds are not sediment related. Total and Dissolved phosphorus values suggest that phosphorus loads are related to runoff from areas that have higher phosphorus concentrations than what is normally found in the soils.

APPENDIX A

Study Contributors and Participants

Name	Present Title (Years)	Education	Previous Experience (Years)
Robert Bartelson	Soil Conservationist	BS	Soil Cons Tech
Karen Brannen	Soil Conservationist 2	BS Agronomy (Soils)	Soil Cons 4 Res Cons 8 Soil Scientist 11
Joni Glanzer	GIS Specialist		
Grady Heitman	District Conservationist	BS	Soil Cons
Mike Knigge	Cartographic Technician		
Sean Kruger	Project Coordinator	BS	
Marvin Nelson	District Conservationist	BS	Soil Cons Soil Cons Tech
Duane Nielsen	Technician		
Robert Smith	Environmental Scientist	BS	
Cindy Steele	Environmental Engineer 8	BS Biology MS Env. Eng PhD Grad Study	Soil Cons 4
Kelly Stout	District Conservationist	BS	Soil Cons

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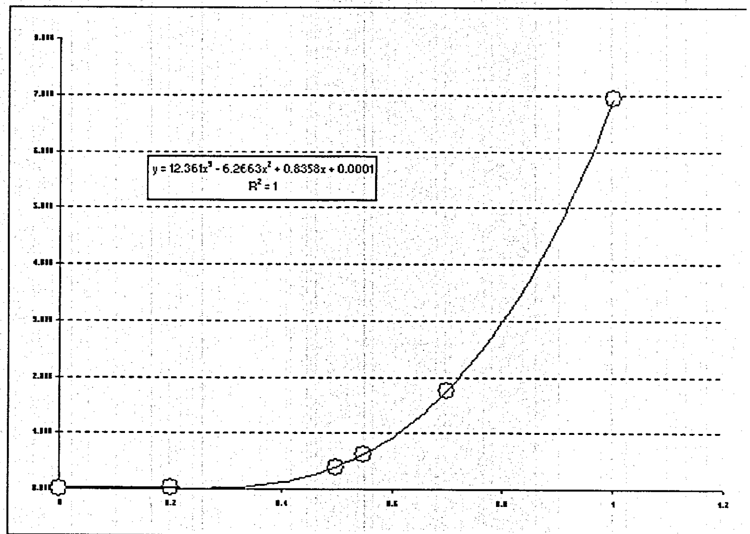
Appendix B. Stage to Discharge Tables

Site WC-1

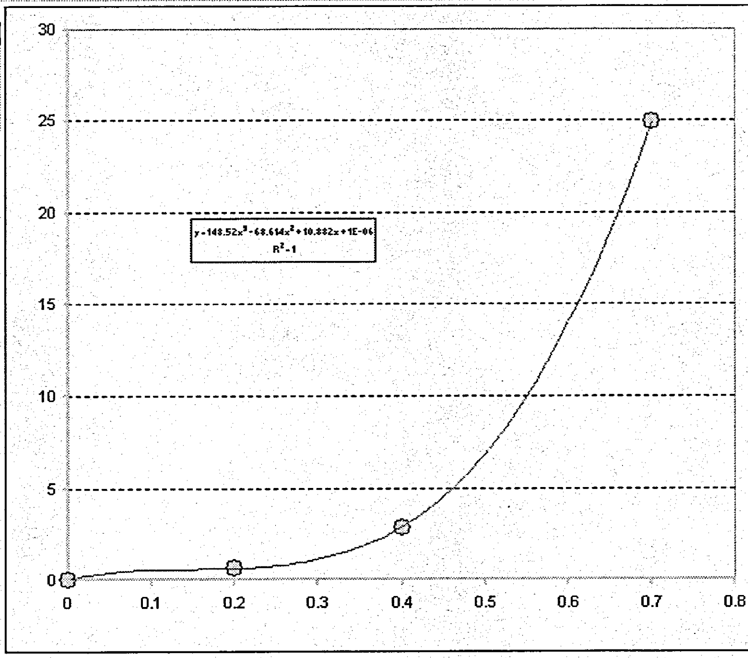
Stage	Flow
0	0.000
0.2	0.020
0.5	0.390
0.55	0.620
0.7	1.760
1	6.930



Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge
0	0.000	0.26	0.011	0.52	0.478	0.78	2.706	1.04	7.996
0.01	0.008	0.27	0.012	0.53	0.523	0.79	2.844	1.05	8.278
0.02	0.014	0.28	0.014	0.54	0.571	0.8	2.987	1.06	8.567
0.03	0.020	0.29	0.017	0.55	0.621	0.81	3.135	1.07	8.863
0.04	0.024	0.3	0.021	0.56	0.674	0.82	3.287	1.08	9.165
0.05	0.028	0.31	0.025	0.57	0.730	0.83	3.445	1.09	9.474
0.06	0.030	0.32	0.031	0.58	0.789	0.84	3.607	1.1	9.790
0.07	0.032	0.33	0.038	0.59	0.851	0.85	3.774	1.11	10.112
0.08	0.033	0.34	0.046	0.6	0.916	0.86	3.947	1.12	10.442
0.09	0.034	0.35	0.055	0.61	0.984	0.87	4.124	1.13	10.779
0.1	0.033	0.36	0.066	0.62	1.056	0.88	4.307	1.14	11.123
0.11	0.033	0.37	0.078	0.63	1.130	0.89	4.495	1.15	11.474
0.12	0.032	0.38	0.091	0.64	1.209	0.9	4.688	1.16	11.832
0.13	0.030	0.39	0.106	0.65	1.290	0.91	4.886	1.17	12.198
0.14	0.028	0.4	0.123	0.66	1.376	0.92	5.091	1.18	12.571
0.15	0.026	0.41	0.141	0.67	1.465	0.93	5.300	1.19	12.951
0.16	0.024	0.42	0.162	0.68	1.558	0.94	5.516	1.2	13.339
0.17	0.022	0.43	0.184	0.69	1.654	0.95	5.737	1.21	13.735
0.18	0.020	0.44	0.208	0.7	1.754	0.96	5.964	1.22	14.139
0.19	0.017	0.45	0.234	0.71	1.859	0.97	6.196	1.23	14.550
0.2	0.015	0.46	0.262	0.72	1.967	0.98	6.435	1.24	14.969
0.21	0.014	0.47	0.292	0.73	2.080	0.99	6.680	1.25	15.396
0.22	0.012	0.48	0.325	0.74	2.196	1	6.931	1.26	15.831
0.23	0.011	0.49	0.359	0.75	2.317	1.01	7.188	1.27	16.275
0.24	0.011	0.5	0.397	0.76	2.442	1.02	7.451	1.28	16.726
0.25	0.011	0.51	0.436	0.77	2.572	1.03	7.720	1.29	17.186

Site WC-2

Stage	Flow
0	0.000
0.2	0.620
0.4	2.880
0.7	24.940



Stage	Discharge
0	0.000
0.01	0.102
0.02	0.191
0.03	0.269
0.04	0.335
0.05	0.391
0.06	0.438
0.07	0.476
0.08	0.507
0.09	0.532
0.1	0.551
0.11	0.564
0.12	0.574
0.13	0.581
0.14	0.586
0.15	0.590
0.16	0.593
0.17	0.597
0.18	0.602
0.19	0.609
0.2	0.620
0.21	0.635
0.22	0.655
0.23	0.680
0.24	0.713
0.25	0.753

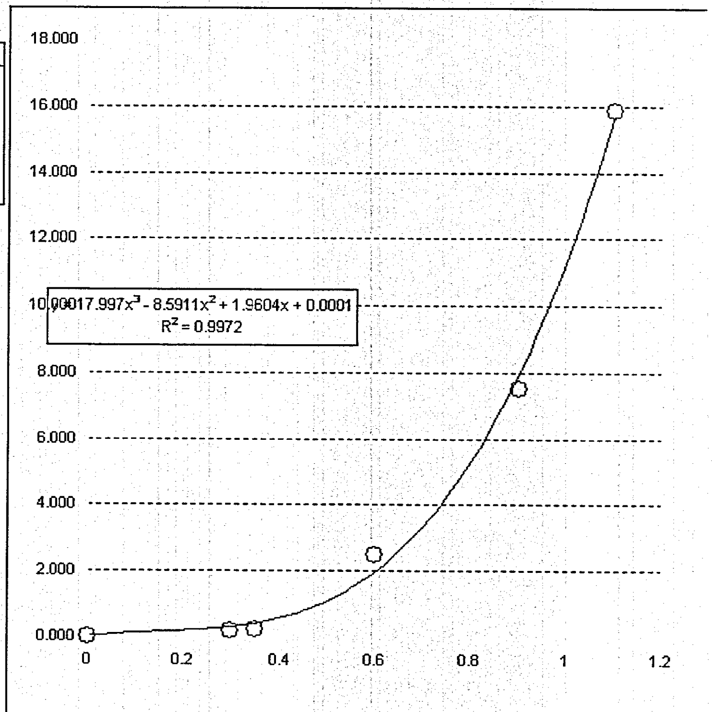
Stage	Discharge
0.26	0.801
0.27	0.859
0.28	0.928
0.29	1.008
0.3	1.099
0.31	1.204
0.32	1.323
0.33	1.456
0.34	1.606
0.35	1.771
0.36	1.954
0.37	2.156
0.38	2.377
0.39	2.618
0.4	2.880
0.41	3.164
0.42	3.470
0.43	3.801
0.44	4.156
0.45	4.536
0.46	4.943
0.47	5.378
0.48	5.840
0.49	6.331
0.5	6.853
0.51	7.405

Stage	Discharge
0.52	7.989
0.53	8.605
0.54	9.255
0.55	9.939
0.56	10.659
0.57	11.415
0.58	12.208
0.59	13.039
0.6	13.908
0.61	14.818
0.62	15.768
0.63	16.760
0.64	17.794
0.65	18.871
0.66	19.993
0.67	21.159
0.68	22.372
0.69	23.632
0.7	24.939
0.71	26.295
0.72	27.700
0.73	29.156
0.74	30.664
0.75	32.223
0.76	33.836
0.77	35.502

Stage	Discharge
0.78	37.224
0.79	39.001
0.8	40.835
0.81	42.726
0.82	44.676
0.83	46.686
0.84	48.755
0.85	50.886
0.86	53.079
0.87	55.334
0.88	57.654
0.89	60.038
0.9	62.488
0.91	65.004
0.92	67.587
0.93	70.239
0.94	72.960
0.95	75.751
0.96	78.613
0.97	81.547
0.98	84.553
0.99	87.633
1	90.788
1.01	94.018
1.02	97.324
1.03	100.708

Site WC-3

Stage	Flow
0	0.000
0.3	0.160
0.35	0.210
0.6	2.510
0.9	7.500
1.1	15.870



Stage	Discharge
0	0.000
0.01	0.019
0.02	0.036
0.03	0.052
0.04	0.066
0.05	0.079
0.06	0.091
0.07	0.101
0.08	0.111
0.09	0.120
0.1	0.128
0.11	0.136
0.12	0.143
0.13	0.149
0.14	0.156
0.15	0.162
0.16	0.168
0.17	0.174
0.18	0.180
0.19	0.186
0.2	0.193
0.21	0.200
0.22	0.207
0.23	0.215
0.24	0.225
0.25	0.234

Stage	Discharge
0.26	0.245
0.27	0.257
0.28	0.271
0.29	0.285
0.3	0.301
0.31	0.318
0.32	0.337
0.33	0.358
0.34	0.381
0.35	0.405
0.36	0.432
0.37	0.461
0.38	0.492
0.39	0.526
0.4	0.561
0.41	0.600
0.42	0.641
0.43	0.685
0.44	0.732
0.45	0.783
0.46	0.836
0.47	0.892
0.48	0.952
0.49	1.015
0.5	1.082
0.51	1.153

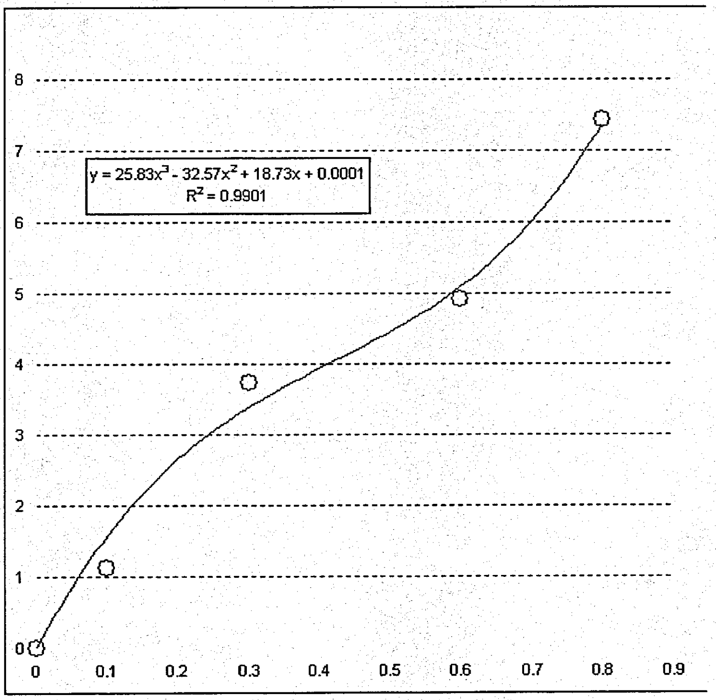
Stage	Discharge
0.52	1.227
0.53	1.305
0.54	1.387
0.55	1.474
0.56	1.564
0.57	1.659
0.58	1.759
0.59	1.862
0.6	1.971
0.61	2.084
0.62	2.202
0.63	2.325
0.64	2.454
0.65	2.587
0.66	2.726
0.67	2.870
0.68	3.019
0.69	3.175
0.7	3.336
0.71	3.503
0.72	3.675
0.73	3.854
0.74	4.039
0.75	4.230
0.76	4.428
0.77	4.632

Stage	Discharge
0.78	4.843
0.79	5.060
0.8	5.285
0.81	5.516
0.82	5.754
0.83	5.999
0.84	6.252
0.85	6.512
0.86	6.779
0.87	7.054
0.88	7.337
0.89	7.627
0.9	7.925
0.91	8.232
0.92	8.546
0.93	8.869
0.94	9.200
0.95	9.539
0.96	9.887
0.97	10.244
0.98	10.609
0.99	10.983
1	11.366
1.01	11.759
1.02	12.160
1.03	12.571

Stage	Discharge
1.04	12.991
1.05	13.421
1.06	13.860
1.07	14.309
1.08	14.768
1.09	15.236
1.1	15.715
1.11	16.204
1.12	16.704
1.13	17.213
1.14	17.733
1.15	18.264
1.16	18.805
1.17	19.358
1.18	19.921
1.19	20.495
1.2	21.080
1.21	21.677
1.22	22.285
1.23	22.904
1.24	23.535
1.25	24.177
1.26	24.832
1.27	25.498
1.28	26.176
1.29	26.867

Site WC-4

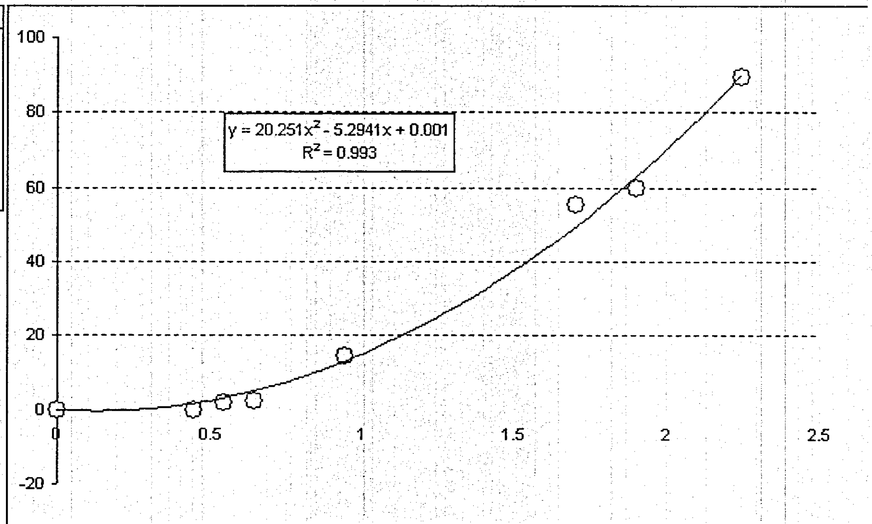
Stage	Flow
0	0
0.1	1.13
0.3	3.73
0.6	4.92
0.8	7.42



Stage	Discharge
0	0.000
0.01	0.184
0.02	0.362
0.03	0.533
0.04	0.699
0.05	0.858
0.06	1.012
0.07	1.160
0.08	1.303
0.09	1.441
0.1	1.573
0.11	1.701
0.12	1.823
0.13	1.941
0.14	2.055
0.15	2.164
0.16	2.269
0.17	2.370
0.18	2.467
0.19	2.560
0.2	2.650
0.21	2.736
0.22	2.819
0.23	2.899
0.24	2.976
0.25	3.051
0.26	3.122
0.27	3.191
0.28	3.258
0.29	3.323
0.3	3.385
0.31	3.446
0.32	3.505
0.33	3.562
0.34	3.618
0.35	3.673
0.36	3.727
0.37	3.780
0.38	3.832
0.39	3.883
0.4	3.934
0.41	3.985
0.42	4.035
0.43	4.085
0.44	4.136
0.45	4.187
0.46	4.238
0.47	4.290
0.48	4.343
0.49	4.397
0.5	4.451
0.51	4.507
0.52	4.565
0.53	4.624
0.54	4.684
0.55	4.747
0.56	4.811
0.57	4.878
0.58	4.947
0.59	5.018
0.6	5.092
0.61	5.169
0.62	5.249
0.63	5.332
0.64	5.418
0.65	5.507
0.66	5.600
0.67	5.697
0.68	5.798
0.69	5.903
0.7	6.011
0.71	6.125
0.72	6.242
0.73	6.365
0.74	6.492
0.75	6.624
0.76	6.761
0.77	6.904
0.78	7.052
0.79	7.205
0.8	7.364
0.81	7.529
0.82	7.700
0.83	7.878
0.84	8.061
0.85	8.252
0.86	8.448
0.87	8.652
0.88	8.863
0.89	9.080
0.9	9.305
0.91	9.538
0.92	9.778
0.93	10.026
0.94	10.281
0.95	10.545
0.96	10.817
0.97	11.097
0.98	11.386
0.99	11.684
1	11.990
1.01	12.305
1.02	12.630
1.03	12.964

Site WC-5

Stage	Discharge
0	0
0.445	0.05
0.545	1.99
0.645	2.33
0.945	14.64
1.7	55.37
1.9	59.67
2.245	89.33



Stage	Discharge
0	0.000
0.01	-0.051
0.02	-0.098
0.03	-0.141
0.04	-0.179
0.05	-0.214
0.06	-0.245
0.07	-0.271
0.08	-0.294
0.09	-0.312
0.1	-0.327
0.11	-0.337
0.12	-0.344
0.13	-0.346
0.14	-0.344
0.15	-0.338
0.16	-0.329
0.17	-0.315
0.18	-0.297
0.19	-0.275
0.2	-0.249
0.21	-0.219
0.22	-0.185
0.23	-0.146
0.24	-0.104
0.25	-0.058
0.26	-0.007
0.27	0.047
0.28	0.105
0.29	0.168
0.3	0.234
0.31	0.305
0.32	0.380
0.33	0.458
0.34	0.541
0.35	0.628
0.36	0.719
0.37	0.814
0.38	0.912
0.39	1.015
0.4	1.123
0.41	1.234
0.42	1.349
0.43	1.468
0.44	1.591
0.45	1.718
0.46	1.850
0.47	1.985
0.48	2.125
0.49	2.268
0.5	2.416

Stage	Discharge
0.51	2.567
0.52	2.723
0.53	2.883
0.54	3.046
0.55	3.214
0.56	3.386
0.57	3.562
0.58	3.742
0.59	3.926
0.6	4.114
0.61	4.306
0.62	4.502
0.63	4.702
0.64	4.907
0.65	5.115
0.66	5.327
0.67	5.544
0.68	5.764
0.69	5.989
0.7	6.217
0.71	6.450
0.72	6.686
0.73	6.927
0.74	7.172
0.75	7.421
0.76	7.673
0.77	7.930
0.78	8.191
0.79	8.456
0.8	8.725
0.81	8.998
0.82	9.276
0.83	9.557
0.84	9.842
0.85	10.131
0.86	10.425
0.87	10.722
0.88	11.024
0.89	11.329
0.9	11.639
0.91	11.952
0.92	12.270
0.93	12.592
0.94	12.917
0.95	13.247
0.96	13.581
0.97	13.919
0.98	14.261
0.99	14.607
1	14.957
1.01	15.311

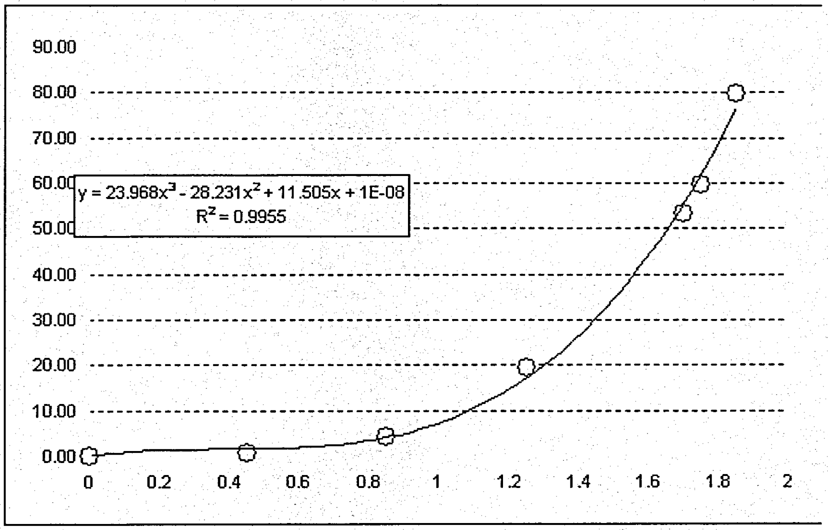
Stage	Discharge
1.02	15.669
1.03	16.031
1.04	16.398
1.05	16.768
1.06	17.142
1.07	17.521
1.08	17.903
1.09	18.290
1.1	18.680
1.11	19.075
1.12	19.473
1.13	19.876
1.14	20.283
1.15	20.694
1.16	21.109
1.17	21.527
1.18	21.950
1.19	22.377
1.2	22.809
1.21	23.244
1.22	23.683
1.23	24.126
1.24	24.573
1.25	25.025
1.26	25.480
1.27	25.939
1.28	26.403
1.29	26.870
1.3	27.342
1.31	27.817
1.32	28.297
1.33	28.781
1.34	29.269
1.35	29.760
1.36	30.256
1.37	30.756
1.38	31.260
1.39	31.768
1.4	32.280
1.41	32.796
1.42	33.316
1.43	33.841
1.44	34.369
1.45	34.901
1.46	35.438
1.47	35.978
1.48	36.523
1.49	37.071
1.5	37.624
1.51	38.180
1.52	38.741

Stage	Discharge
1.53	39.306
1.54	39.874
1.55	40.447
1.56	41.024
1.57	41.605
1.58	42.190
1.59	42.779
1.6	43.372
1.61	43.969
1.62	44.570
1.63	45.175
1.64	45.785
1.65	46.398
1.66	47.015
1.67	47.637
1.68	48.262
1.69	48.892
1.7	49.525
1.71	50.163
1.72	50.805
1.73	51.450
1.74	52.100
1.75	52.754
1.76	53.412
1.77	54.074
1.78	54.740
1.79	55.410
1.8	56.084
1.81	56.762
1.82	57.444
1.83	58.130
1.84	58.821
1.85	59.515
1.86	60.213
1.87	60.916
1.88	61.622
1.89	62.333
1.9	63.047
1.91	63.766
1.92	64.489
1.93	65.215
1.94	65.946
1.95	66.681
1.96	67.420
1.97	68.163
1.98	68.910
1.99	69.661
2	70.416
2.01	71.175
2.02	71.938
2.03	72.705

Stage	Discharge
2.04	73.477
2.05	74.252
2.06	75.031
2.07	75.815
2.08	76.602
2.09	77.394
2.1	78.189
2.11	78.989
2.12	79.793
2.13	80.600
2.14	81.412
2.15	82.228
2.16	83.048
2.17	83.872
2.18	84.700
2.19	85.532
2.2	86.368
2.21	87.208
2.22	88.052
2.23	88.900
2.24	89.753
2.25	90.609
2.26	91.469
2.27	92.334
2.28	93.202
2.29	94.075
2.3	94.951
2.31	95.832
2.32	96.717
2.33	97.605
2.34	98.498
2.35	99.395
2.36	100.296
2.37	101.201
2.38	102.110
2.39	103.023
2.4	103.940
2.41	104.861
2.42	105.786
2.43	106.715
2.44	107.649
2.45	108.586
2.46	109.527
2.47	110.473
2.48	111.422
2.49	112.376
2.5	113.334
2.51	114.295
2.52	115.261
2.53	116.231
2.54	117.204

Site WC-6 Outlet to Lake Louise

Stage	Discharge
0	0.00
0.45	0.70
0.85	4.06
1.25	19.31
1.7	53.46
1.75	59.50
1.85	79.74



Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge
0	0.00	0.41	1.62	0.82	3.67	1.23	16.04	1.64	48.66
0.01	0.11	0.42	1.63	0.83	3.81	1.24	16.56	1.65	49.79
0.02	0.22	0.43	1.63	0.84	3.95	1.25	17.08	1.66	50.94
0.03	0.32	0.44	1.64	0.85	4.10	1.26	17.62	1.67	52.11
0.04	0.42	0.45	1.64	0.86	4.26	1.27	18.17	1.68	53.30
0.05	0.51	0.46	1.65	0.87	4.42	1.28	18.74	1.69	54.50
0.06	0.59	0.47	1.66	0.88	4.60	1.29	19.31	1.7	55.73
0.07	0.68	0.48	1.67	0.89	4.77	1.3	19.90	1.71	56.97
0.08	0.75	0.49	1.68	0.9	4.96	1.31	20.51	1.72	58.23
0.09	0.82	0.5	1.69	0.91	5.15	1.32	21.12	1.73	59.51
0.1	0.89	0.51	1.70	0.92	5.35	1.33	21.75	1.74	60.81
0.11	0.96	0.52	1.72	0.93	5.56	1.34	22.39	1.75	62.13
0.12	1.02	0.53	1.74	0.94	5.78	1.35	23.05	1.76	63.47
0.13	1.07	0.54	1.75	0.95	6.00	1.36	23.72	1.77	64.83
0.14	1.12	0.55	1.78	0.96	6.23	1.37	24.41	1.78	66.21
0.15	1.17	0.56	1.80	0.97	6.47	1.38	25.10	1.79	67.60
0.16	1.22	0.57	1.82	0.98	6.72	1.39	25.82	1.8	69.02
0.17	1.26	0.58	1.85	0.99	6.98	1.4	26.54	1.81	70.46
0.18	1.30	0.59	1.88	1	7.24	1.41	27.28	1.82	71.92
0.19	1.33	0.6	1.92	1.01	7.52	1.42	28.04	1.83	73.40
0.2	1.36	0.61	1.95	1.02	7.80	1.43	28.81	1.84	74.90
0.21	1.39	0.62	1.99	1.03	8.09	1.44	29.60	1.85	76.42
0.22	1.42	0.63	2.04	1.04	8.39	1.45	30.40	1.86	77.96
0.23	1.44	0.64	2.08	1.05	8.70	1.46	31.21	1.87	79.52
0.24	1.47	0.65	2.13	1.06	9.02	1.47	32.04	1.88	81.11
0.25	1.49	0.66	2.19	1.07	9.35	1.48	32.89	1.89	82.71
0.26	1.50	0.67	2.24	1.08	9.69	1.49	33.75	1.9	84.34
0.27	1.52	0.68	2.31	1.09	10.04	1.5	34.63	1.91	85.99
0.28	1.53	0.69	2.37	1.1	10.40	1.51	35.52	1.92	87.66
0.29	1.55	0.7	2.44	1.11	10.77	1.52	36.43	1.93	89.35
0.3	1.56	0.71	2.52	1.12	11.15	1.53	37.36	1.94	91.07
0.31	1.57	0.72	2.59	1.13	11.54	1.54	38.30	1.95	92.81
0.32	1.58	0.73	2.68	1.14	11.94	1.55	39.26	1.96	94.57
0.33	1.58	0.74	2.77	1.15	12.35	1.56	40.24	1.97	96.35
0.34	1.59	0.75	2.86	1.16	12.77	1.57	41.23	1.98	98.15
0.35	1.60	0.76	2.96	1.17	13.20	1.58	42.24	1.99	99.98
0.36	1.60	0.77	3.06	1.18	13.65	1.59	43.27	2	101.83
0.37	1.61	0.78	3.17	1.19	14.10	1.6	44.31	2.01	103.70
0.38	1.61	0.79	3.29	1.2	14.57	1.61	45.37	2.02	105.60

Appendix C. Inlake Samples

SITE	DATE	DEPTH	WTMP	SECCHI	DO	COND	TURB	FPH	TALKA	TSOL	TSSOL	AMMO	NIT	TKN	TPO4	TDPO4	FEC	TVSS	Chl-A	Tnit	orgnit	inorg
LL-1	21-Jun-99	SURFACE	22.1	1	8.60	617		8.11	134	512	10	0.01	0.10	1.97	0.531	0.427	10		17.42	2.07	1.96	0.11
LL-1	20-Jul-99	SURFACE	24.24	1	9.81	667	44	8.05	145	540	11	0.01	0.05	1.68	0.704	0.582	10		41.54	1.73	1.67	0.06
LL-1	10-Aug-99	SURFACE	24.53	0.6	18.03	675	76	8.44	154	568	14	0.01	0.05	1.67	1.010	0.634	10	11	140.37	1.72	1.66	0.06
LL-1	14-Sep-99	SURFACE	15.59	1.3	8.47	651	30	8.62	163	561	8	0.01	0.10	1.80	0.847	0.75	10	4	42.21	1.90	1.79	0.11
LL-1	14-Oct-99	SURFACE	11.78	2.2	11.46	607	25	7.95	165	553	14	0.01	0.05	1.56	0.528	0.427	20	7	15.04	1.61	1.55	0.06
LL-1	22-Dec-99	SURFACE	2.95	2.4	15.55	525	4.7	7.77	174	584	7	0.01	0.05	1.38	0.235	0.208	10	1	0.11	1.43	1.37	0.06
LL-1	27-Jan-00	SURFACE	3.79	2.5	12.63	580		7.04	183	613	3	0.01	0.05	1.26	0.204	0.184	10	1	7.34	1.31	1.25	0.06
LL-1	22-Feb-00	SURFACE	4.71	3.4	13.22	593	3.1	8.26	184	616	<1	0.01	0.05	1.03	0.172	0.154	<2	<1	2.95	1.08	1.02	0.06
LL-1	21-Mar-00	SURFACE	5.2	1.4	12.14	644	18.4	8.26	171	566	7	0.01	0.05	1.23	0.170	0.116	<10	2	16.68	1.28	1.22	0.06
LL-1	12-May-00	SURFACE	18.08		9.65	897	14.1	8.55	177	569	6	0.01	0.05	0.95	0.216	0.189	<10	3		1.00	0.94	0.06
LL-1	21-Jun-99	BOTTOM	21		4.60	654		8.01	133	506	10	0.01	0.05	1.63	0.478	0.413				1.68	1.62	0.06
LL-1	20-Jul-99	BOTTOM	23.58		5.40	666	22	7.91	144	534	8	0.01	0.05	1.45	0.643	0.574		3		1.50	1.44	0.06
LL-1	10-Aug-99	BOTTOM	24.46			675	103	8.64	156	562	14	0.01	0.05	1.81	0.848	0.638		11		1.86	1.80	0.06
LL-1	14-Sep-99	BOTTOM	15.54		7.90	650	25	8.38	165	558	10	0.01	0.10	1.66	0.842	0.756		5		1.76	1.65	0.11
LL-1	14-Oct-99	BOTTOM	11.72		10.80	611	13	7.91	163	545	6	0.01	0.05	1.46	0.482	0.44	0	1		1.51	1.45	0.06
LL-1	22-Dec-99	BOTTOM	2.67		15.56	519	7.6	7.68	175	583	7	0.01	0.05	1.22	0.243	0.206		2		1.27	1.21	0.06
LL-1	27-Jan-00	BOTTOM	3.91		11.23	587		6.81	182	618	3	0.01	0.05	1.31	0.204	0.177		1		1.36	1.30	0.06
LL-1	22-Feb-00	BOTTOM	4.42		13.23	589	3.8	7.95	184	618	2	0.01	0.05	1.06	0.182	0.16		1		1.11	1.05	0.06
LL-1	21-Mar-00	BOTTOM	4.78		11.91	635	28.6	8.26	167	565	5	0.01	0.05	1.29	0.170	0.115		1		1.34	1.28	0.06
LL-1	12-May-00	BOTTOM	17.47		6.74	889	25.6	8.35	178	566	6	0.01	0.05	1.00	0.238	0.206		3		1.05	0.99	0.06
LL-2	21-Jun-99	SURFACE	22	1	7.60			8.07											19.3			
LL-2	20-Jul-99	SURFACE	24.59	1	10.78	672	22	8.17	144	542	12	0.01	0.05	1.92	0.664	0.588	10	7	19.77	1.97	1.91	0.06
LL-2	10-Aug-99	SURFACE	24.41	0.6	14.88	677	114	8.89	154	566	17	0.01	0.05	2.49	0.759	0.614	10	15	175.54	2.54	2.48	0.06
LL-2	14-Sep-99	SURFACE	15.52	1.4	9.98	651	16	8.35	164	562	8	0.01	0.10	1.74	0.785	0.736	10	5	42.55	1.84	1.73	0.11
LL-2	14-Oct-99	SURFACE	11.64	1.8	11.37	614	38	7.92	165	553	14	0.01	0.05	1.56	0.528	0.427	20	7	21.04	1.61	1.55	0.06
LL-2	22-Dec-99	SURFACE	2.29	2.8	16.34	510	20.9	7.63	171	580	6	0.01	0.05	1.30	0.239	0.201	10	1	0.09	1.35	1.29	0.06
LL-2	27-Jan-00	SURFACE	3.4	2.5	14.76	566	7.2	6.96	185	622	3	0.01	0.05	1.24	0.202	0.188	10	2	1.13	1.29	1.23	0.06
LL-2	22-Feb-00	SURFACE	4.37	3.3	12.64	583	5.2	8.10	182	619	<1	0.01	0.05	1.19	0.186	0.162	<2	<1	0.03	1.24	1.18	0.06
LL-2	21-Mar-00	SURFACE	5.09	1.6	12.26	637	16.8	8.25	171	569	9	0.01	0.10	1.06	0.173	0.126	<10	3	17.65	1.16	1.05	0.11
LL-2	12-May-00	SURFACE	17.67		9.08	889	11.4	8.49	175	570	6	0.01	0.05	1.42	0.224	0.181	<10	3		1.47	1.41	0.06
LL-2	21-Jun-99	BOTTOM	18		0.10																	
LL-2	20-Jul-99	BOTTOM	22.8		1.72	651	17	7.69	161	561	42	0.44	0.05	2.23	1.100	0.926		8		2.28	1.79	0.49
LL-2	10-Aug-99	BOTTOM	21.3		5.58	662	58	8.16	170	564	32	0.36	0.05	1.97	0.954	1.15		9		2.02	1.61	0.41
LL-2	14-Sep-99	BOTTOM	15.39		8.51	649	18	8.30	163	561	9	0.01	0.10	1.67	0.801	0.721		5		1.77	1.66	0.11
LL-2	14-Oct-99	BOTTOM	11.75		10.10	612	21	7.99	163	545	6	0.01	0.05	1.46	0.482	0.44		1		1.51	1.45	0.06
LL-2	22-Dec-99	BOTTOM	3.57		11.35	537	7.5	7.53	170	580	6	0.01	0.05	1.23	0.211	0.184		3		1.28	1.22	0.06
LL-2	27-Jan-00	BOTTOM	3.34		15.03	566	9.9	7.04	184	644	30	0.01	0.05	1.34	0.272	0.191		4		1.39	1.33	0.06
LL-2	22-Feb-00	BOTTOM	4.38		9.56	590	10.9	7.66	184	614	1	0.01	0.05	1.09	0.181	0.164		<1		1.14	1.08	0.06
LL-2	21-Mar-00	BOTTOM	4.68		11.82	630	30	8.21	171	570	7	0.01	0.05	0.99	0.169	0.122		1		1.04	0.98	0.06
LL-2	12-May-00	BOTTOM	17.03		6.51	882	22.6	8.29	177	567	6	0.01	0.05	1.24	0.222	0.186		2		1.29	1.23	0.06

Appendix D. Fisheries Report

Introduction

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

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

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

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

Study Area

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

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

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

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

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

Methods

Fish Community Survey

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

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

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

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

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

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

Angler Use and Sport Fish Harvest

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

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

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

    1. Yes
    2. No
    3. No opinion

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

Results and Discussion

Lake Louise

Fish Community Survey

Largemouth Bass

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

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

Table 2. Stock density index objective ranges for largemouth bass and bluegill under three different management strategies (taken from Willis et al. 1993).

	Largemouth Bass			Bluegill	
Option	PSD	RSD-P	RSD-M	PSD	RSD-P
Panfish	20-40	0-10		50-80	10-30
Balance	40-70	10-40	0-10	20-60	5-20
Big Bass	50-80	30-60	10-25	10-50	0-10

Mean Wr values for all length categories exceeded 100 indicating excellent condition (Table 5). Sub-stock largemouth bass Wr values were significantly higher than stock-length bass. However, no significant length related trends in Wr values for stock-length individuals were identified; thus, an overall stock-length mean Wr can be used. Largemouth bass condition was similar to 1997 (Blackwell 1998) with a mean stock-length Wr value of 103 obtained in both 1998 and 1997. Lake Louise largemouth bass condition is slightly higher than typically would be expected for a largemouth bass population managed under a panfish option and would be expected because of the apparent reduced growth rates. Gabelhouse (1987) recommended a Wr target range of 85-95 when maximum production of bluegill was desired.

Annual mortality (natural and angler harvest) was estimated to be 29% from catch curve analysis and 33% using the Chapman-Robson method. Largemouth bass older than age 4 have been reduced to absent in recent electrofishing samples. The absence of the older age classes may be indicative of these individuals being harvested by anglers. Some largemouth bass do survive and reach older ages as is indicated by the presence of age-7 and -8 bass in the 1998 sample (Table 4).

Bluegill

Bluegills are abundant in Lake Louise composing the majority of fishes collected during electrofishing and trap netting (Table 6). The 1998 proportion of quality-length bluegills was significantly greater in both the electrofishing and trap net samples than in the respective 1997 samples. The electrofishing PSD value (62; Table 3) was within the objective range for bluegill managed under the panfish option (Table 2), but the trap net PSD (85; Table 3) exceeded the objective range. Relative stock density of preferred length values (Table 3) were below the objective range for the panfish option (Table 2). As in 1997, a significant difference in the proportion of quality-length bluegill existed between Lake Louise electrofishing and trap net samples. However, comparison of the length frequency distributions (Figure 3) failed to identify the two samples as being independent. Electrofishing is known to underestimate bluegill size structure (Reynolds and Simpson 1978), because of this, it is believed that the trap net PSD and RSD-P values provide a closer approximation of Lake Louise bluegill size structure. Trap net PSD values have remained fairly constant since 1995 with only a slight dip in 1997 (Figure 3).

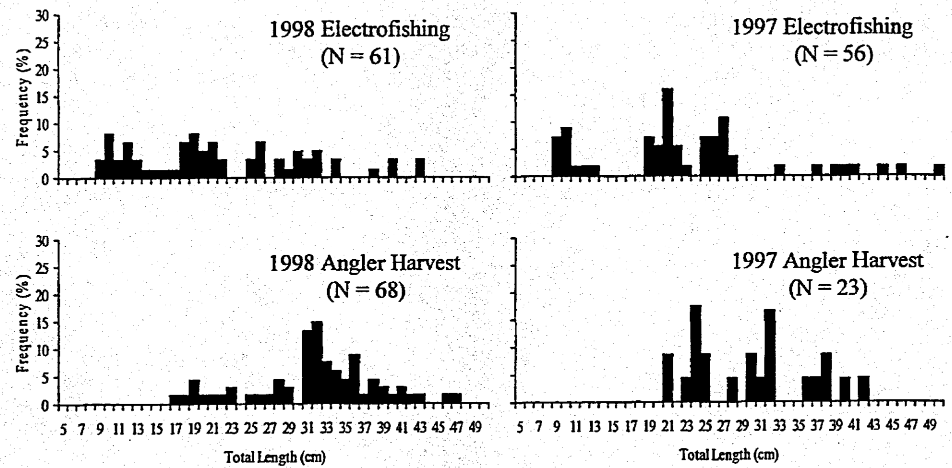


Figure 1. Lake Louise length frequency distributions for largemouth bass captured by electrofishing and harvested by anglers in 1998 and 1997 (N is the total number captured).

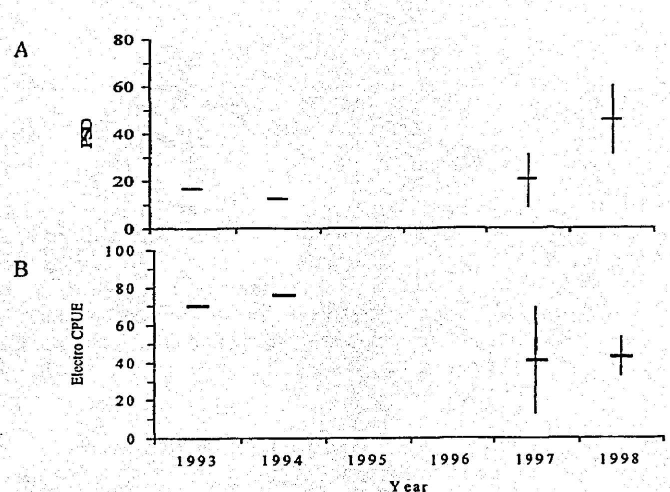


Figure 2. Lake Louise largemouth bass electrofishing: A) PSD with 90% confidence intervals and B) mean catch per unit effort with 80% confidence intervals. Horizontal lines represent the mean and vertical lines represent 80% confidence interval.

7

Table 3. Catch per unit effort (CPUE; standard error is given in parentheses), proportional stock density (PSD) and relative stock density of preferred-length (RSD-P) estimates (90% confidence interval lower and upper values are given in parentheses) for bluegill, largemouth bass, yellow perch, walleye and black bullhead collected from Lake Louise during 1998.

Species	Gear	Stock CPUE	PSD	RSD-P
Bluegill	electrofish	337.1 (77.22)	62 (57, 67)	2 (0, 3)
Bluegill	trap net	27.0 (5.68)	85 (81, 89)	9 (6, 12)
Largemouth Bass	elecrofish	42.9 (5.46)	45 (31, 60)	15 (4, 26)
Yellow Perch	gill net	35.5 (13.5)	48 (38, 58)	0
Yellow Perch	trap net	1.3 (0.45)	--[a]	--[a]
Walleye	gill net	2.5 (2.5)	--[a]	--[a]
Black bullhead	gill net	1.5 (1.5)	--[a]	--[a]
Black bullhead	trap net	1.0 (0.33)	--[a]	--[a]

[a]low sample size does not allow for calculation of stock density indices

Bluegill condition remains excellent with all length category values exceeding 100 in both electrofishing and trap net samples (Table 5). Relative weight values differed significantly across length categories making use of an overall mean Wr inappropriate. In both samples, stock- to quality-length bluegill were in significantly better condition than the larger length groups. The lower condition of larger length groups may be related to recent spawning activities. Bluegill growth was similar to that reported for 1997 (Blackwell 1998) and would be considered excellent. Mean back calculated lengths at age exceed the South Dakota average (Willis et al. 1992) for ages 1-7 (Table 7).

Electrofishing stock-length bluegill CPUE (337.1; Table 3) was significantly higher in 1998 than 1997, but trap net CPUE (27.0; Table 3) was lower, although not significantly. Trap net CPUE values have remained fairly stable since 1992 (Figure 3). Age-3 bluegills dominate the bluegill catch (65%) for both electrofishing and trap nets. In 1997, 33% of the electrofishing bluegill catch was age 3 and 59% of the trap net catch was age 3. Thus, it appears that bluegill mortality following age 3 must be high. Anglers probably begin harvesting Lake Louise bluegill during their fourth growing season (age 3+). The bulk of angler harvest in 1997 and 1998 occurred between 170 and 200 mm (Figure 4). Annual mortality was estimated at 46% with the Chapman-Robson method and 57% by catch-curve analysis. Mortality estimates were made from the trap net captured bluegill and only ages greater than 3 because of the low number of age-1 and –2 bluegill in the trap net sample. Mortality rate estimates in 1998 were similar to the 1997 estimates. In 1997, bluegill mortality was estimated at 49% (Chapman-Robson method) and 41% (catch-curve) (Blackwell 1998). Adult bluegill mortality appears to be substantial. It is likely that the derived mortality estimates represent angler induced mortality because most largemouth bass predation likely affects age-0 and –1 bluegills. It is possible that anglers may be overharvesting the larger Lake Louise bluegills. In both 1998 and 1997, the trap net bluegill RSD-P was lower than the suggested panfish option range. In 1997, an estimated 6,500 (15.9/ha; 39.4/acre) bluegills were harvested May-August and during 1998 the estimated harvest was 10,029 (150.1/ha; 60.8/acre). It does not appear that a reduction in bluegill daily limit would do much to reduce Lake Louise bluegill harvest. In 1998, only 4.8% of the anglers indicating bluegills as their primary target, harvested their limit (25 bluegills) and 73% of the bluegill anglers harvested fewer than 10 bluegills. It appears that angling pressure is sufficient for the bluegill population to be "nickeled and dimed" by Lake Louise anglers.

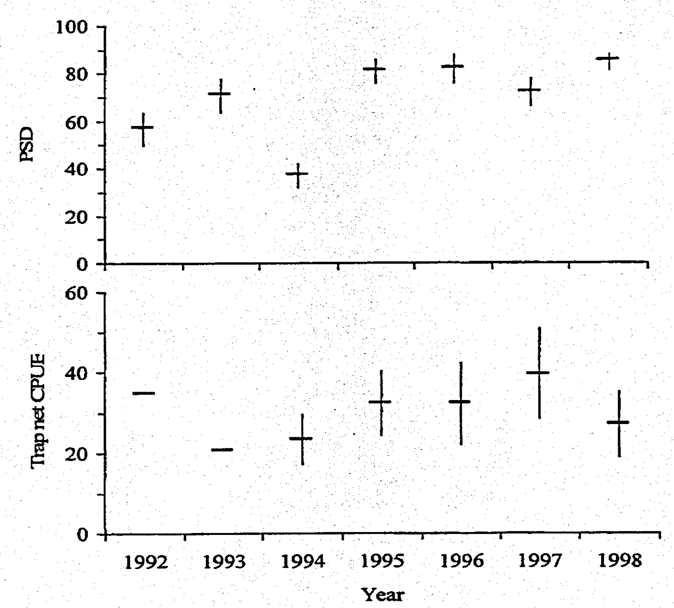


Figure 3. Lake Louise bluegill trap net A) PSD with 80 % confidence intervals and B) mean catch per unit effort (CPUE) with 80% confidence intervals for 1992 through 1998. Horizontal bars represent the mean and vertical bars represent the 80% confidence interval.

Yellow Perch
Yellow perch were the most abundant species collected with gill nets in 1998 (Table 6). The 1998 gill net stock-length yellow perch CPUE (35.5/net; Table 3) was significantly lower than that reported in 1997 (203.5/net; Blackwell 1998). The proportion of quality-length yellow perch was significantly lower in 1998 than 1997. It appears that a fairly strong yellow perch year class in the stock- to quality-length category has resulted in the PSD decrease. Only 10 yellow perch were collected in the trap nets resulting in a mean CPUE of 1.25 (Table 3).

The yellow perch appear to be in good condition with mean Wr values for most length categories exceeding 90 (Table 5). No length-related trends in yellow perch condition were identified. Yellow perch mean lengths at age were similar to the South Dakota average (Willis et al 1992), but slightly lower than those reported for Lake Louise in 1994 (Meester 1995). The 1995 year class was the most abundant in the gill net sample composing approximately 56% of the collected yellow perch.

Yellow perch annual mortality was estimated to be 50% with the Chapman-Robson technique and 49% by catch-curve analysis. In neither 1997 nor 1998, were preferred-length yellow perch collected by gill netting. Angler harvest may not allow many individuals to exceed 250 mm. In both 1998 and 1997, the angler harvest length frequency mode was at 230 mm TL (Figure 5).

Table 4. Lake Louise largemouth bass year class, age in 1998, sample size (N), mean back-calculated total length at age for each year class, mean back calculated length at age for the population, population standard error, 1997 and 1994 Lake Louise mean length at age, and the South Dakota largemouth bass mean length at age (Willis et al. 1990).

			Age										
Year Class	Age	N	1	2	3	4	5	6	7	8	9	10	11
1997	1	14	100										
1996	2	14	76	161									
1995	3	5	88	169	207								
1994	4	14	97	188	242	272							
1993	5	5	87	174	218	269	302						
1992	6	1	68	124	234	331	349	369					
1991	7	2	84	167	207	245	303	350	391				
1990	8	2	85	162	232	293	331	382	410	423			
Mean			86	164	223	282	321	367	400	423			
Standard Error			4	7	6	14	11	9	9				
1997			87	187	230	273	320	357	385	407	436	453	493
1994			94	162	237	310	390	422					
South Dakota			91	184	251	305	345	400	435				

Black Bullhead
Black bullheads do not appear to be abundant in Lake Louise. This is likely the result of the high largemouth bass density. Trap net and gill net bullhead catches were low (Table 3). Most black bullheads collected exceed 300 mm TL. Saffel et al. (1990) found black bullhead length to be positively correlated with largemouth bass CPUE and inversely related to largemouth bass PSD in South Dakota ponds. They found that ponds with high largemouth bass densities typically contained a high proportion of black bullheads greater than 230 mm TL.

Walleye
Seven walleyes (six stock-length) were collected during gill netting in 1998 (Table 6). The mean stock-length walleye gill net CPUE was 2.5 (Table 3). Walleye condition was good with all values greater than 85 (Table 5). Walleye back calculated lengths were greater than reported for Lake Louise in 1996 (Table 9; Meester 1997) and the South Dakota mean (Wolf et al. 1994).

Walleyes have not been abundant in samples or angler harvest in 1997 and 1998. Walleye fingerlings have been biennially stocked since 1989. It does not appear that fingerling survival has been very successful. It is highly probable the abundant largemouth bass heavily predate stocked walleyes and do not allow for formation of strong year classes. In 1996, 23 walleyes were caught in eight trap net nights (Meester 1997). Age data revealed that 10 walleyes were from the 1993 year class, a stocked year, but six walleyes were aged to be part of a 1994 year class, a non-stocking year. Thus, one questions if walleye fingerling stocking is justifiable or if stocking was discontinued whether a remnant walleye population would persist.

Currently, it appears that largemouth predation is adequate for controlling bluegill, yellow perch, and bullhead densities at Lake Louise probably negating the need for a secondary predator. The presence of walleyes likely does no harm, but is the cost to benefit ratio sufficient to warrant the continued stocking of walleyes. Less than 1% of Lake Louise anglers targeted walleyes in 1998 (Table 12) and in 1997 only 1.6% indicated walleyes as their primary target species (Blackwell 1998).

Table 5. Mean relative weight values by Gabelhouse (1984) length categories (standard error values are in parentheses) for bluegill, largemouth bass, yellow perch, and walleye collected at Lake Louise during June and July 1998. Means followed by different letters within a row are significantly different (S-Q = stock to quality length, Q-P = quality to preferred length, and P-M = preferred to memorable length).

Species	Sub-stock	S-Q	Q-P	P-M	Stock
Bluegill $_{electrofish}$	--	127 (1.10)z	118 (1.00)y	100 (1.60)x	121 (0.74)
Bluegill $_{trap\ net}$	--	114 (2.58)z	107 (0.67)y	106 (1.10)y	108 (0.65)
Largemouth Bass $_{electro}$	113 (0.85)z	105 (0.70)y	100 (1.71)y	100 (1.05)y	103 (0.78)
Yellow Perch $_{gill\ net}$	--	99 (0.13)	97 (0.43)	--	98 (0.07)
Yellow Perch $_{Trap\ Net}$	--	93 (3.39)	86 (1.94)	83	88 (1.88)
Walleye $_{gill\ net}$	--	97(6.68)	89	86 (2.88)	91 (3.40)

Table 6. Number collected and percent (%) composition of species collected in trap nets and gill nets at Lake Louise during July 1998.

	Trap Net Catch		Gill Net Catch	
Species	Number	% Composition	Number	% Composition
Bluegill	216	91	20	19
Yellow Perch	10	4	72	69
Largemouth Bass	2	1	2	2
Walleye	2	1	7	7
Black Bullhead	8	3	3	3

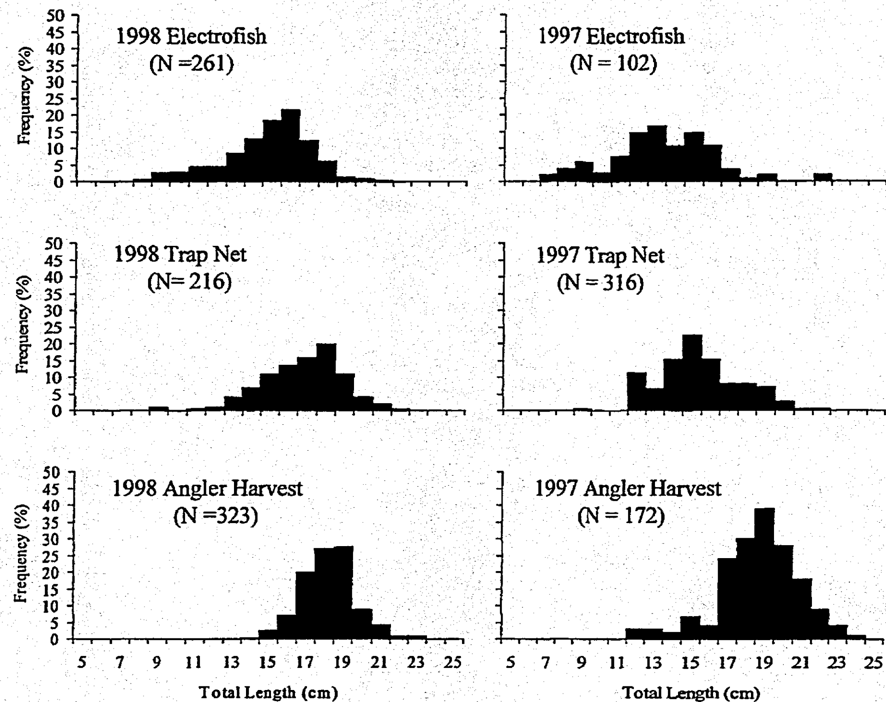


Figure 4. Lake Louise length frequency distributions for bluegill captured by electrofishing, trap netting, and harvested by anglers during 1998 and 1997 (N is the total number captured).

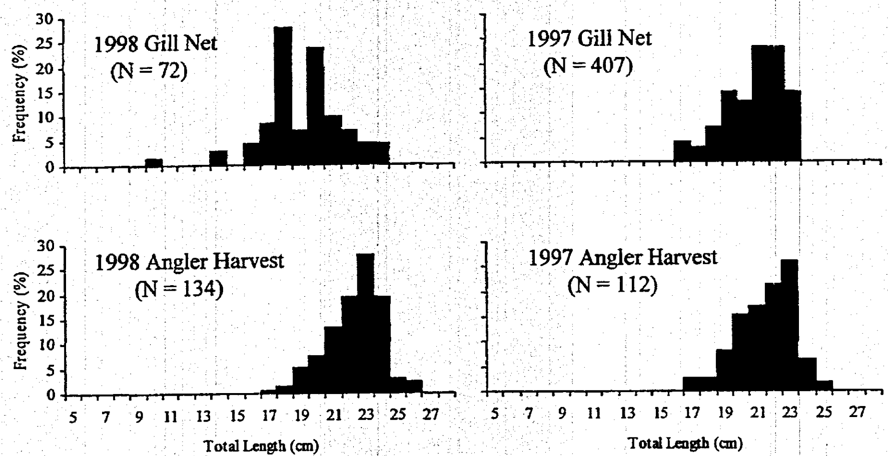


Figure 5. Lake Louise length frequency distributions for yellow perch captured by gill netting and harvested by anglers in 1998 and 1997 (N is the total number captured).

Table 7. Lake Louise bluegill year class, age in 1998, sample size (N), back calculated total length at age, the weighted mean back calculated length at age, weighted mean standard error, 1997, 1995 and 1994 Lake Louise mean length at age and the South Dakota bluegill mean length at age (Willis et al. 1992).

			Age							
Year Class	Age	N	1	2	3	4	5	6	7	8
1997	1	5	74							
1996	2	12	74	105						
1995	3	58	66	109	141					
1994	4	16	68	113	153	174				
1993	5	4	69	122	163	185	197			
1992	6	0								
1991	7	3	56	108	133	158	183	201	215	
Weighted Mean			68	110	144	174	191	201	215	
Standard Error			1.19	1.62	2.35	2.98	3.99	2.79	1.99	--
1997			66	110	147	172	191	207	205	218
1995			51	96	137	160	183	190		
1994			68	111	155	182				
South Dakota			44	84	122	152	166	182	215	

Table 8. Lake Louise yellow perch year class, age in 1998, sample size (N), back calculated total length at age, the weighted mean back calculated length at age, weighted mean standard error, 1997, 1995 and 1994 Lake Louise mean length at age and the South Dakota yellow perch mean length at age (Willis et al. 1992).

			Age				
Year Class	Age	N	1	2	3	4	5
1997	1	3	91				
1996	2	12	89	145			
1995	3	18	92	139	183		
1994	4	11	76	127	175	207	
1993	5	4	72	130	176	210	229
Weighted Mean			88	137	179	208	229
Standard Error			2.46	2.96	3.40	4.29	1.102
1994			93	157	209	232	
South Dakota			80	139	181	210	251

Table 9. Lake Louise walleye year class, age in 1998, sample size (N), back calculated total length at age, the weighted mean back calculated length at age, weighted mean standard error, 1997, 1995 and 1994 Lake Louise mean length at age and the South Dakota walleye mean length at age (Wolf et al. 1994).

			Age				
Year Class	Age	N	1	2	3	4	5
1997	1	1	120				
1996	2	2	122	192			
1995	3	1	163	277	373		
1994	4	1	265	390	472	517	
1993	5	1	271	325	377	469	541
Weighted Mean			188	296	407	493	541
Standard Error			34	42	32	24	
1994			147	280	384	423	484
South Dakota			163	288	388	449	506

Angler Use and Harvest

Angler Demographics

In 1998, most anglers fishing Lake Louise indicated they were South Dakota residents (98.8%) (Table 10). Non-resident anglers fishing Lake Louise in 1998 originated from Minnesota and Illinois. The monthly mean trip length in 1998 exceeded 3 hours each month and also exceeded 4 hours in May and August (Table 8). Fishing pressure was similar in May, June and July, but decreased in August. Similar to 1997, fishing pressure was almost equally divided between weekdays and weekend/holidays during the survey period (Table 10).

As in 1997, most Lake Louise anglers (95%) traveled less than 161 km (100 mi), one way, to fish Lake Louise (Table 11). It is conceivable that 161 km may indicate the distance anglers are willing to travel and fish in one day. In 1998, local anglers, those traveling less than 40 km (25 mi), were the most abundant anglers at Lake Louise (Table 11). The monthly percentage of local anglers exceeded all other categories except during August. It is possible that local anglers may have decided to fish Lake Louise more often in 1998 because of the excellent angling opportunities and because of the reduced fishing quality experienced at Lake Oahe in 1998. Miller, Huron and Pierre were the most frequently provided place of residence by anglers in 1998.

Similar to 1997, anglers indicated that they were targeting largemouth bass, bluegill, and any fish in nearly the same proportion (Table 12). Yellow perch were targeted by 3% of Lake Louise anglers and walleyes were targeted by only 0.6% of the anglers.

Table 10. Lake Louise 1998, monthly and overall number of interviews, estimated angler hour and days, percent of anglers fishing by boat, percent of total anglers fishing weekends and holidays, percent of anglers that are South Dakota residents, and mean trip length.

	May	June	July	August	∑1998	∑1997
Interviews	74	46	37	13	170	127
Angler hours	3,218 (736)	2,361 (499)	2,556 (407)	1,168 (542)	9,303	10,225
Angler days	736 (179)	755 (189)	675 (136)	248 (147)	2,414	3,246
Percent (%) boat anglers	62.7	74.9	79.8	70.4	--	--
Percent (%) weekend/holiday	68.3	59.4	44.3	40.2	--	--
Percent (%) resident	100	95.7	100	100	98.8	95.3
Mean trip length (hours)	4.37	3.13	3.79	4.72	3.94	3.27

Table 11. Distance (km) traveled by anglers, one way, to fish Lake Louise during May through August, 1998, 1998 combined and 1997 combined.

Distance (km)	May %	June %	July %	August %	All 1998	All 1997
<40	50.0	39.1	43.2	23.1	43.3	32.3
40 - 81	14.9	19.6	16.2	30.8	17.5	16.5
82-161	33.8	32.6	37.8	38.5	34.5	40.9
162-322	0.0	2.2	2.7	7.7	2.3	5.5
322+	1.4	6.5	0	0	2.3	4.7

Fishing Pressure

An estimated 9,303 hours were spent fishing Lake Louise during May through August 1998. The 1998 pressure is similar to that estimated during the same period in 1997 (10,225 hours; Blackwell 1998). Lake Louise provided an estimated 2,414 angler days during May through June 1998 which translates into $180,950 to local economies. The dollar amount is based on the average South Dakota angler's daily expenditure of $75 (U.S. Department of Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of Census 1997).

In general, Lake Louise angler catch (Table 13) and harvest (Table 14) rates were higher in 1998 than 1997. The estimated catch rates for all species combined ranged from 2.20 (May) to 3.78 (June; Table 13). Harvest rates for all species combined ranged from 1.10 (July) to 1.97 (June; Table 14). The catch and harvest rates experienced at Lake Louise during 1998 and 1997 would likely be considered high. It appears that anglers fishing Lake Louise have a reasonable expectation of catching more than two fish per hour and harvesting more than one fish for every hour fished.

Bluegill

Bluegills were the principal fish species caught and harvested at Lake Louise in 1998. An estimated 18,489 bluegill were caught and 10,029 harvested during the 1998-survey period (Table 15). Bluegill catch and harvest rates were high (Tables 13 and 14). Catch rates ranged from a low of 1.30 (May) to 2.60 (June) and harvest rates ranged from 0.81 (May) to 1.45 (June). Angler harvested bluegills ranged from 14 cm to 23 cm TL (Figure 3). The estimated biomass of harvested bluegills during the 1998 survey period was 19.8 kg/ha (17.7 lb/acre) and in 1997 an estimated 13.8 kg/ha (12.3 lb/acre) were harvested.

It appears that anglers do not harvest bluegills in proportion to their availability at Lake Louise. In both 1998 and 1997, the angler harvest length-frequency histogram is shifted to the right of the electrofishing and trap net sample histograms (Figure 3). Thus, anglers harvest a higher proportion of bluegill greater than 15 cm than less than 15 cm. Santucci and Wahl (1991) found angler bluegill catch to underestimate the relative abundance of small bluegills at Ridge Lake, Illinois. They found length distributions of angler-caught bluegills to be biased toward large bluegills (>13 cm TL).

Largemouth bass
Largemouth bass harvest increased substantially in 1998 over that estimated in 1997. An estimated 1,477 largemouth bass were harvested during the survey period and 25% of the caught largemouth bass were harvested (Table 15). Monthly mean harvest rates ranged from 0.01 (July) to 0.49 (August; Table 14) while catch rates ranged from 0.47 (June) to 0.85 (July; Table 13).

Harvested largemouth bass ranged in total length from 16 cm to 47 cm (Figure 1). Most angler largemouth bass harvest was of quality- to preferred-length fish. Largemouth bass harvest was nearly equal between anglers who indicated largemouth bass as their target species and those who indicated any or bluegill as a target species. However, almost 50% of the largemouth bass caught by bluegill anglers were harvested while those indicating any fish as a target harvested 15% and largemouth bass anglers harvested 18% of the bass they caught.

Yellow Perch
In 1998, yellow perch total catch was less than half the 1997 catch and approximately 1,400 fewer yellow perch were harvested in 1998 (Table 15). Anglers harvested 91% of the yellow perch caught during the 1998 survey period (Table 15). Catch rates ranged from 0.21 (July) to 0.66 (June; Table 13) and harvest rates had a low of 0.06 (August) and a high of 0.47 (June; Table 14). Yellow perch harvested by anglers between 17 cm TL and 26 cm TL (Figure 4). Length frequency histograms of angler harvested yellow perch are nearly identical between 1998 and 1997. It appears most yellow perch are harvested by anglers once they reach 20 cm (8 in) TL and that most perch are harvested before they reach 10 inches.

Other Species
Anglers caught few walleyes, black bullheads, or northern pike in 1998. These species appear to be minor components of the angler catch and likely occur as incidental catch for many anglers. Anglers caught and harvested 36 walleyes during the 1998-survey period.

Table 12. Percent (%) of anglers targeting selected fish species at Lake Louise from May through August 1998 and May through August, combined 1998 and combined 1997.

	Percent (%)					
Target Species	May	June	July	August	1998	1997
Any	21.6	43.4	24.3	0.0	27.0	29.9
Bluegill	40.5	30.4	43.2	15.4	37.1	31.5
Largemouth bass	28.4	10.9	21.6	46.2	23.9	25.2
Yellow perch	2.7	6.5	0.0	0.0	3.0	8.7
Walleye	0.0	0.0	0.0	7.7	0.6	1.6
Bluegill/yellow perch	5.4	6.5	2.7	23.1	6.6	3.1
Bluegill/largemouth bass	1.4	2.2	8.1	7.7	3.6	0.0

Table 13. Estimated 1998 and 1997 angler catch rates for Lake Louise during the last three weeks in May through August for largemouth bass, bluegill, yellow perch, black bullhead, walleye, northern pike, and all species combined (two standard errors are given in parentheses).

	May[a] Catch/hour		June Catch/hour		July Catch/hour		August Catch/hour	
Species	1998	1997	1998	1997	1998	1997	1998	1997
Largemouth bass	0.62	0.61	0.47	0.74	0.85	0.24	0.61	0.08
	(0.29)	(0.46)	(0.38)	(0.64)	(0.46)	(0.15)	(0.91)	(0.08)
Bluegill	1.30	1.24	2.60	2.32	2.16	1.52	2.26	1.73
	(0.45)	(2.48)	(0.77)	(1.48)	(0.67)	(0.53)	(1.66)	(0.76)
Yellow perch	0.26	0.04	0.66	0.37	0.21	0.49	0.25	1.15
	(0.16)	(0.05)	(0.37)	(0.30)	(0.16)	(0.52)	(0.31)	(0.52)
Black bullhead	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.04
	(0.02)	(0.00)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	(0.05)
Walleye	0.01	0.02	0.01	0.03	0.01	0.01	0.01	0.00
	(0.01)	(0.04)	(0.01)	(0.03)	(0.01)	(0.01)	(0.02)	(0.00)
Northern pike	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.01)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)
All species	2.20	1.91	3.78	3.49	3.22	2.29	3.13	3.00
	(0.56)	(2.53)	(0.94)	(1.64)	(0.83)	(0.76)	(1.91)	(0.93)

[a] only last three weeks in May

Table 14. Estimated 1998 and 1997 angler harvest rates for Lake Louise during the last three weeks in May through August for largemouth bass, bluegill, yellow perch, black bullhead, walleye, northern pike, and all species combined (two standard errors are given in parentheses).

	May[a] Harvest/hour		June Harvest/hour		July Harvest/hour		August Harvest/hour	
Species	1998	1997	1998	1997	1998	1997	1998	1997
Largemouth bass	0.24	0.08	0.04	0.04	0.01	0.01	0.49	0.02
	(0.17)	(0.11)	(0.05)	(0.03)	(0.02)	(0.02)	(0.92)	(0.04)
Bluegill	0.81	0.99	1.45	0.64	1.02	0.66	1.19	0.40
	(0.31)	(1.99)	(0.61)	(0.66)	(0.51)	(0.45)	(1.21)	(0.22)
Yellow perch	0.23	0.00	0.47	0.26	0.07	0.46	0.06	0.48
	(0.16)	(0.00)	(0.32)	(0.23)	(0.09)	(0.52)	(0.09)	(0.40)
Black bullhead	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03
	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.05)
Walleye	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.00
	(0.00)	(0.00)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.00)
Northern pike	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)
All species	1.30	1.07	1.97	0.99	1.10	1.14	1.75	0.93
	(0.38)	(1.99)	(0.69)	(0.77)	(0.52)	(0.69)	(1.52)	(0.46)

[a] only last three weeks in May

Table 15. Estimated number of largemouth bass (LMB), bluegill (BLG), yellow perch (YEP), black bullhead (BLB), and walleye (WAE) caught by anglers, harvested by anglers and the percent of the those caught that were harvested during the last three weeks in May through August 1998 and 1997 at Lake Louise.

Parameter	LMB		BLG		YEP		BLB		WAE	
	1998	1997	1998	1997	1998	1997	1998	1997	1998	1997
Catch	5,885	4,357	18,489	18,660	2,326	5,311	108	150	36	178
Harvest	1,477	308	10,029	6,500	2,114	3,566	35	55	36	103
% Harvest	25%	7%	54%	35%	91%	67%	32%	37%	100%	58%

Summary
The Lake Louise fish community continues to resemble the panfish option. The fish community changed little from 1997. An increase in largemouth bass PSD was experienced, but will likely decrease as an abundance of sub-stock bass reach stock length. The largemouth bass population is primarily composed of age-4 and younger individuals. Annual largemouth bass mortality was estimated at approximately 30%. Bluegill size structure remained high with a trap net PSD of 85 and a RSD-P of 9. Annual mortality rates for bluegill and yellow perch exceeded 45%. The yellow perch population size structure and density appear to be reduced over 1997. The gill net yellow perch PSD decreased in 1998 to 48 and the stock-length CPUE decreased to 35.5. Walleyes remain a minor constituent of the Lake Louise fish community.

Anglers fished an estimated 9,303 hours during the last three weeks in May through August 1998. Bluegill remain the most caught fish species with monthly catch rates ranging from 1.3 to 2.6 bluegill per angler hour. Anglers fishing Lake Louise in 1998 appeared to be more harvest oriented than those fishing in 1997. Anglers harvested 54% (10,029) of the estimated 18,489 bluegills caught from Lake Louise and 91% (2,114) of the 2,326 yellow perch caught. Largemouth bass harvest increased substantially over 1997 with 25% (1,477) of the 5,885 caught bass being harvested. It appears angler harvest may be reducing the density of larger bluegill and yellow perch.

A nearly equal representation for targeted species was obtained for largemouth bass, bluegill, and any fish. Almost all Lake Louise anglers in 1998 were South Dakota residents. In general, anglers travel less than 161 km, one way, to fish Lake Louise. The highest percentage of Lake Louise anglers in 1998 was local anglers traveling less than 40 km, one way. The economic impact of the Lake Louise fishery for the survey period was estimated to be $180,950.

Recommendations

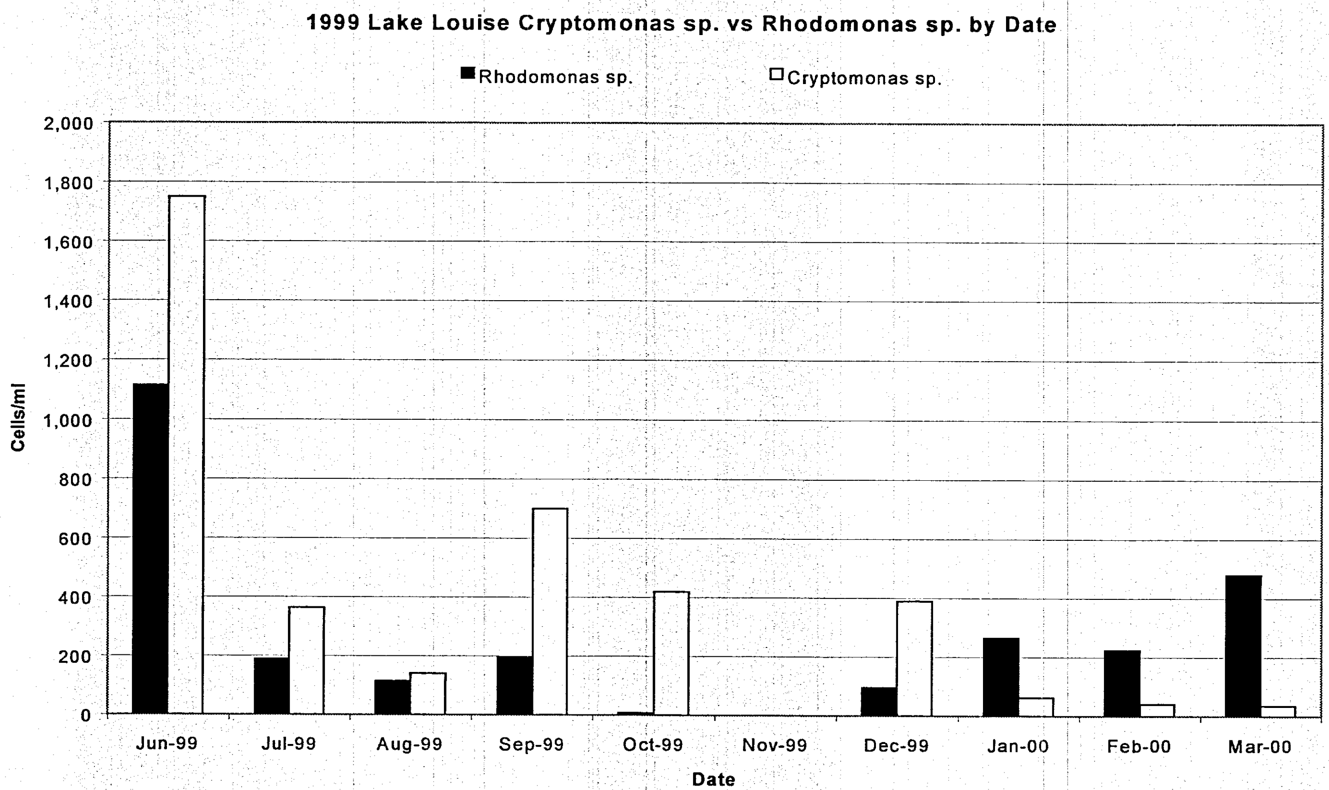
Evaluate panfish harvest and potential impacts anglers are having on panfish populations. Excessive bluegill and yellow perch harvest may be a present and future concern at Lake Louise. Coble (1988) indicated that if angling mortality is sufficient to increase total mortality then angling could shift the length frequency distribution of a bluegill population to smaller sizes. He believed that consistent bluegill recruitment combined with removal of large bluegill would result in a population composed of few large (> 150 mm TL) and many small fish. Currently, few Lake Louise bluegills exceed 200 mm TL. A reduction in the bluegill daily creel would likely do little to reduce bluegill harvest because only 4.8% of interviewed anglers in 1998 harvested a limit. Some innovative panfish regulations may be needed in the future to reduce bluegill harvest (e.g., regular daily creel with only 5 bluegill over 180 mm). As Coble (1988) stated, it is time to reexamine the belief that angling has little or no effect on bluegill populations.

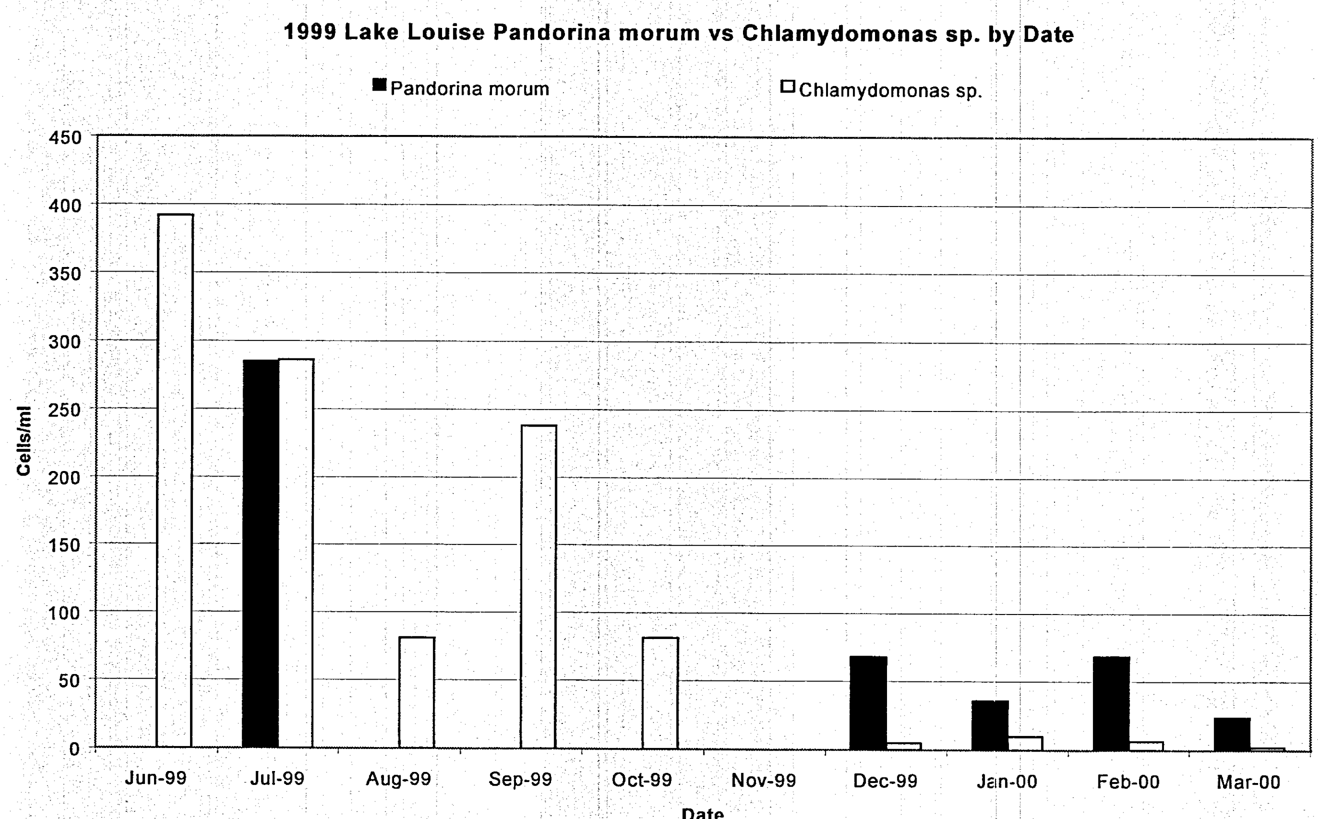
Walleye stockings into Lake Louise need to be critically evaluated. Few walleyes have been collected during annual sampling and anglers caught and harvested few in 1997 and 1998. The high-density largemouth bass population may be limiting walleye recruitment.

The fish community should be evaluated on an annual basis using electrofishing, trap nets and gill nets to monitor potential changes. It is far easier to make minor changes to a fishery than to completely restructure a fish community. Electrofishing should be completed in a manner (i.e., shocking intervals or stations) that allows for statistical comparisons across years.

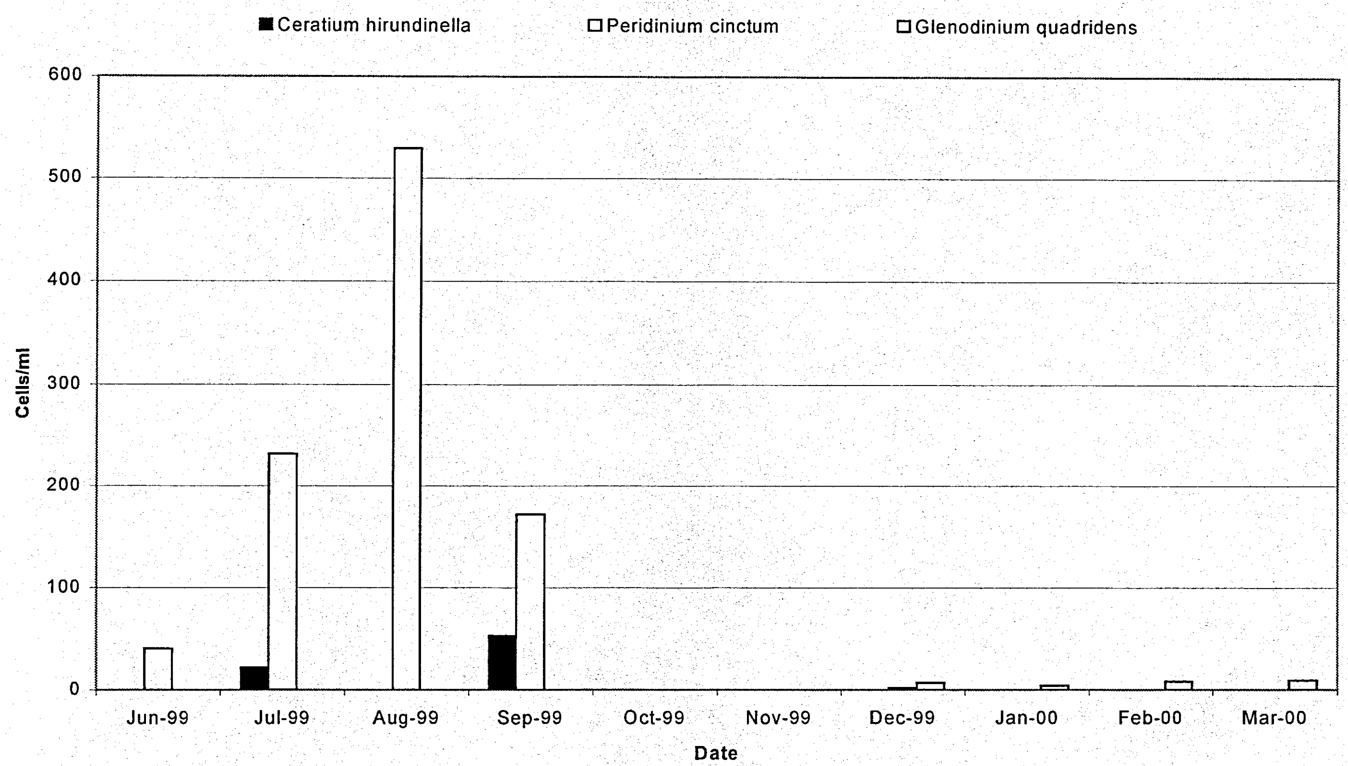
The angler use and harvest survey should be repeated in the year 2003 to continue to gain information from South Dakota small lakes and ponds. This information fulfills Objective 4, Strategy 4.1 of the Small Lakes and Ponds Strategic Plan (SDGF&P 1997).

Appendix E. Phytoplankton Tables

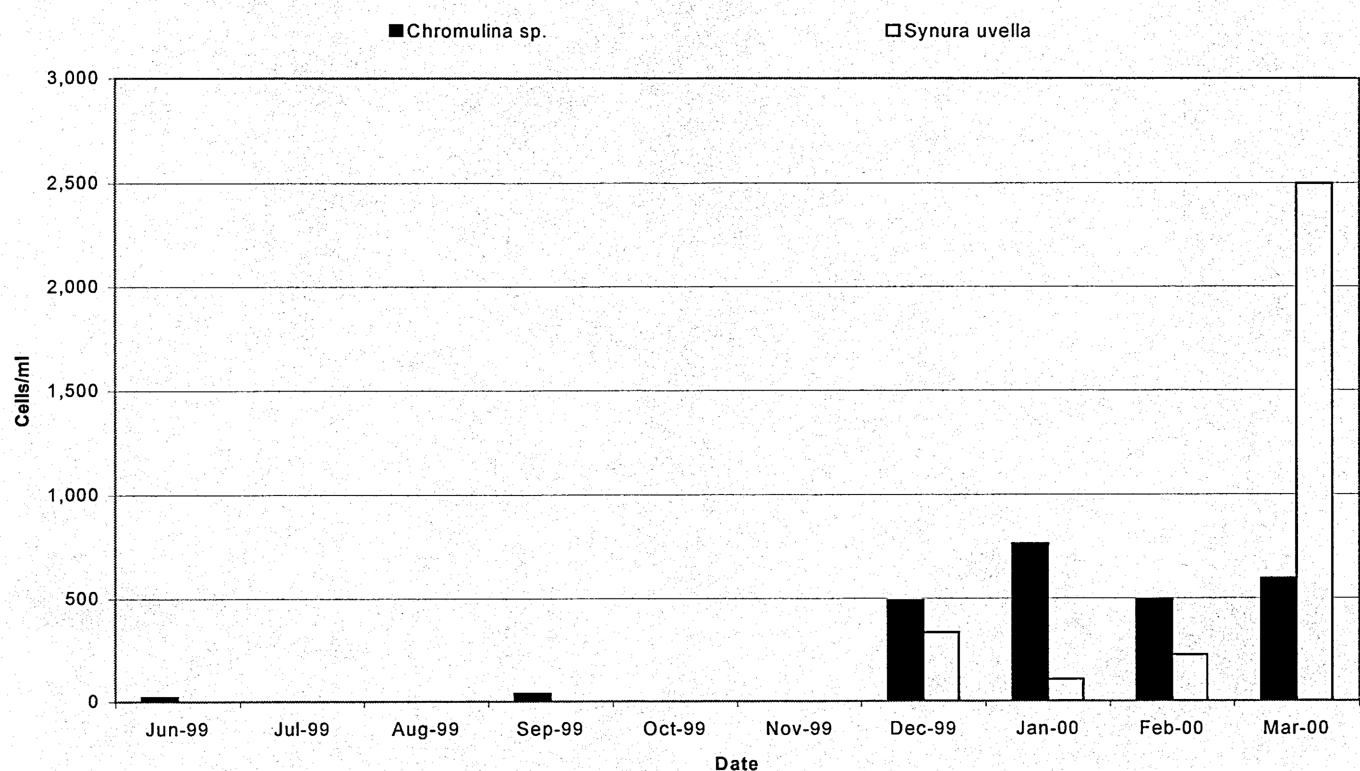




1999 Lake Louise Ceratium sp. vs. Peridinium sp. by Date



1999 Lake Louise Chromulina sp. vs. Synura uvella by Date



Appendix F. Total Maximum Daily Load Summary (TMDL)

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

LAKE LOUISE

WOLF CREEK WATERSHED

(HUC 10160009)

HAND COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

MARCH, 2001

Lake Louise Total Maximum Daily Load

Waterbody Type:	Lake (Impounded)
303(d) Listing Parameter:	TSI Trend, Fecal Coliform, Accumulated Sediment
Designated Uses:	Recreation, Warmwater semipermanent aquatic life
Size of Waterbody:	163 acres
Size of Watershed :	211,329 acres
Water Quality Standards:	Narrative and Numeric
Indicators:	Average TSI, lake depth, and fecal counts
Analytical Approach:	**AGNPS, BATHTUB, FLUX, PSAIC**
Location:	HUC Code: 10160009
Goal:	10 % reduction in the phosphorus load
Target:	TSI <70 average during the growing season

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

Lake Louise is a 163-acre man-made impoundment located in central Hand County, South Dakota. The 1998 South Dakota 303(d) Waterbody List (page 22) identified Lake Louise for TMDL development for trophic state index (TSI), increasing eutrophication trend, fecal coliform bacteria, and accumulated sediment.

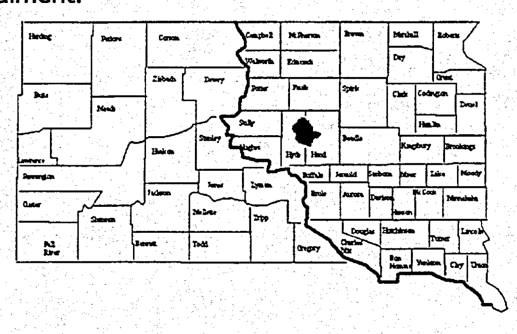


Figure 30. Watershed Location in South Dakota

The damming of Wolf Creek 15 miles north of Ree Heights created the lake, which has an average depth of 9 feet (3 meters) and over 6 miles (9.7 km) of shoreline. The lake has a maximum depth of 22 feet (6.7 m), holds 1,463 acre-feet of water, and is subject to periods of stratification during the summer. The outlet for the lake empties into Wolf Creek, which eventually reaches Turtle Creek south of Redfield. Turtle Creek discharges into the James River near Redfield, South Dakota.

Problem Identification

Wolf Creek is the primary tributary to Lake Louise and drains predominantly grazing lands with some cropland acres. Winter feeding areas for livestock are present in the watershed. The stream carries nutrient loads, which degrade water quality in the lake and cause increased eutrophication. The assessment study did not find impairment to Lake Louise from fecal coliform bacteria or accumulated sediment.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Lake Louise 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:

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

Individual parameters, including the lake's Trophic State Index (TSI) (Carlson, 1977) value, determine the support of beneficial uses and compliance with standards. A gradual increase in fertility of the water due to nutrients washing into the lake from external sources is a sign of the eutrophication process. Lake Louise is identified in both the 1998 South Dakota Waterbody List and "Ecoregion Targeting for Impaired Lakes in South Dakota" as not supporting its aquatic life beneficial use.

Lake Louise Watershed

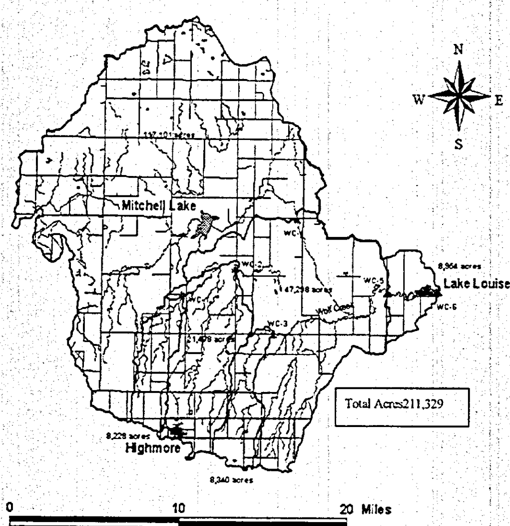


Figure 31. Lake Louise and Wolf Creek

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

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

Lake Louise currently has a mean TSI of 71.16, which is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of the high productivity is high phosphorus loads from the watershed.

The numeric target, established to improve the trophic state of Lake Louise, is a growing season average TSI of less than 70. This target may be achieved through a 10% reduction in phosphorus from Wolf Creek in addition to inlake aeration.

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

Of the 2,129 kg. of phosphorus that enter the lake on an average annual basis, approximately 270 kg or 12.5% are accounted for by AGNPS from the animal feeding operations. Pages 65-66 of the assessment final report.

The PSIAC portion of the report accounted for an additional 647 kg/yr of phosphorus or 30% of the load from the range and crop ground. Of this 30%, only 4% can be reduced through improved management practices. Pages 63-64 of the assessment final report.

The remaining 57.5% of the phosphorus load that was unaccounted for in the modeling will be attributed to natural background sources.

As identified in the suspended solids loading to the lake section (page 21 of the assessment final report) and the sediment survey of the lake (page 69 of the assessment final report) sediment loading to the lake is not a significant concern.

Fecal coliform data from the assessment and from beach samples indicated that less than 2% of the beach samples have resulted in beach closures, each of which occurred during 1996. These closures do not represent a recurring problem and do not impair the beneficial uses of the lake.

No TMDL goals will be developed for fecal coliform or accumulated sediment and it is recommended Lake Louise be de-listed in the next 303d report.

Linkage Analysis

Water quality data was collected from six monitoring sites within the Lake Louise and Wolf Creek watershed. Samples collected at each site were taken according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on 10% of the samples according to South Dakota's EPA approved Clean Lakes Quality Assurance/Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed on pages 10-69 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The Pacific Southwest Inter Agency (PSIAC) model was used to estimate potential sediment load reductions from the watershed through the implementation of various best management practices. See the PSIAC section of the final report, pages 63-64.

The Agriculture Nonpoint Pollution Source (AGNPS) feeding area subroutine was used to provide comparative values for each of the animal feeding operations located in the watershed. See the AGNPS section of the final report, pages 65-66.

The impacts of phosphorus reductions on the condition of Lake Louise were calculated using BATHTUB, an Army Corps of Engineers model. The model predicted that by only reducing phosphorus from Wolf Creek, up to a 90% reduction in loading to the lake would result in little to no change in the TSI of the lake.

The greatest improvements in the lakes TSI were calculated when modeling incorporated aeration of the water column in the lake itself, potentially reducing nutrient release from the bottom sediments. The combination of aeration and a 5 to 10% reduction in phosphorus loading from Wolf Creek would result in a sufficient TSI shift to partially restore the lakes beneficial uses. A discussion of the reduction response modeling may be found on pages 44-45 of the final assessment report.

TMDL and Allocations

TMDL

	0 kg/yr.	(WLA)
+	704 kg/yr.	(LA)
+	1,212 kg/yr.	(Background)
	Implicit	(MOS)
	1,916 kg/yr.	(TMDL)

Wasteload Allocations (WLAs)

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

Load Allocations (LAs)

A 6% reduction in the phosphorus load to Lake Louise may be obtained through the improvement of five of the animal waste systems identified in the AGNPS section of the final report reducing the annual load from animal feeding areas from 270 kg/yr to 143 kg/yr.

Rangeland and cropland BMPs targeting 1,400 acres of cropland and 18,000 acres of rangeland will result in a 4% reduction in phosphorus that is attached to 7.3% of the suspended solids loading to the lakes. This will reduce the cropland and rangeland phosphorus loads from 647 kg/yr to 561 kg/yr.

Seasonal Variation

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

Margin of Safety

The margin of safety is implicit as conservative estimations were used in the development of the phosphorus loads from the rangeland and cropland best management practices applied in the PSIAC model. This is addressed in greater detail on pages 63-64 of the assessment final report.

Critical Conditions

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

Follow-Up Monitoring

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

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

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

Public Participation

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

1. Central Plains Water Development District Board Meetings (8)
2. Hyde County Conservation District Board Meetings (2)
3. Hand County Conservation District Board Meetings (7)
4. Cottonwood Lake Association Meetings (2)
5. Kiwanis Club of Miller South Dakota

Individual contact with landowners in the watershed.

Articles in the local newspapers (3)

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

Implementation Plan

The South Dakota DENR is working with the Hand County Conservation District and the Central Plains Water Development District to initiate an implementation project beginning in the spring of 2002. It is expected that a local sponsor will request project assistance during the fall 2001 EPA Section 319 funding round.

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