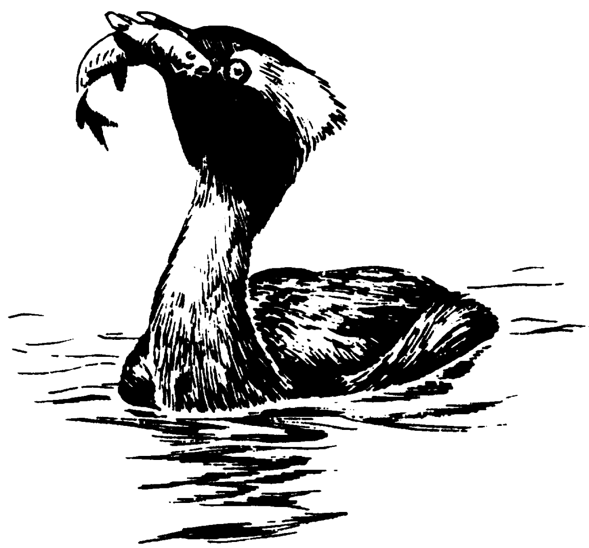
Phase I Watershed Assessment
Final Report and TMDL

Center Lake Trophic State Index TMDL
Custer County, South Dakota



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

September 2007

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

Center Lake Watershed Assessment Final Report and Total Maximum Daily Load

By

Rebecca Spawn-Stroup
Aquatic Ecologist, Consultant
Natural Resource Solutions

and

Aaron Larson
Environmental Program Scientist
SD Department of Environment and Natural Resources

Sponsor

Black Hills Resource Conservation and Development

September 2007

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

Executive Summary

Center Lake was included in the 2002 and 2004 South Dakota 303(d) lists as an impaired waterbody (SDDENR, 2002; SDDENR, 2004). Additional information supporting these listings was derived from statewide lake assessment data within the 2002 305(b) South Dakota Report to Congress (SDDENR, 2002), which states that the sources of excess nutrients, siltation and algae are highway maintenance and runoff, natural sources, and recreation and tourism activities. All the above documents listed the following impairments: high pH levels and a Trophic State Index (TSI) values.

Since this study was conducted, SD DENR has published the 2006 Integrated Report for Surface Water Quality Assessment and developed new criteria for assessing TSI impairment. Center Lake was again listed as impaired in 2006 for TSI and pH impairments. The TSI impairment listing was based on the revised TSI criteria, which requires Center Lake to maintain a median chlorophyll-*a* and Secchi depth TSI value of ≤ 48.

A Center Lake watershed assessment project was initiated in order to (1) assess current physical, chemical, and biological condition of Center Lake and its tributaries, (2) determine non-point source critical areas within the Center Lake watershed, (3) define management prescriptions for identified non-point source critical areas, and (4) develop a Total Maximum Daily Load (TMDL) for each identified impairment. Water quality samples were collected monthly from two lake sites, two tributary sites, one inlet site and one outlet site were sampled from August 2001 to August 2002. Continuous stage data was also collected from the tributary sites throughout the study period in order to determine sediment and nutrient loadings.

While most of the assessed parameters fell within state water quality standards, a number of water temperature, dissolved oxygen, pH and TSI values exceeded the applicable water quality criterion. Approximately 30% of the temperature measurements were above the limit of 18.3° C (65° F), 25% of the dissolved oxygen measurements were below the minimum limit of 6 mg/L, and 40% of the pH measurements exceeded the upper pH limit of 8.6 standard units. TSI values indicate eutrophic conditions, with average and median TSI values > 50.

Lake modeling results indicate that a 70% percent reduction of total phosphorus load is required to meet the fishery-based TSI criterion (median chlorophyll and Secchi depth TSI value ≤ 48). A 70% reduction of total phosphorus load was set as the TMDL goal to achieve fully supporting status.

Non-point source critical areas within the study watershed were identified using export coefficient calculations. The subwatershed areas were represented by tributary sites CLT-3 and CLT-4, with CLT-5 representing the entire watershed. Export coefficient values for entire watershed were higher than values for subwatershed CLT-3 and subwatershed CLT-4, (in particular, solids and alkalinity were markedly higher for CLT-

5), which may indicate a problem area exists in the lower watershed somewhere below subwatersheds CLT-3 and CLT-4.

The source of phosphorus loading from the Center Lake watershed is a combination of septic system failure, recreational uses, vehicle traffic, as well as natural background sources (i.e. wildlife, weathering, etc.). However, degraded water quality in Center Lake is primarily attributed to recreational activity within the watershed. Although much of the watershed remains in its natural state, the intense usage of recreational facilities within Custer State Park has degraded the watershed condition.

Additional restroom facilities, waste receptacles, and fish-cleaning stations are recommended for the Center Lake recreational area to reduce the litter and human waste associated with the recreational use of Center Lake. Park managers should also consider alternative wastewater treatment options to replace or enhance the current septic system servicing the Center Lake recreational area.

Roadways near Center Lake and streams contributing to Center Lake should be inspected for erosion and excess weathering. Identified erosional areas should be repaired or stabilized to prevent further sedimentation of the lake. Stream bank and shoreline protection and enhancement are recommended to allow sediment and nutrient loads to be filtered and reduced before reaching the lake.

Implementation of the management practices recommended above should result in a 70% reduction of the total phosphorus load to Center Lake, which is required to achieve the TMDL target of a median chlorophyll and Secchi depth TSI $\leq$ 48.

It should be noted that water quality data presented in this report may not be representative of a typical year, as the study period was during a time of drought. Nonetheless, lake and watershed management recommendations will improve the water quality of Center Lake and its watershed. Long-term monitoring is recommended following the implementation of management practices to evaluate the effectiveness of suggested management activities.

Acknowledgements

The assessment of Center Lake and its watershed could not have been completed without the assistance of the following organizations. Their cooperation is sincerely appreciated.

Black Hills Resource Conservation and Development

Custer County Conservation District

Natural Resource Conservation Service – Custer County

South Dakota Department of Health

South Dakota Department of Environment and Natural Resources

South Dakota Department of Game, Fish and Parks

United States Environmental Protection Agency – Non-Point Source Program

Table of Contents

List of Figures

List of Tables

Introduction

The purpose of the Custer State Park Lakes Watershed Assessment was to determine the sources of impairment for three small reservoirs, Center Lake, Sylvan Lake, and Legion Lake, as well as the associated inlet and outlet tributaries. This report discusses the current physical, chemical and biological condition of Center Lake and contributing streams and tributaries, potential management recommendations to reduce nutrient and pH levels in Center Lake, and a Total Maximum Daily Load (TMDL) summary for Trophic State Index and pH impairment of Center Lake.

Watershed Description

The Center Lake watershed is approximately 6,270 acres and is located in the north half of Custer State Park. The Center Lake watershed contains heavily forested areas with several campgrounds, day use facilities, the Black Hills Playhouse complex, and beach area facilities in close proximity to the lake and its associated tributaries. The watershed and the sampling locations are shown in Figure 1. Average annual precipitation is approximately 25.4 inches. Approximately 73 % of the precipitation occurs during the months of April through September. In the summer, the average temperature is 65 degrees F. During the winter, the average temperature is 31 degrees F. Average monthly precipitation data (from the weather station located in Custer, SD) for the project period is shown in Figure 2 (source: http://abe.sdstate.edu/weather/weather.htm). Custer is located less than fifteen miles west of the Center Lake watershed and was the closest weather station available for the study period.

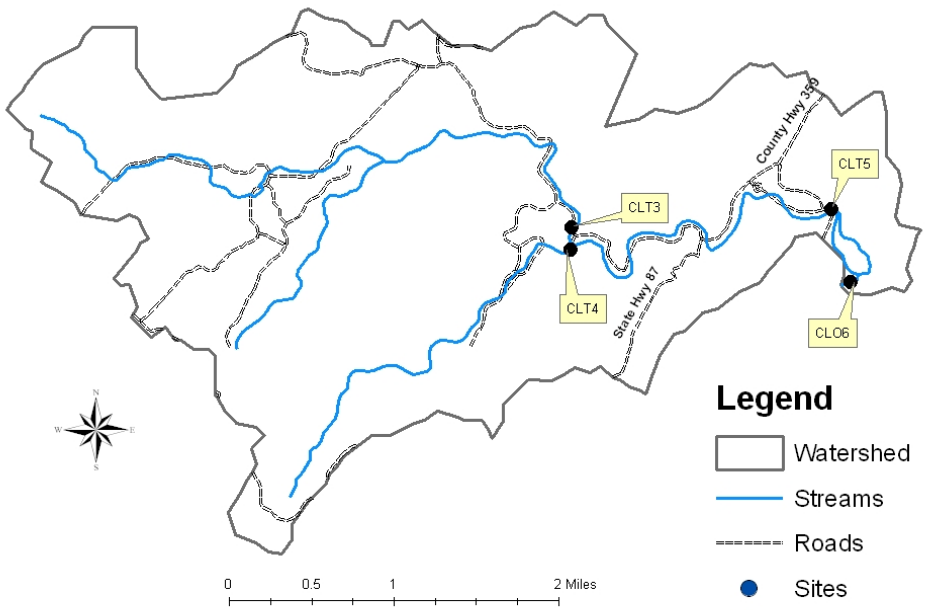


Figure 1. Center Lake watershed and tributary sites, Custer County, SD.

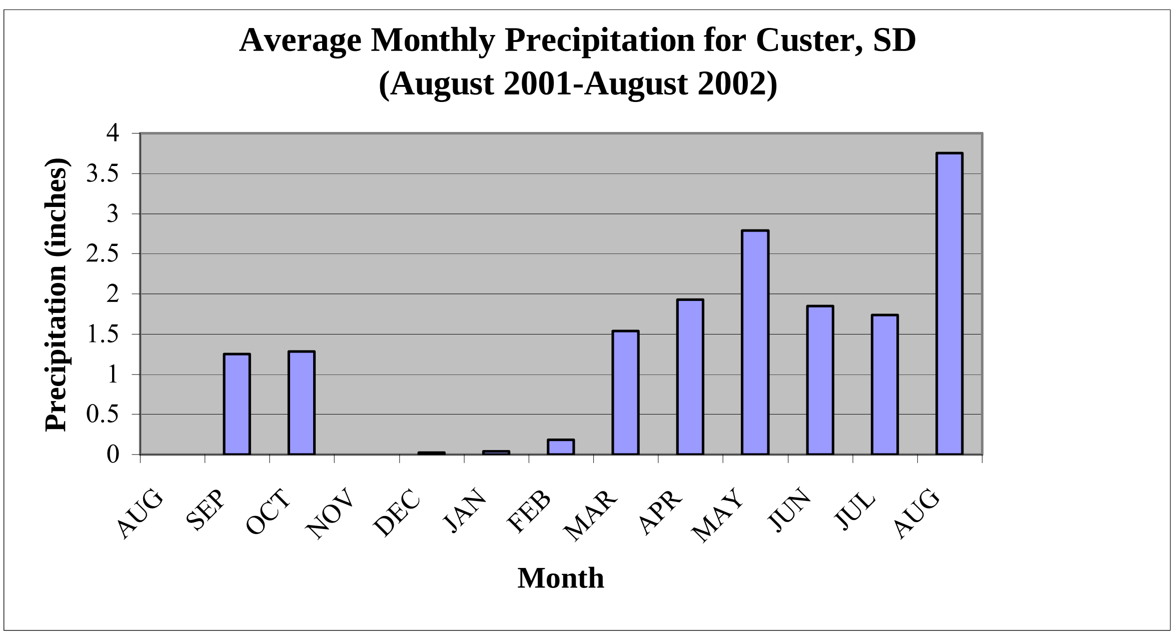


Figure 2. Average monthly precipitation for Custer, SD from 2000-2001.

The primary landuses in the watershed are forestry and recreational. The streams in this watershed drain predominantly forested land and receive runoff from relatively undisturbed lands. The major soil association found in the Center Lake watershed is Buska-Mocmont-Rock outcrop, defined as follows: Rock outcrop and deep, well drained, gently sloping to very steep, loamy soils formed in material weathered from micaceous schist and granite; on mountains.

The primary inflow of Center Lake is Grace Coolidge Creek, draining approximately 6,270 acres. The outlet for Center Lake is also Grace Coolidge Creek. The entire Center Lake watershed is in Custer county, which has a population of 7,275 residents as recorded in the year 2000 census.

Beneficial Use Assignment and Water Quality Standards

All water bodies within the State of South Dakota have been assigned beneficial uses. All waters (both lakes and streams) in the state receive the beneficial uses of fish and wildlife propagation, recreation and livestock watering. Additionally, all streams are also assigned the use of irrigation. The state assigns additional uses to particular water bodies based on a beneficial use analysis of each water body. Water quality standards have been defined in South Dakota state statutes in support of these uses. These standards consist of suites of criteria that provide physical and chemical benchmarks from which management decisions can be developed.

The following beneficial uses have been assigned to Center Lake: (1) coldwater permanent fish propagation, (2) immersion recreation, (3) limited contact recreation, and (4) wildlife propagation, recreation and livestock watering. Table 1 lists the criteria that must be met to maintain the above beneficial uses. When multiple standards exist for a particular parameter, the most stringent standard is used.

Table 1. Surface water quality standards for Center Lake

Parameter	Standard *	Use requiring standard
Nitrate – N	≤ 88 mg/L	Wildlife propagation, recreation, and stock watering
Total Ammonia	$\leq (0.275/(1+10^{7.204-pH})) + (39.0/(1+10^{pH-7.204}))$	Coldwater permanent fish propagation
Undissociated Hydrogen Sulfide	≤ 0.002 mg/L	Coldwater permanent fish propagation
Alkalinity ($CaCO_3$)	≤ 1313 mg/L	Wildlife propagation, recreation, and stock watering
pH	≥ 6.6 - ≤ 8.6	Coldwater permanent fish propagation
Conductivity at 25° C	≤ 7,000 umhos/cm	Wildlife propagation, recreation, and stock watering
Total Dissolved Solids	≤ 4,375 mg/L	Wildlife propagation, recreation, and stock watering
Total Suspended Solids	≤ 53mg/L	Coldwater permanent fish propagation
Temperature	≤ 65 º F (18.3 º C)	Coldwater permanent fish propagation
Dissolved Oxygen	≥ 6.0 mg/L	Coldwater permanent fish propagation
Fecal Coliform Bacteria	≤ 400 colonies/100mL	Immersion recreation

* These values reflect daily maximum concentrations (criteria are also established for 30-day averages).

All South Dakota streams are assigned the beneficial uses of irrigation, fish and wildlife propagation, recreation, and livestock watering. These standard beneficial uses have been assigned to all streams in the Center Lake watershed. Table 2 lists the criteria that must be met to maintain the beneficial uses of irrigation, fish and wildlife propagation, recreation and livestock watering.

Table 2. State surface water quality standards for tributary site CLT-4*

Parameter	Standard +	Use requiring standard
Alkalinity ($CaCO_3$)	≤ 1313 mg/L	Wildlife propagation, recreation, and stock watering
pH	6.0 – 9.5	Wildlife propagation, recreation, and stock watering
Conductivity	≤ 4,375 umhos/cm	Irrigation
Total Dissolved Solids	≤ 4,375 mg/L	Wildlife propagation, recreation, and stock watering
Nitrate-N	≤ 88 mg/L	Wildlife propagation, recreation, and stock watering

* Tributary CLT-4 has less stringent standards than portions of Grace Coolidge Creek, because it is not designated with the beneficial uses of cold water permanent fish life propagation or limited contact recreation.
+ These values reflect daily maximum concentrations (criteria also available for 30-day averages).

Grace Coolidge Creek, from the confluence of Battle Creek to S12, T35, R5E, has the additional beneficial uses of coldwater permanent fish propagation and limited contact recreation. These uses are in addition to the uses assigned to all streams (irrigation, fish and wildlife propagation, recreation and livestock watering). Figure 3 displays the portion of Grace Coolidge Creek that is designated with the beneficial uses of coldwater permanent fish propagation and limited contact recreation. Table 3 lists the criteria that must be met to support the beneficial uses of coldwater permanent fish life propagation and limited contact recreation.

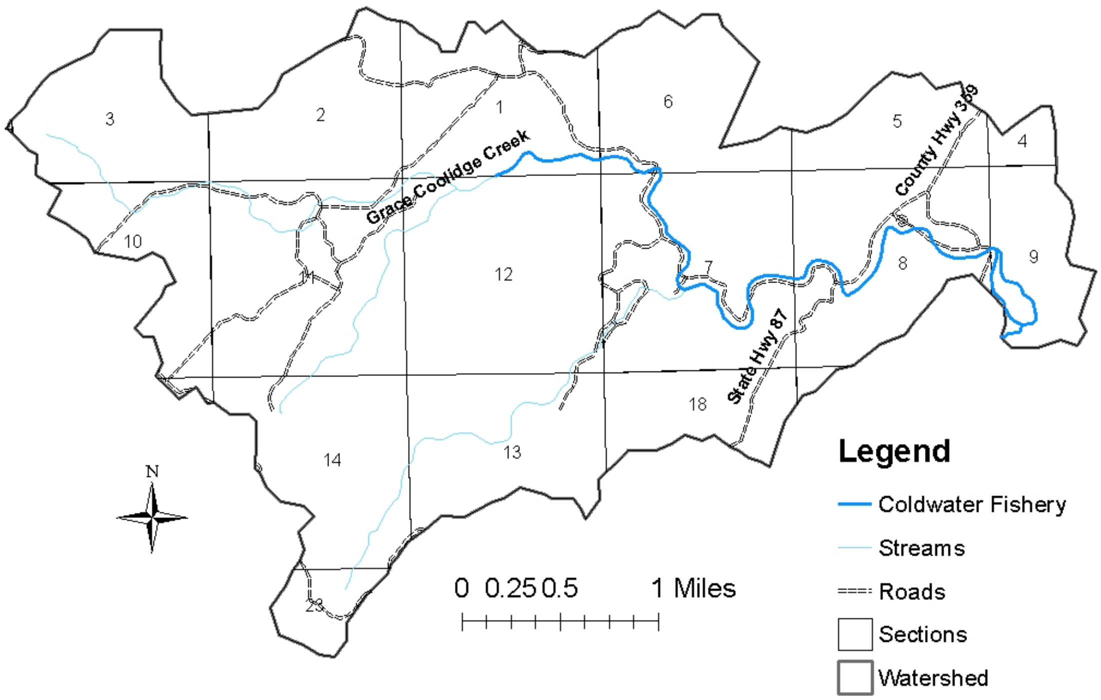


Figure 3. Center Lake watershed showing beneficial use assignments for Grace Coolidge Creek, SD. The stream segment identified as a coldwater fishery is also designated with the limited contact recreation use.

Table 3. State surface water quality standards for tributary sites CLT-3, CLT-5 and CLO-6.*

Parameter	Standard *	Use requiring standard
Nitrate – N	≤ 88 mg/L	Wildlife propagation, recreation, and stock watering
Total Ammonia	$\leq (0.275/(1+10^{7.204-pH})) + (39.0/(1+10^{pH-7.204}))$	Coldwater permanent fish propagation
Undissociated Hydrogen Sulfide	≤ 0.002 mg/L	Coldwater permanent fish propagation
Alkalinity ($CaCO_3$)	≤ 1313 mg/L	Wildlife propagation, recreation, and stock watering
pH	≥ 6.6 - ≤ 8.6	Coldwater permanent fish propagation
Conductivity at 25° C	≤ 7,000 umhos/cm	Wildlife propagation, recreation, and stock watering
Total Dissolved Solids	≤ 4,375 mg/L	Wildlife propagation, recreation, and stock watering
Total Suspended Solids	≤ 53mg/L	Coldwater permanent fish propagation
Temperature	≤ 65 º F (18.3 º C)	Coldwater permanent fish propagation
Dissolved Oxygen	≥ 6.0 mg/L	Coldwater permanent fish propagation
Fecal Coliform Bacteria	≤ 2,000 colonies/100mL	Limited contact recreation

* These values reflect daily maximum concentrations (criteria are also established for 30-day averages).

Threatened and Endangered Species

The threatened and endangered species that could potentially be found in the Center Lake watershed have been listed in Table 4, below. None of the species listed were encountered during this study. However, care should be taken when considering management activities in the watershed.

Table 4. The U.S. F&WS threatened and endangered species that could potentially be found in the Center Lake watershed.

Species Scientific Name	Species Common Name
Couesius plumbeus	Lake Chub
Senecio spartioides	Broom Groundsel
Carex brunnescens	Brownish Sedge
Storeria Occipitomaculata pahasapae	Black Hills Redbelly Snake
Stipa robusta	Sleepy Grass
Catostomus platyrhynchus	Mountain Sucker
Eriophorum polystachion	Tall Cottongrass
Liochlorophis vernalis	Smooth Green Snake
Elymus diversiglumis	Interrupted Wildrye
Lesquerella arenosa var argillosa	Sidesaddle Bladderpod

Project Goals, Objectives and Activities

The primary goals of this assessment project were to locate and document sources of impairment to the Center Lake watershed and to develop feasible restoration alternatives in order to decrease sedimentation and nutrient loads.

Objectives and Tasks

Objective 1: Lake Sampling

The first objective was to determine the current condition of Center Lake and calculate the trophic state. This information was used to determine the total amount of nutrient loading that is occurring in the lake and the reduction of nutrients required to improve the trophic condition of Center Lake and meet the TMDL goal (median chlorophyll and Secchi depth TSI $\leq$ 48).

Water quality samples and field measurements were collected at two in-lake sites on Center Lake. In-lake samples were tested to assess ambient nutrient concentrations in the lake. Energy Laboratories, Inc. in Rapid City, SD analyzed all water chemistry samples and fecal coliform samples.

Objective 2: Tributary Sampling

Sediment and nutrient loadings from Grace Coolidge Creek in the Center Lake watershed were estimated through hydrologic and chemical monitoring. The information was then used to locate critical areas in the watershed to be targeted for implementation.

Water quality samples and field measurements were collected from four stream sites (two tributary sites as well as from the Center Lake inlet and outlet sites). Samples were collected monthly over a one-year period. Water level recorders were installed at all sites to maintain a continuous stage record for the project period. Discrete discharge measurements were taken on a regular schedule. Discharge measurements and water level data were used to calculate a hydrologic budget for the system. Discharge measurements and concentrations of sediment and nutrients were used to calculate total loadings from the watershed. Energy Laboratories, Inc. in Rapid City, SD analyzed all water chemistry samples.

Biological samples were collected for the tributary sites as well. Fecal coliform samples were collected for all four tributary sites, and benthic macroinvertebrate samples were collected for only the inlet site and site CLT-3. The South Dakota State Health Laboratory analyzed the fecal coliform samples. Natural Resource Solutions, an environmental consulting firm in South Dakota, analyzed all benthic macroinvertebrate samples.

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

Approved quality assurance/quality control (QA/QC) procedures were utilized to ensure the collection of accurate and defendable data. QA/QC samples consisted of field blanks and field replicate samples. Replicate and blank samples were analyzed for at least 10% of the total number of collected water samples. All QA/QC activities were conducted in accordance with the EPA approved Quality Assurance Project Plan for the Water Resource Assistance Program. The activities involved with QA/QC procedures and the results of QA/QC monitoring are reported in a subsequent section of this report.

Objective 4: Watershed Modeling

Due to the homogenous landuse (predominantly forested land), watershed modeling was not utilized for the Center Lake watershed. Instead, export coefficients were used in order to identify critical areas in the watershed. Results of the FLUX and BATHTUB modeling were used in conjunction with the nutrient and hydrologic budget to assist in determining critical areas in the watershed.

Objective 5: Public Participation

Informational meetings were held to inform the involved parties and the general public of progress on the study. These meetings provided an avenue for input from the residents in the area. News releases were also made available to local news media.

Objective 6: Development of Restoration Alternatives

Feasible watershed restoration alternatives and recommendations for the Center Lake watershed are documented in this report. This effort will provide data for the development of an implementation project for the Center Lake watershed.

Methods

Tributary Assessment Methods

Four stream sites were selected for chemical and hydrologic monitoring. All stream samples and measurements were collected using methods described in *Standard Operating Procedures for Field Samplers* for the South Dakota Water Resources Assistance Program (Stueven et al., 2000a). Water and air temperature, pH, and dissolved oxygen measurements were taken using a YSI meter. Table 5 lists all parameters assessed at all stream sites.

Table 5. Parameters measured at stream sites.

Physical	Chemical	Biological
Air temperature	Dissolved oxygen	Fecal coliform bacteria
Water temperature	Ammonia	Benthic macroinvertebrates
Discharge	Unionized ammonia	
Depth	Nitrate/nitrite	
Visual observations	TKN	
Water level	Total phosphorus	
Total solids	Total dissolved phosphorus	
Total dissolved solids	Field pH	
Total suspended solids	Conductivity	
	Alkalinity	

Water level recorders were installed at sites to maintain a continuous stage record for the project period. OTT Thalimedes stage recorders were installed at sites CLT-3, CLT-4, CLT-5 and CLO-6. Daily stage averages were calculated for all sites. Instantaneous discharge measurements were taken with a hand-held current velocity meter. A regression equation was developed from the relationship between discharge and stage data to estimate hydrologic load for the drainage system. Watershed loads were calculated from discharge measurements and sample concentrations of sediment and nutrients. FLUX, a eutrophication model developed by the Army Corps of Engineers (US ACOE, 1999), was used to estimate nutrient and sediment loading.

Lake Assessment Methods

Physical, chemical, and biological parameters were examined for Center Lake on a monthly basis from August 2001 to August 2002, excluding the months March and April 2002. Samples were collected from surface and bottom depths at two sites (Figure 4). Water temperature, dissolved oxygen, conductivity, field pH, and water depth were measured using a YSI multi-probe meter. As with tributary sampling, all samples and measurements were collected using methods described in *Standard Operating Procedures for Field Samplers* for the South Dakota Water Resources Assistance Program (Stueven et al., 2000a).

The biological parameters examined for Center Lake were Fecal coliform and chlorophyll *a*, from surface and bottom depths. Although chlorophyll *a* samples were collected, the chlorophyll *a* samples were not promptly sent to the laboratory for analysis. After the samples had been held in a freezer for almost a year, when they were sent to the laboratory for analysis it was discovered that the samples were then too degraded to yield viable results. Thus, all data for chlorophyll *a* in this report are model-predicted values. Table 6 lists all parameters measured for Center Lake.

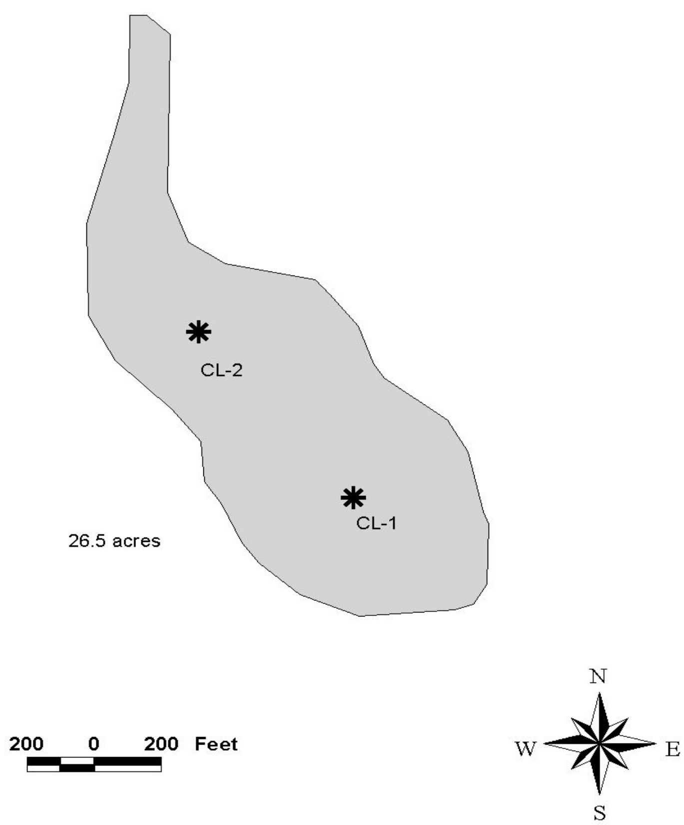


Figure 4. Location of lake sampling sites for Center Lake, Custer County, SD.

Table 6. Parameters measured at lake sites.

Physical	Chemical	Biological
Air temperature	Total alkalinity	Fecal coliform bacteria
Water temperature	Unionized ammonia	Chlorophyll *a**
Secchi transparency	Total Kjeldahl Nitrogen	
Visual observations	Nitrate/Nitrite	
Total solids	Total phosphorus	
Total dissolved solids	Total dissolved phosphorus	
Total suspended solids	Dissolved oxygen	
Depth	Conductivity	
	Field pH	

* All data for chlorophyll *a* in this report are estimated values only; see explanation in preceding paragraph.

Results

Tributary Physical and Chemical Parameters

Annual Loading

Hydrologic and constituent loads were estimated from sample data and instantaneous flow measurements using the FLUX model in order to develop nutrient and hydrologic budgets for Center Lake. Approximately 183,427 acre-ft of water flowed into Center Lake from the gauged watershed during the project period. The amount of water delivered per acre for the gauged watershed was 29.2 acre-ft/year. Total flow volume and mean flow rate for each site are listed in Table 7.

Table 7. Hydrologic loads delivered from the Center Lake watershed. CLO-6 is the outlet site and CLT-5 is the inlet site.

Site	Flow Duration (project period)	Total Flow Volume (hm^3)	Mean Flow Rate (hm^3/yr)	Mean Flow Rate (cfs)
CLT-3	365 days	0.145	0.145	0.147
CLT-4	365 days	0.061	0.061	0.077
CLT-5	365 days	0.552	0.552	0.631
CLO-6	365 days	0.401	0.401	0.439

Note: 1 hm^3 = 1,000,000 m^3 and 1m^3 ≈ 35.3 ft^3

Seasonal and annual loads for each measured parameter (nutrients and solids) were also calculated using the FLUX model (Table 8). Seasonal constituent loads were derived in the following manner: winter is the sum of December, January and February loads; spring is the sum of March, April and May loads; summer is the sum of June, July and August loads; and fall is the sum of September, October and November loads. Relatively consistent loading occurred throughout the study period, with slightly higher loading occurring in the spring due to snowmelt runoff and rain events. Figure 5 and Figure 6 are graphical representations of seasonal annual loading for the nutrients total nitrogen and total phosphorus, respectively.

Table 8. Seasonal and annual loads (kg) delivered from the Center Lake watershed.

Parameter	Spring	Summer	Fall	Winter	Annual
Total Nitrogen	40.2	39.4	36.3	35.5	151.4
Ammonia	7.3	7.1	6.6	6.5	27.5
Nitrate+Nitrite	3.8	3.6	3.2	3.2	13.8
Total Kjeldahl Nitrogen	36.5	35.8	33	32.3	137.6
Organic Nitrogen	29.2	28.6	26.5	25.8	110.1
Total Phosphorus	12	12	11.9	11.8	47.7
Total Dissolved Phosphorus	9.3	9.2	9.1	9	36.6
Alkalinity	7,052.6	6,930.2	6,390.3	6,329.5	26,702.6
Total Solids	11,730.6	11,527.1	10,629.1	10,527.8	44,414.6
Total Dissolved Solids	11,127.2	10,934.1	10,082.3	9,986.1	42,129.7
Total Suspended Solids	11,127.2	10,934.1	10,082.3	9,986.1	42,129.7
Inorganic Nitrogen	10.9	10.8	9.9	9.7	41.3

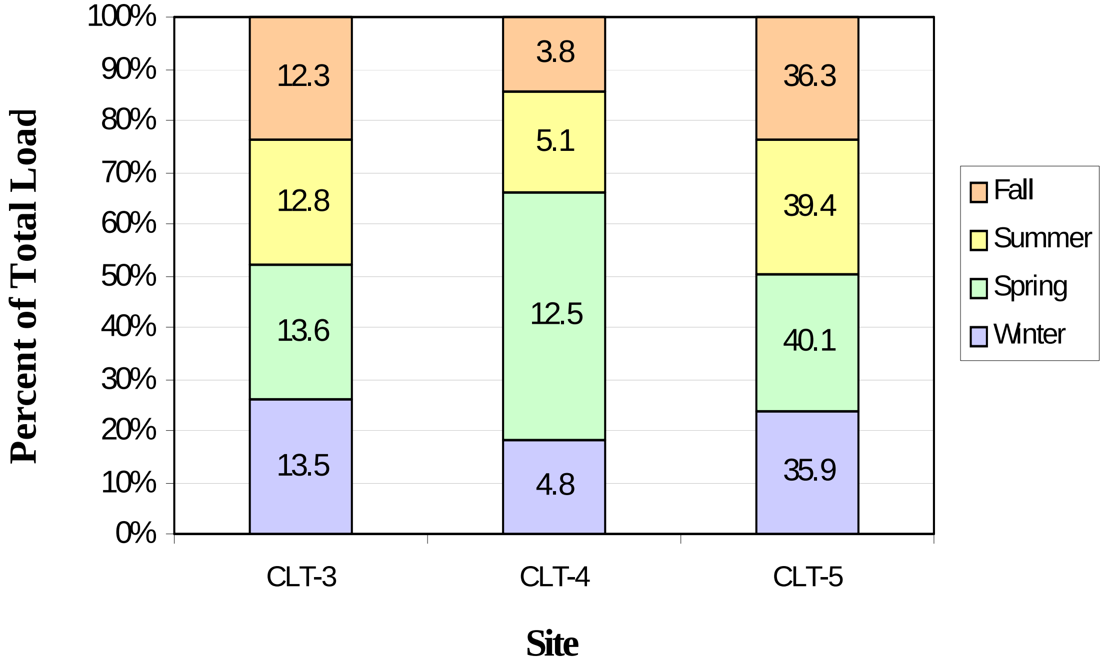


Figure 5. Seasonal loading of total nitrogen (kg) by site for tributary sites.

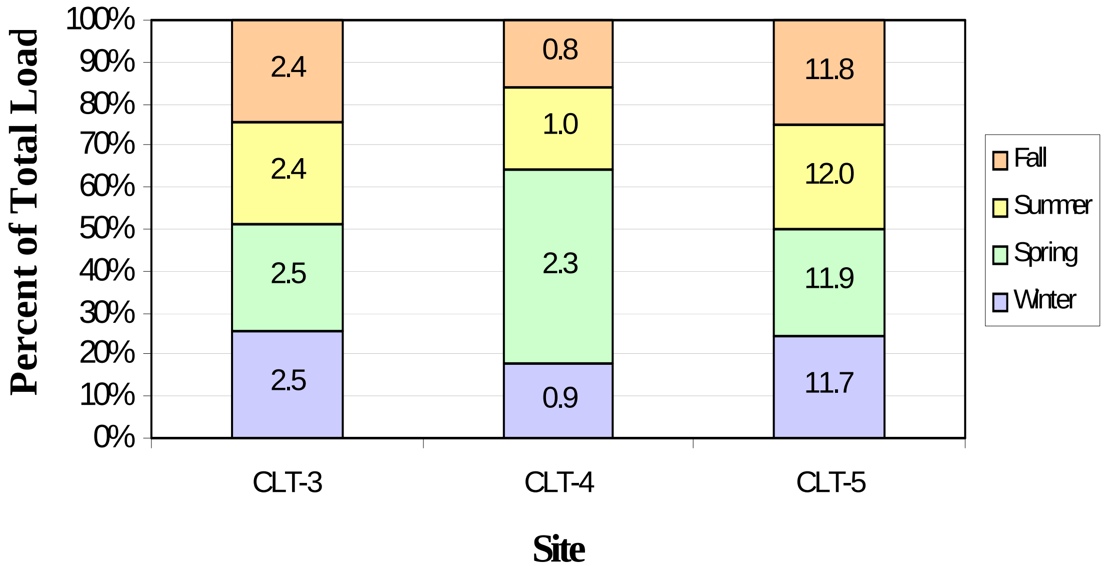


Figure 6. Seasonal loading of total phosphorus (kg) by site for tributary sites.

Tributary Export Coefficients

Export coefficient values were used to make comparisons between subwatersheds CLT-3 and CLT-4, and the total watershed, CLT-5. The CLT-3 subwatershed had higher total solids, higher total dissolved solids and higher alkalinity than subwatershed CLT-4 (Table 9). CLT-4 had higher Ammonia, total Nitrogen and total Phosphorus than CLT-3. The inlet site (CLT-5) represents the whole watershed. CLT-5 exhibited higher export coefficient values than CLT-3 and CLT-4, including total phosphorus export coeffiecients (Figure 7). These higher total export coefficient values for the inlet indicate a problem area exists in some area of the watershed below CLT-3 and CLT-4.

Table 9. Export coefficient values for each parameter for all tributary sites (kg/acre/yr).

Parameter	CLT-3	CLT-4	CLT-5
Alkalinity	1.60664	0.89747	4.25879
TKN	0.01373	0.01361	0.02199
Nitrite+Nitrate	0.00154	0.00119	0.00219
Ammonia	0.00228	0.00238	0.00440
Organic Nitrogen	0.01139	0.01576	0.01759
Inorganic Nitrogen	0.00389	0.00357	0.00662
Total Nitrogen	0.01611	0.01948	0.02419
Total Phosphorus	0.00302	0.00372	0.00756
Total Dissolved Phosphorus	0.00204	0.00223	0.00582
Total Suspended Solids	0.12657	0.12312	0.36654
Total Dissolved Solids	3.25623	2.78922	6.71925
Total Solids	3.38312	2.92662	7.08367

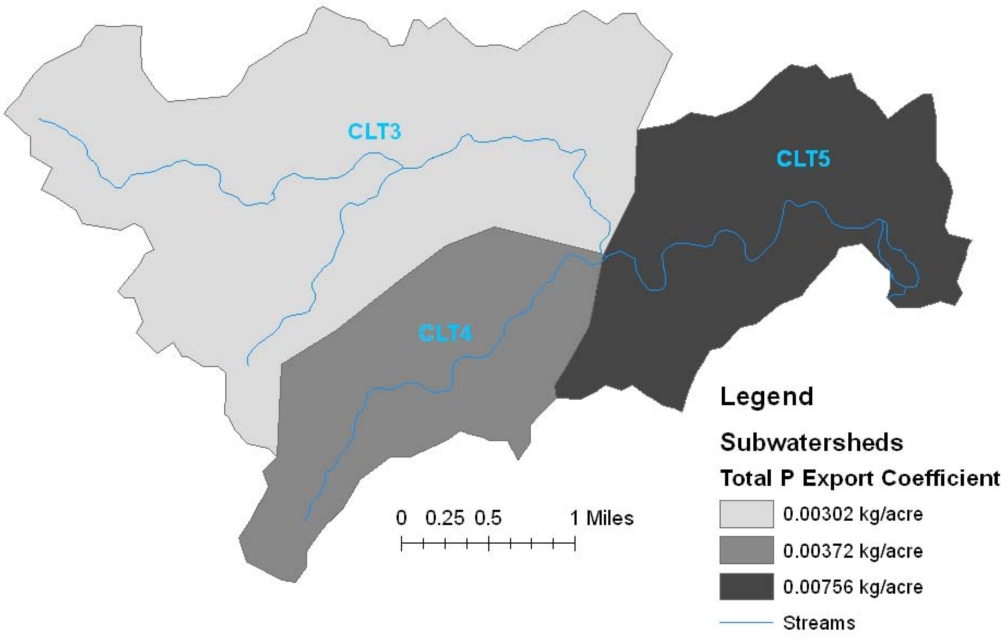


Figure 7. Center Lake subwatersheds showing total phosphorus export coefficients. Darker color indicates higher phosphorus delivery.

Water Temperature

Water temperature, as with all environmental variables in aquatic systems, is extremely interconnected to other variables, directly impacting all biological, chemical, and physical processes. Temperature can influence metabolic rates of aquatic organisms, toxicity of pollutants, and levels of dissolved oxygen. The greatest source of heat in freshwaters is solar radiation, especially waterbodies that are directly exposed to the sun (Hauer and Lamberti, 1996).

As can be expected in flowing water systems, water temperatures were highly variable. Greatest variability was observed at site CLT-3. Average temperature at site CLT-3 was 10.52 degrees Celsius. Average temperature at the inlet site (CLT-5) was 12.56, while average temperature at the outlet site (CLO-6) was 14.02 degrees Celsius. Two stream temperature measurements exceeded the criterion during this assessment (see Table 10): one at CLT-5 (19.10 degrees Celsius) and one at CLO-6 (20.10 degrees Celsius). The outlet site overall exhibited higher temperatures than the other sites (Figure 8). Note: the legend for all box plots follows Figure 8.

Table 10. Descriptive statistics of water temperature (degrees Celsius) for tributary sites.

Water Temperature, C°

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	10.52	9.60	3.30	18.20	5.13
CLT-4	9.77	8.30	4.50	16.00	4.11
CLT-5	12.56	12.56	5.20	19.10	4.46
CLO-6	14.02	13.60	8.15	20.10	3.95

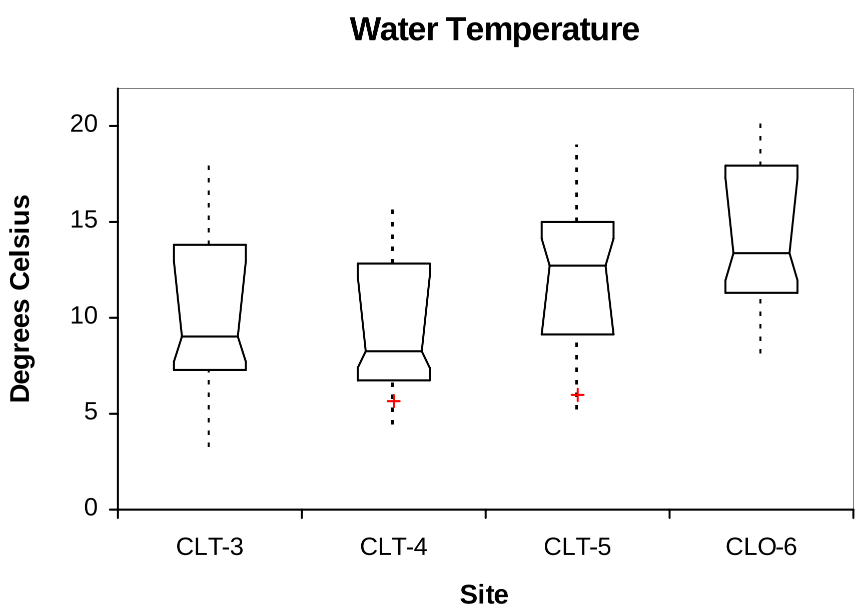
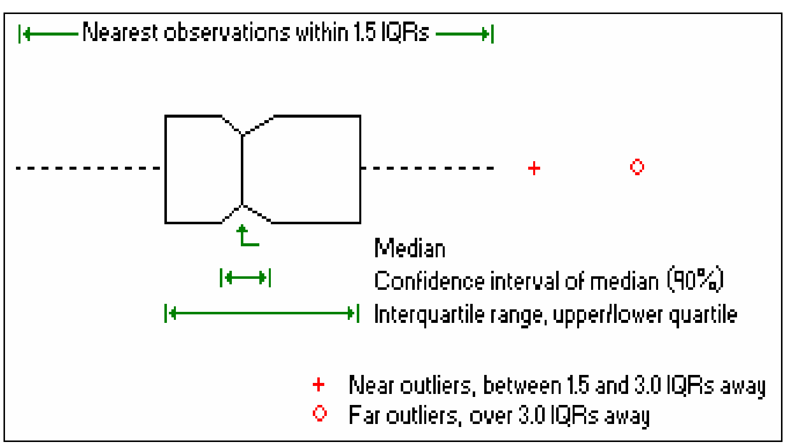


Figure 8. Box plot of water temperature by site for tributary sites, demonstrating medians, quartiles (25th and 75th percentiles), non-outlier minima and maxima, and outliers (see legend, below).

Box plot Legend:



Dissolved Oxygen

As suggested by Wetzel (2001), oxygen is perhaps the most fundamental parameter of lakes. Dissolved oxygen (DO) is essential to the metabolism of all aerobic aquatic organisms. For this reason, it is important to monitor the solubility and dynamics of oxygen distribution, in order to better understand the distribution of aquatic organisms.

Concentrations of DO vary both spatially and temporally. Seasonal loadings of organic matter greatly influence DO concentrations (Wetzel, 2001). Physical factors, such as temperature and pressure, also dramatically influence concentrations of DO. The DO capacity of a waterbody increases considerably with colder water temperatures.

Highest average DO concentration (9.19 mg/L) was observed at site CLT-3. Average DO concentration at the inlet site was 8.36 mg/L, while average DO concentration was 6.43 mg/L at the outlet (Table 11). Overall, site CLT-3 exhibited higher DO concentrations, while the outlet site (CLO-6) exhibited the lowest overall DO concentrations (Figure 9). At the outlet site, five out of eight samples were below the DO criterion, which requires DO concentrations ≥ 6 mg/L. This is attributed to the extremely low flows observed at this site (0.21 to 0.60 cfs). CLO-6 was the only monitored site where flow ceased during the study. Due to the low flows experienced at this site, oxygen concentrations below the standard are attributed to effects of the dam. DO concentrations likely increase further downstream, as the stream flow increases, to a level that meets water quality standards. Only one other site, designated as a coldwater fishery, experienced a DO concentration below the standard. At site CLT-5, one DO measurement was recorded below the standard, but this measurement (5.96 mg/L) was only just below the standard and was considered an outlier.

Table 11. Descriptive statistics of dissolved oxygen (mg/L) for tributary sites.

Dissolved Oxygen, mg/L

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	9.19	9.19	6.15	11.10	1.44
CLT-4	8.90	8.90	5.66	10.63	1.39
CLT-5	8.36	8.36	5.96	10.43	1.26
CLO-6	6.43	5.34	4.70	10.60	1.88

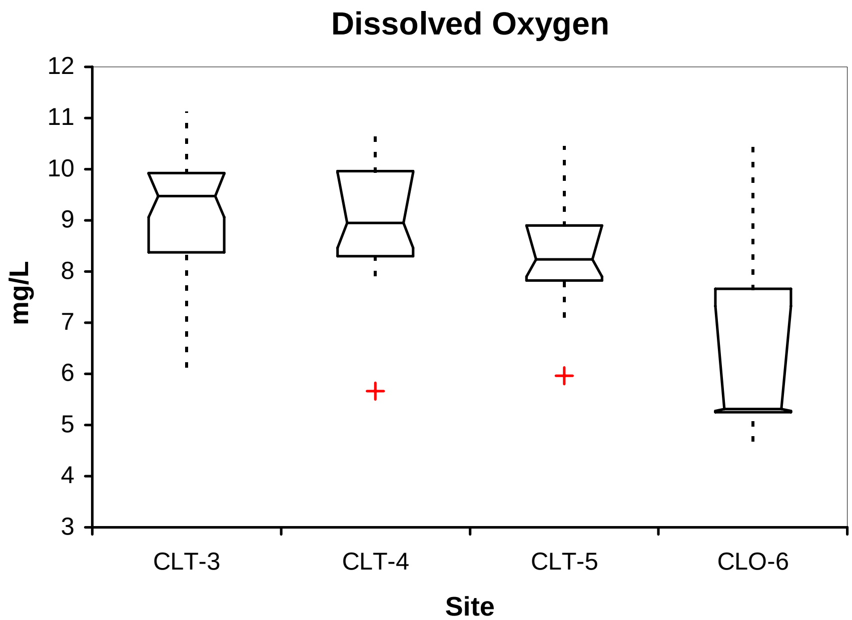


Figure 9. Box plot of dissolved oxygen by site for tributary sites.

Acidification and Alkalinity

The primary measurements of acidification are alkalinity and pH. The pH scale ranges from 0 to 14, with 7 being neutral. Water with pH < 7 is considered acidic, while water with pH > 7 is considered basic. The pH of water is regulated largely by the interaction of hydrogen ions. Natural waters exhibit wide variations in acidity and alkalinity. The pH of natural waters ranges between the extremes of 2 and 12 (Wetzel, 2001), yet most forms of aquatic life require an environment with a pH of 6.5 to 9.0.

Field pH for the tributary sites ranged from 7.00 to 12.40. Average field pH at the inlet site was 8.19, while average pH at the outlet site was 8.28. Mean pH appeared generally consistent across tributary sites, with the highest average being found at the outlet site (Table 12). Field pH measurements were similar across all sample dates for all sites, except for two very high measurements taken at the inlet and outlet sites on September 26, 2002 (Figure 10). With the exception of these two extreme outliers, which were likely due to instrumentation error, field pH measurements were fairly consistant and fell within the water quality standard for the cold water permanent fish propagation use (6.6 to 8.6 standard units).

Table 12. Descriptive statistics of field pH (standard units) for tributary sites.

Field pH, standard Units

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	7.73	7.70	7.30	8.20	0.25
CLT-4	7.63	7.63	7.00	8.30	0.38
CLT-5	8.19	8.00	7.00	11.80	1.25
CLO-6	8.28	7.70	7.10	12.40	1.59

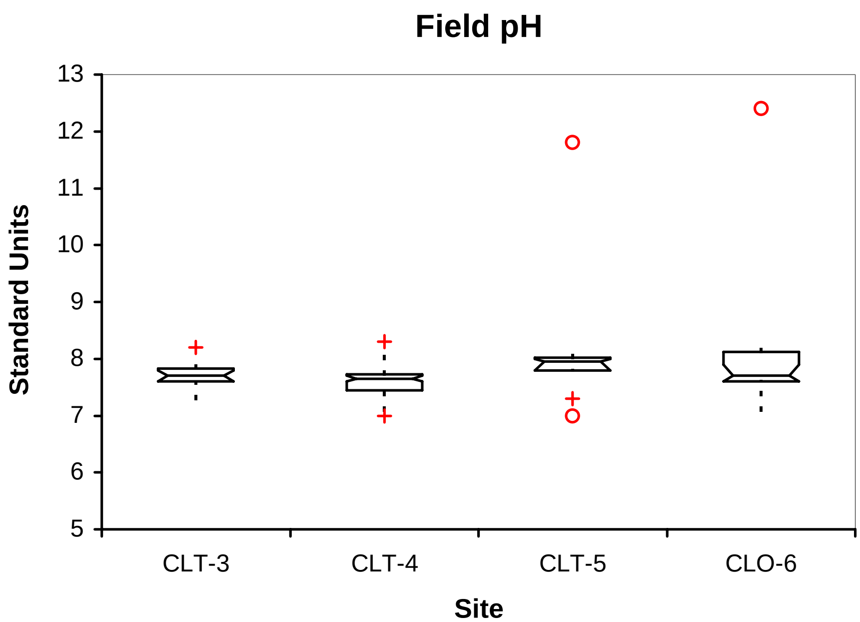


Figure 10. Box plot of field pH by site for tributary sites. Two high extreme outliers observed at CLT-5 and CLO-6 were attributed to instrumentation error.

Alkalinity is a term that refers to the buffering ability of the carbonate system in water. The term is also used interchangeably with 'acid neutralizing capacity' (ANC), which is the capacity to neutralize strong inorganic acids (Wetzel, 2001). Alkalinity is a product of geological setting. Soils rich in carbonate rock, such as limestone, provide a source of high alkalinity (Monson, 2000). In general, increased alkalinity inhibits drastic pH changes. Alkalinity typically ranges from 20 to 200 mg/L in natural environments (Lind, 1985).

Alkalinity concentrations of stream samples were rather low, as can be expected from drainage composed of predominantly granite and carbonate-poor soils. Average alkalinity concentrations from inlet and outlet samples were similar, although somewhat higher at the outlet site (Table 13). Like most parameters, greater variability in alkalinity concentrations was observed below the impoundment (Figure 11). The alkalinity standard of ≤ 1313 mg/L was not exceeded.

Table 13. Descriptive statistics of alkalinity (mg/L) for tributary samples.

Alkalinity, $CaCO_3$, mg/L

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	35.20	38.00	26.00	40.00	5.08
CLT-4	20.80	22.00	16.00	24.00	2.86
CLT-5	48.20	48.20	34.00	62.00	7.40
CLO-6	53.25	54.00	20.00	76.00	14.93

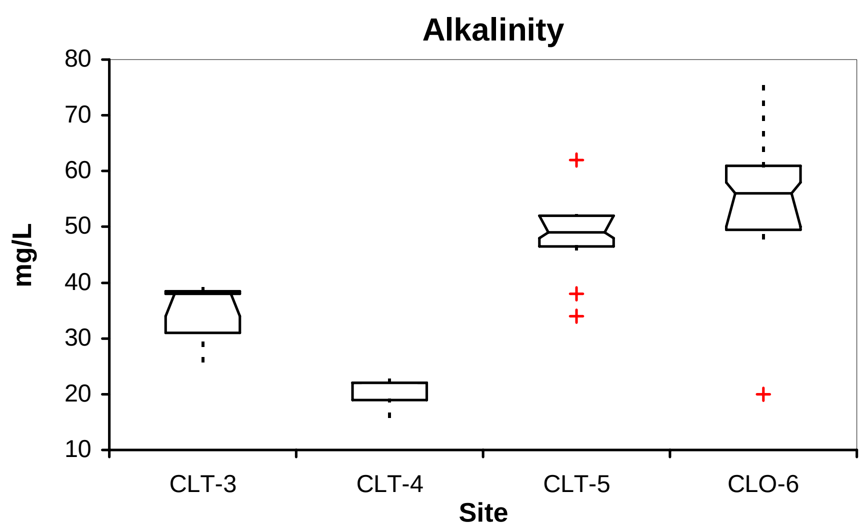


Figure 11. Box plot of alkalinity by site for tributary sites.

Solids

"Solids" is a general term that refers to suspended or dissolved materials that are present in the waterbody. Three solids parameters were examined in this assessment: total solids, total suspended solids and total dissolved solids. Total solids include the sum of dissolved and suspended material. Dissolved solids are those materials small enough to pass through a 2.0 µm filter. Suspended solids consist of larger materials that do not pass through the filter;

this material is also referred to as the residue. The suspended materials include both organic and inorganic forms.

Concentrations of total solids were comparable at the inlet and outlet sites (Figure 12). Inlet sample concentrations ranged from 73 to 100 mg/L (mean = 80.80). Outlet sample concentrations ranged from 68 to 100 mg/L (mean = 83.75) (Table 14). FLUX estimated an annual load of 44,415 kg of total solids was delivered to Center Lake from the watershed. This equates to an average of approximately 7.1 kg per watershed acre.

Table 14. Descriptive statistics of total solids (mg/L) for tributary samples.

Total Solids, mg/L

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	73.50	74.00	59.00	96.00	10.21
CLT-4	56.90	56.00	32.00	94.00	15.72
CLT-5	80.80	78.00	73.00	100.00	7.48
CLO-6	83.75	84.00	68.00	100.00	11.24

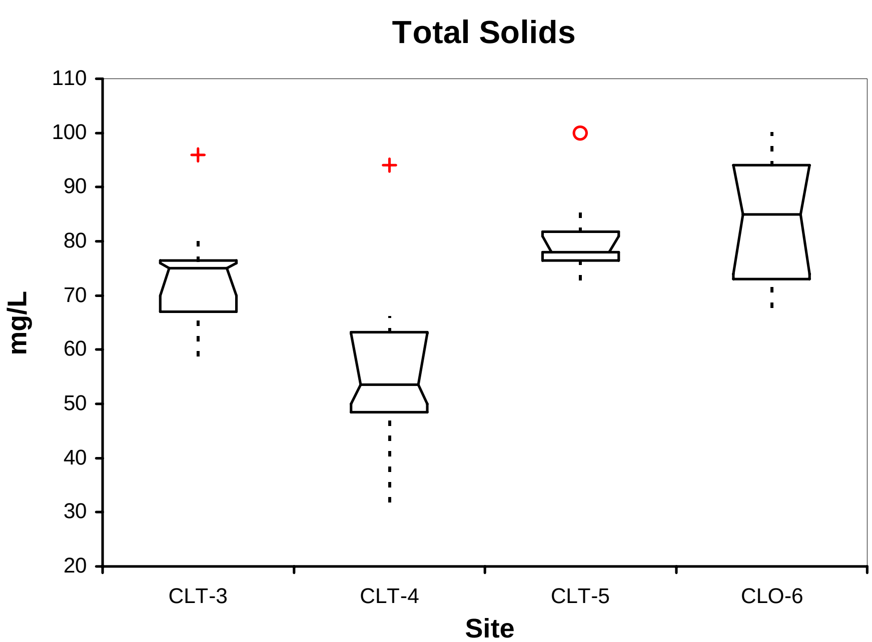


Figure 12. Box plot of total solids by site for tributary sites.

Concentrations of suspended solids at the inlet ranged from 2.5 to 12.0 mg/L (mean = 4.35), while concentrations at the outlet ranged from 2.5 to 9.0 mg/L (mean = 4.31).
Median concentrations of total suspended solids (TSS) were similar across all sites, but elevated concentrations were observed in samples from the inlet site (Figure 13). Average

TSS concentration across all sample dates was also highest at the inlet site CLT-5 (Table 15).

When samples were analyzed for TSS, 5.0 mg/L was designated as the detection limit. Therefore, a concentration below 5.0 mg/L was considered undetectable. The samples with TSS levels below the detection limit were assigned values of half the detection limit (2.5 mg/L), assuming that a trace amount was present. TSS levels were below the detection limit in 79 % of the samples collected in Center Lake. FLUX estimated an annual load of 2,298 kg of total suspended solids was delivered to Center Lake from the watershed, or 0.37 kg per watershed acre.

Table 15. Descriptive statistics of suspended solids (mg/L) for tributary samples.

Total Suspended Solids, mg/L

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	2.75	2.50	2.50	5.00	0.75
CLT-4	3.05	2.50	2.50	8.00	1.65
CLT-5	4.35	2.50	2.50	12.00	3.23
CLO-6	4.31	2.50	2.50	9.00	2.56

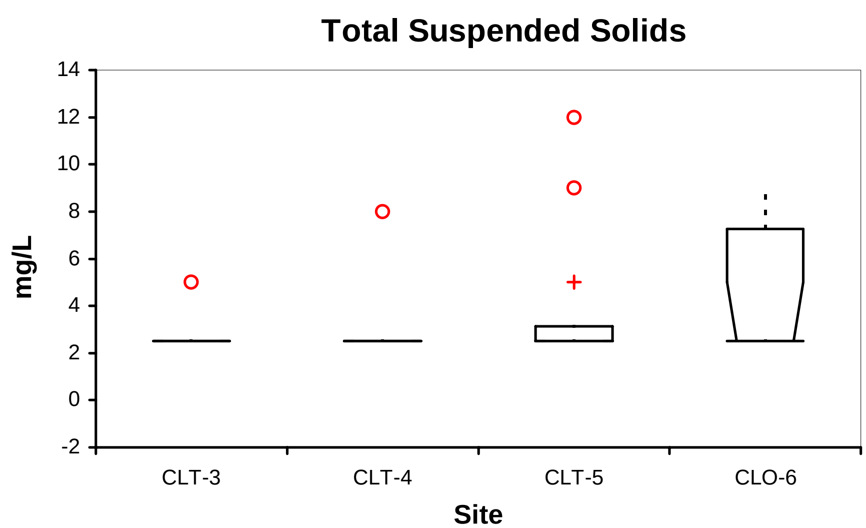


Figure 13. Box plot of total suspended solids (TSS) by site for tributary sites.

Nitrogen

Three types of nitrogen were assessed in tributary samples: (1) nitrate/nitrite, (2) ammonia, and (3) Total Kjeldahl Nitrogen (TKN). With these three parameters, relative concentrations of organic and inorganic nitrogen can be determined, as well as total nitrogen concentrations.

Average total nitrogen concentration for inlet samples was 0.28 mg/L. Outlet average concentration was 0.44 mg/L (Table 16). Total nitrogen concentrations of CLO-6 outlet samples were more variable than other sites (Figure 14).

Annual loads for all assessed forms of nitrogen are listed in Table 8. FLUX model output indicated total nitrogen concentration at the inlet was 0.27 mg/L. Estimated total nitrogen annual load was 151.7 kg, which is equivalent to 0.024 kg per watershed acre.

When samples were analyzed for total nitrogen (total nitrogen = inorganic nitrogen + organic nitrogen), the detection limits for the combined parameters dictate the detection limit for total nitrogen. All values below the detection limit were assigned values of half the detection limit, assuming that a trace amount was present. The lowest values reported in Table 16 reflect half the detection limits for total nitrogen. Total nitrogen levels were below the detection limit in 76 % of the samples collected in Center Lake.

Table 16. Descriptive statistics of total nitrogen (mg/L) for tributary samples.

Total Nitrogen

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	0.367	0.275	0.275	0.740	0.193
CLT-4	0.414	0.375	0.375	0.725	0.110
CLT-5	0.275	0.275	0.275	0.275	0.000
CLO-6	0.443	0.320	0.275	1.050	0.278

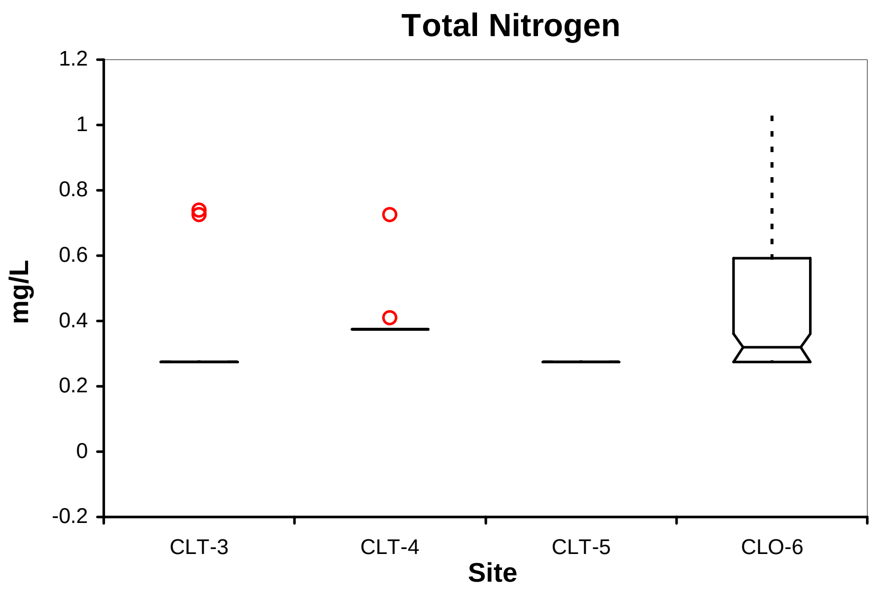


Figure 14. Box plot of total nitrogen by site for tributary sites.

As with total Nitrogen, when samples were analyzed for inorganic nitrogen (inorganic nitrogen = ammonia + nitrite + nitrate), and for organic nitrogen (organic nitrogen = TKN - ammonia), the detection limits of the combined parameters dictated the detection limits for inorganic and organic nitrogen. All values below the detection limit were assigned values of half the detection limit, assuming that a trace amount was present. The lowest values reported in Table 17 and Table 18 reflect half the detection limits for inorganic and organic nitrogen, respectively.

Concentrations of organic nitrogen consistently exceeded concentrations of inorganic nitrogen (Figure 15). Site CLO-6 exhibited the greatest variation in concentrations of both inorganic and organic nitrogen (Table 17 and Table 18). Possible sources of organic nitrogen in stream samples may include vegetation from the watershed, algae growth, and animal waste.

Table 17. Descriptive statistics of inorganic nitrogen (mg/L) for tributary samples.

Inorganic Nitrogen, mg/L

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	0.122	0.075	0.075	0.540	0.147
CLT-4	0.079	0.075	0.075	0.110	0.011
CLT-5	0.080	0.075	0.075	0.125	0.016
CLO-6	0.206	0.165	0.075	0.650	0.188

Table 18. Descriptive statistics of organic nitrogen (mg/L) for tributary samples.

Organic Nitrogen, mg/L

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	0.245	0.200	0.200	0.650	0.142
CLT-4	0.335	0.300	0.300	0.650	0.111
CLT-5	0.200	0.200	0.200	0.200	0.000
CLO-6	0.238	0.200	0.050	0.500	0.143

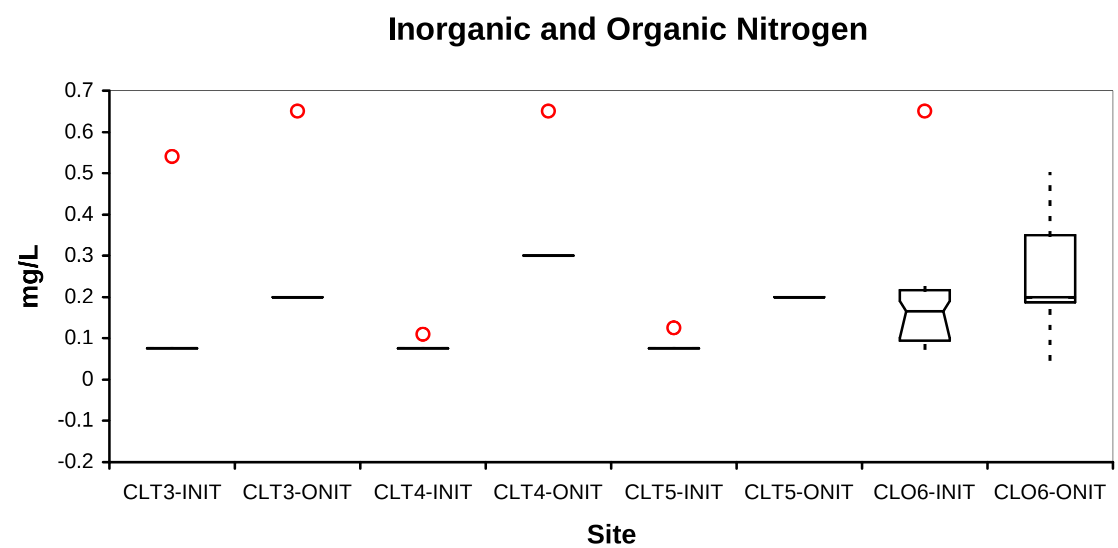


Figure 15. Box plot of organic and inorganic nitrogen concentrations by site for tributary sites.

Phosphorus

Phosphorus is present in all aquatic systems. Its natural sources include the leaching of phosphate-bearing rocks and organic matter decomposition. Other potential sources of phosphorus include man-made fertilizers, runoff from highway maintenance operations, leaking and/or otherwise faulty septic systems, animal waste, and runoff from burned areas.

Outlet total phosphorus concentrations are slightly higher than inlet total phosphorus concentrations (Figure 16). Total phosphorus concentrations at the inlet ranged from 0.03 to 0.15 mg/L (mean = 0.09), while concentrations at the outlet ranged from 0.07 to 0.28 mg/L (mean = 0.16) (Table 19). FLUX model output indicated total phosphorus concentration at the inlet was 0.0857 mg/L. FLUX estimated total phosphorus annual load was 47.40 kg, equivalent to 7.6 grams per watershed acre.

Table 19. Descriptive statistics of total phosphorus (mg/L) for tributary samples.

Total Phosphorus

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	0.070	0.060	0.040	0.130	0.034
CLT-4	0.080	0.090	0.050	0.120	0.030
CLT-5	0.090	0.095	0.030	0.150	0.037
CLO-6	0.164	0.160	0.070	0.280	0.061

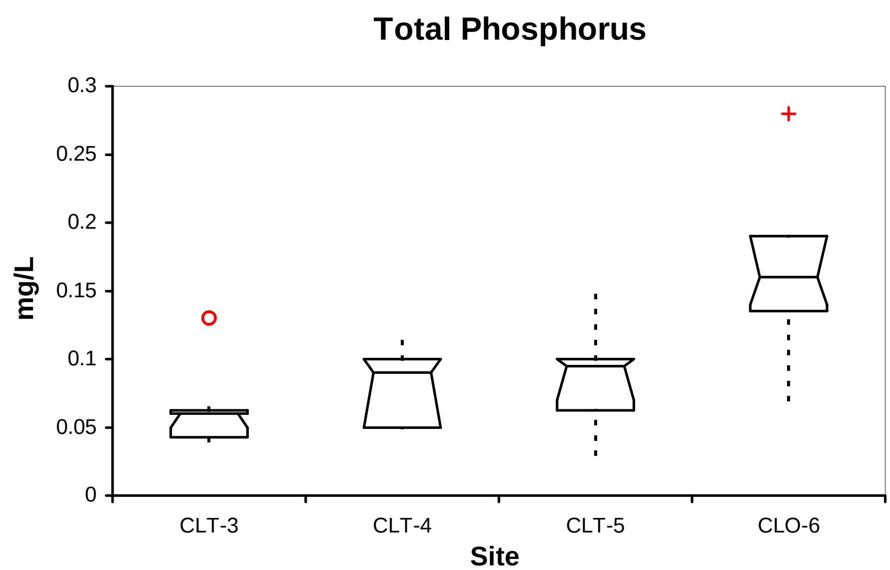


Figure 16. Box plot of total phosphorus by site for tributary sites.

Total dissolved phosphorus (TDP) concentrations at the inlet (CLT-5) ranged from 0.02 to 0.12 mg/L (mean = 0.07), while concentrations at the outlet ranged from 0.01 to 0.11 mg/L (mean = 0.06) (Table 20). TDP concentrations at the inlet and outlet were higher as well as more variable than concentrations at the other two sites (Figure 17). FLUX model output indicated TDP concentration at the inlet was 0.0660 mg/L. FLUX estimated TDP annual load was 36.5 kg, which is equivalent to 5.8 grams per watershed acre.

Table 20. Descriptive statistics of total dissolved phosphorus (mg/L) for tributary samples.

Total Dissolved Phosphorus, mg/L

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	0.050	0.050	0.010	0.090	0.024
CLT-4	0.054	0.055	0.020	0.080	0.020
CLT-5	0.070	0.070	0.020	0.120	0.028
CLO-6	0.061	0.065	0.005	0.110	0.031

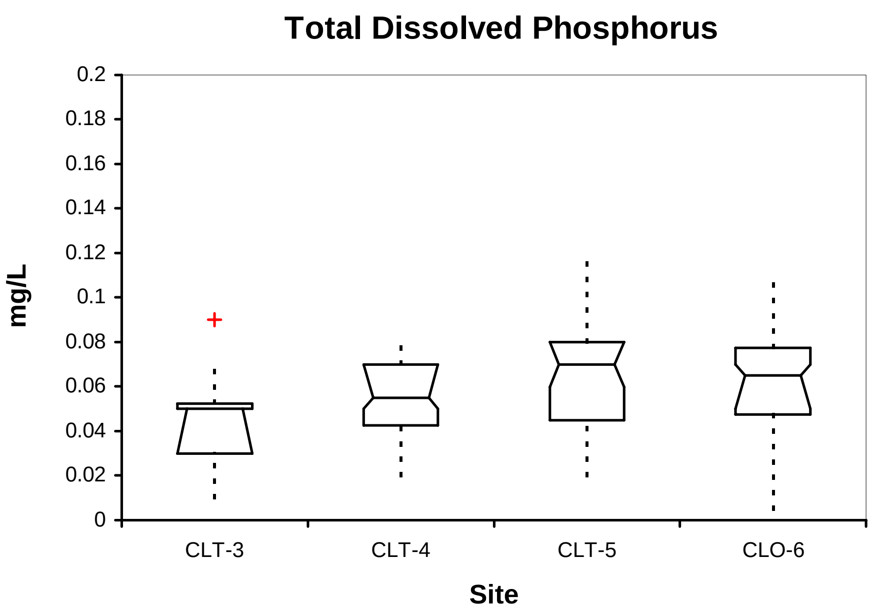


Figure 17. Box plot of total dissolved phosphorus by site for tributary sites.

Tributary Biological Parameters

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestinal tract of all warm-blooded animals. Although these organisms are not usually disease-causing organisms themselves, their presence indicates fecal contamination and a higher probability of infectious, water-borne disease.

Fecal bacteria concentrations are often highly variable. Environmental factors (e.g. sunlight exposure, water temperature, etc.) can affect concentrations of fecal bacteria in a waterbody. The life span of fecal bacteria is relatively short compared to the associated animal waste, so the absence of fecal bacteria does not necessarily equate to the absence of animal waste.

Fecal bacteria concentrations at the inlet ranged from 1 to 1,700 bacteria colonies per 100 ml of sample (mean = 193). Concentrations at the outlet ranged from 1.0 to 490 colonies per 100 ml (mean = 73). The variability in this data is evident in the high standard deviations (Table 21). Concentrations were well below State standards for all sample dates except in July 2002 (please see Appendix C for all data by sample date). In July, site CLT-3 came very near to exceeding the state maximum for limited contact recreation (≤ 2,000 CFU/100ml) with a concentration at 2,000 CFU/100ml. Although a concentration of 2,000 CFU/100ml is considered acceptable, this value was much higher than all other values for site CLT-3 during the sampling period (mean = 207 CFU/100ml).

Table 21. Descriptive statistics of fecal coliform bacteria (number of colonies per 100 ml) for tributary samples.

Fecal Coliform Bacteria, CFU/100ml

Site	Mean	Median	Minimum	Maximum	Standard Deviation
CLT-3	207.4	9.0	1.0	2000	629.9
CLT-4	107.4	2.0	1.0	1000	313.9
CLT-5	193.5	25.0	1.0	1700	529.8
CLO-6	73.25	5.5	1.0	490	169.7

Benthic Macroinvertebrates

Benthic macroinvertebrate populations are known to be key indicators of stream ecosystem health. Life spans for some of these organisms are as long as three years, and their complex life cycles and limited mobility provide ample time for the community to respond to cumulative effects of environmental perturbations. The analysis of benthic macroinvertebrate communities can thus be related to a stream's biological health, or integrity, defined by Karr and Dudley (1981) as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of the natural habitat of the region."

The multimetric approach to bioassessment using benthic macroinvertebrates uses attributes of the assemblage in an integrated way to reflect overall biotic condition. Community attributes, which can contribute meaningfully to bioassessment, include assemblage structure, sensitivity of community members to stress or pollution, and functional feeding traits. Each metric component contributes an independent measure of the biotic integrity of a stream site.

In November 2001, benthic macroinvertebrate samples were collected using the kick-net method, from three transect locations across sites CLT-3 and CLT-5 of Grace Coolidge Creek, South Dakota. Each sample was a composite of three individual transect sub-samples, each collected a distance of approximately 10 meters apart. (See Figure 18 for a diagram of transect spacing).

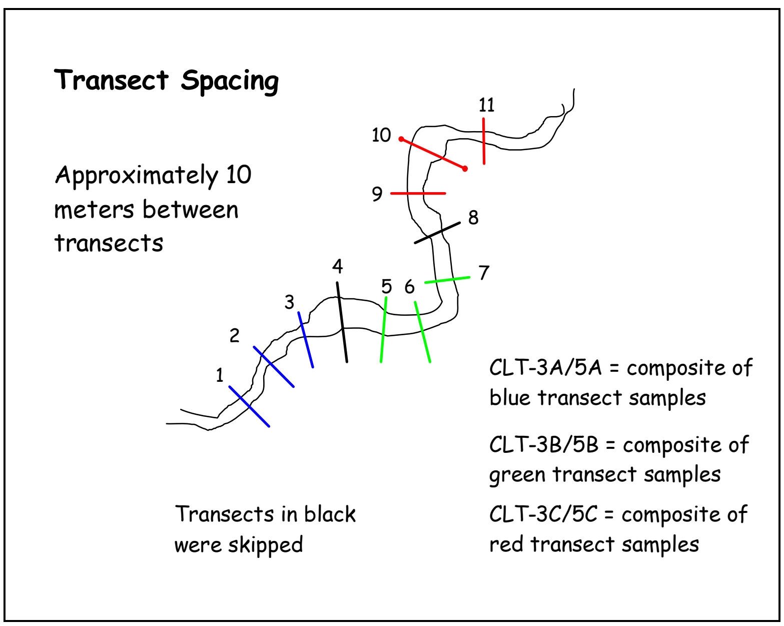


Figure 18. Transect spacing and composite structure (adapted from Milewski, 2001).

The benthic macroinvertebrate samples were processed and identified using the U.S. Environmental Protection Agency's (EPA's) Rapid Bioassessment Protocols for Streams and Rivers (RBP III) Techniques (Plafkin et al.1989), and the SDDENR's SOP for South Dakota Benthic Macroinvertebrate sample processing.

Sample processing consisted of obtaining approximately a 300-organism subsample. Organisms were enumerated and identified to the taxonomic level specified in the SDDENR's SOP. The requirements for subsampling and taxonomic resolution were deviated from only when the quality of the specimen was lacking due either to immaturity, or when body parts needed for identification were missing. In either case, when organisms could not be confidently taken to the taxonomic level outlined in the SOP, they were more conservatively identified.

Community structure, function and sensitivity to impact were characterized for each sample, using whenever possible a specific battery of metrics requested by the SDDENR. The data were entered into an Excel spreadsheet, as well as into the "Ecological Data Analysis System (EDAS), a metrics analysis program designed by Tetra Tech, Inc., which functions within the Microsoft Access database. The EDAS program computed most of the desired metrics, however, several metrics could not be computed by the EDAS program, and therefore were computed by Natural Resource Solutions, an environmental consulting firm in Brookings, SD.

Because reference conditions for streams in South Dakota were not available, the metrics could not be scored in order to determine a standardized impairment rating for each site. Thus, the overall biotic health and the final impairment rating reported for each site were determined based upon best professional judgment, after careful review of the metrics results. The biotic health for each site was reported using the following scale, from worst to best: Poor, Fair, Good, Very Good, and Excellent. A general impairment rating for each site was reported as follows: Severe Impairment, Moderate Impairment, Minimum Impairment, and Slight Impairment.

Tolerance values and Functional Feeding Group determinations used for this analysis were taken from the U.S. Environmental Protection Agency's Rapid Bioassessment Protocols for Streams and Rivers, Appendix B (Plafkin et al.1989). Tolerance values are given on a 0 to 10 scale, with 0 representing an extremely sensitive, or intolerant organism, and 10 representing a highly tolerant organism. Please see Appendix A, "Benthic Macroinvertebrates of the Center Lake Watershed, SD" for a table of all benthic macroinvertebrates found during this analysis, and their corresponding tolerance values and functional feeding group (FFG) traits.

The Taxa Richness for the first transect subsample of site CLT-3 (CLT-3A) was moderate, with 25 total taxa, although this was in part due to fairly diverse Diptera, an order typically considered tolerant of impairment relative to other insect groups (Table 22). The Diptera, and in particular the family Chironomidae within the Diptera order, were also very abundant, with Diptera at 77 percent and Chironomidae at 75 percent. Because they tend to be highly tolerant organisms, the Diptera and Chironomidae, when occurring in great abundance, are generally regarded as indicators of impairment.

Conversely, we can see from the data results that the values are quite low for the more sensitive orders, namely the Ephemeroptera, Plecoptera and Trichoptera. A common measure used as an indicator of water quality is the combination of these three sensitive taxa groups, referred to as "EPT." For this site, the values for EPT taxa Richness, EPT abundance, percent EPT and the EPT to Chironomidae ratio all were quite low, which may be an indication of poor water quality.

This benthic macroinvertebrate community was dominated by tolerant organisms, with a total of 28 percent tolerant organisms, and 77 percent sediment tolerant organisms, with intolerant organisms (organisms sensitive to impairment) at only 4.5 percent.

Tolerant predators, filterers, omnivores and scavengers dominated this community, while more sensitive shredders and scrapers were not in abundance (functional feeding groups known to be more sensitive to impairment and good indicators of a complex substrate). These results suggest that organic enrichment may exist here, which is likely limiting the biotic integrity at this site.

The average tolerance value for the top five most dominant taxa for this site was 6.2, and the average Hilsenhoff Biotic Index (HBI) for the sampled assemblage was 6.1. These results again indicate that a moderately tolerant benthic macroinvertebrate community exists here. The HBI metric is a measure of a community's tolerance to pollution, rating the tolerance level on a scale of 0 to 10. The higher the HBI value, the more tolerant the community is to pollution; the lower the value the more sensitive the community is to pollution.

Analysis of the entire suite of metrics indicates potential elevated nutrient levels, increased sedimentation, and higher temperatures and/or lower flows, all of which may be limiting biotic integrity. From the sampled assemblage, the data strongly suggest that this site has a moderately tolerant benthic macroinvertebrate community overall, particularly to increased levels of sedimentation and organic enrichment.

Overall assessment for subsample CLT-3A: Fair biotic condition, with a moderately tolerant benthic macroinvertebrate community dominating this site. Cumulative metric data suggests moderate impairment.

Table 22. Benthic Macroinvertebrate metric results utilized for analysis of tributary site CLT-3A.

METRIC	VALUE	Status*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	25	Mod (↓)	1st Dom. *Larsia* sp. 31%	6	Predator
EPT Taxa Richness	9	Mod (↓)	2nd Dom. *Thienemannimyia* sp. 16%	6	Predator
Ephemeroptera Taxa	2	Low (↓)	3rd Dom. Sphaeriidae (imm.) 12%	8	Filterer
Plecoptera Taxa	3	Low (↓)	4th Dom. *Microtendipes pedellus* 12%	7	Filterer
Trichoptera Taxa	4	Low (↓)	5th Dom. *Micropsectra* sp. 7%	4	Collector
Diptera Taxa	9	Mod (↑)	**METRIC**	**Value**	**Status***
Chironomidae Taxa	6	Low (↑)	Hilsenhoff Biotic Index (HBI)	6.1	Mod (↑)
Predator Taxa	11	Mod (↑)	ShannonWeiner Diversity (Log 10)	0.97	Low (↓)
Tolerant Taxa	7	Low (↑)	Biotic Index	16	Mod (↓)
Intolerant Taxa	6	Low (↓)	% EPT	6.0	Low (↓)
Total Abundance	352	Mod (↓)	% Ephemeroptera	1.7	Low (↓)
Extrapolated Abundance	1,408	Mod (↓)	% Plecoptera	2.6	Low (↓)
EPT Abundance	21	Low (↓)	% Trichoptera	1.7	Low (↓)
Chiro Abundance	263	High (↑)	% Hydropsychidae/Trichoptera	0.0	Low (↓)
EPT/Chiro Abundance	0.08	Low (↓)	% Chironomidae	75	High (↑)
Gatherer Abundance	37	Mod (↓)	% Tanytarsini	0.0	Low (↓)
Filterer Abundance	86	High (↑)	% Diptera	77	High (↑)
% Shredders	8.2	Low (↓)	% Non-Insects	10	Low (↑)
% Grazers+Scrapers	0.6	Low (↓)	% Oligochaeta	0.6	Low (↑)
% Scraper/Scraper+Filterers	2.3	Low (↓)	% Intolerant Organisms	4.5	Low (↓)
% Scrapers/Filterers	0.0	Low (↓)	% Tolerant Organisms	28	Mod (↑)
% Omnivores+Scavengers	44	Mod (↑)	% Sediment Tolerant Organisms	77	High (↑)
% Predators	56	High (↑)	Overall Assessment:		
% Collector-Gatherers	10.5	Low (↓)	Biotic Health: Fair, possibly poor; more data needed		
% Filterers	24	Mod (↑)	Impairment: Moderate; more data needed		

* Arrows (↑↓) indicate each metric's response to environmental perturbation and/or impairment.
+ FFG = Functional Feeding Group

There were several indicators that subsample CLT-3B was moderately healthy (Table 23). The average HBI was 4.8, indicating that a marginally sensitive benthic community likely exists at this site. Likewise, the average tolerance values of the dominant taxa was 5.2, indicating a community with a tolerance resting midway between the range of tolerant and sensitive.

The following taxa found in relatively high abundance also may indicate moderately good health: *Paraleptophlebia* sp. at 7 % abundance, a sensitive Ephemeropteran with a low tolerance value of 2; Baetidae at 8 % abundance, marginally sensitive Ephemeroptera with a tolerance value of 4; *Optioservus* sp. at 14 %, a marginally sensitive Coleoperan with a tolerance value of 4; and *Zapada cinctipes*, a sensitive Plecopteran with a low tolerance value of 2.

Taking into consideration the presence of the sensitive taxa, even though not abundant, their presence in moderate numbers indicates that this site is capable of supporting a marginally sensitive benthic macroinvertebrate community. The presence of these taxa may indicate lower suspended solids, normal nutrient levels, faster/higher flows, cooler temperatures, and/or a more complex substrate.

Overall assessment for subsample CLT-3B: Fair to good, supporting a moderately sensitive benthic macroinvertebrate community, with data suggesting moderate to possibly minimum impairment.

Table 23. Benthic Macroinvertebrate metric results utilized for analysis of tributary site CLT-3B.

METRIC	VALUE	Status*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	28	Mod (↓)	1st Dom. *Larsia* sp. 28%	6	Predator
EPT Taxa Richness	12	Mod (↓)	2nd Dom. *Optioservus* sp. 14%	4	Scraper
Ephemeroptera Taxa	3	Low (↓)	3rd Dom. *Thienemannim*yia sp. 9%	6	Predator
Plecoptera Taxa	4	Low (↓)	4th Dom. *Polypedilum* sp. 8%	6	Shredder
Trichoptera Taxa	5	Low (↓)	5th Dom. Baetidae (imm./broken) 8%	4	Collector
Diptera Taxa	9	Low (↑)	**METRIC**	**Value**	**Status***
Chironomidae Taxa	7	Low (↓)	Hilsenhoff Biotic Index (HBI)	4.8	Mod (↑)
Predator Taxa	10	Mod (↑)	ShannonWeiner Diversity (Log 10)	1.09	Low (↓)
Tolerant Taxa	7	Low (↑)	Biotic Index	19	Mod (↓)
Intolerant Taxa	8	Low (↓)	% EPT	30	Mod (↓)
Total Abundance	300	Mod (↓)	% Ephemeroptera	15	Low (↓)
Extrapolated Abundance	1,200	Mod (↓)	% Plecoptera	8	Low (↓)
EPT Abundance	91	Mod (↓)	% Trichoptera	8	Low (↓)
Chiro Abundance	139	Mod (↑)	% Hydropsychidae/Trichoptera	87	High ( )
EPT/Chiro Abundance	0.65	Low (↓)	% Chironomidae	46	High (↑)
Gatherer Abundance	53	Mod (↓)	% Tanytarsini	0.0	Low (↓)
Filterer Abundance	28	Low (↑)	% Diptera	49	High (↑)
% Shredders	14	Mod (↓)	% Non-Insects	4	Low (↑)
% Grazers+Scrapers	15	Low (↓)	% Oligochaeta	1.0	Low (↑)
% Scraper/Scraper+Filterers	61	High (↓)	% Intolerant Organisms	16	Low (↓)
% Scrapers/Filterers	2	Low (↓)	% Tolerant Organisms	5.0	Low (↑)
% Omnivores+Scavengers	55	Mod (↑)	% Sediment Tolerant Organisms	49	Mod (↑)
% Predators	45	High (↑)	Overall Assessment:		
% Collector-Gatherers	18	Low (↓)	Biotic Health: Fair to Good		
% Filterers	9	Low (↑)	Impairment: Moderate to minimum		

* Arrows (↑↓) indicate each metric's response to environmental perturbation and/or impairment.
+ FFG = Functional Feeding Group

The third subsample of site CLT-3 (CLT-3C) was by far the most healthy of the three transect subsamples, with many indicators of good biotic health (Table 24). Although diversity and richness measures were only moderately high, this site had high numbers of intolerant taxa present at 45 percent, and moderately low numbers of tolerant taxa, at 18 percent. As would follow, the percent EPT was quite high at 53 percent, as well as EPT abundance, with 166 of the 311 total organisms being Ephemeroptera, Plecoptera and Trichoptera. The EPT to Chironomidae ratio was also very high, at 2.34.

The dominant taxon at this site was *Paraleptophlebia* sp., a sensitive Ephemeropteran collector with a low tolerance value of 2. The following sensitive Plecoptera also were found in abundance at this site: *Paracapnia* sp., a sensitive shredder with a very low tolerance value of 1, *Sweltsa* sp., a highly sensitive predator, also with a low tolerance value of 1, and *Zapada cinctipes*, a sensitive shredder with a tolerance value of 2. In addition, *Lepidostoma* sp., a sensitive Trichopteran shredder with a tolerance value of 3 was found in abundance here. Although not in abundance, *Glossosoma* sp. and *Limnephilus* sp. also were collected here, both sensitive Trichoptera with tolerance values of 0 and 3, respectively. Taking into consideration the presence of these intolerant (sensitive) taxa, this site appears to be fairly healthy, as it is capable of supporting a sensitive benthic macroinvertebrate community. The presence of these sensitive taxa may indicate lower suspended solids, healthy nutrient levels, faster/higher flows, cooler temperatures, and/or a complex substrate.

Sensitive collectors, predators and shredders were in abundance , while more tolerant taxa groups were more scarce in this community. The average tolerance value of the dominant taxa for this site was 2.8, and the average Hilsenhoff Biotic Index was 3.9. The very low average tolerance value and HBI score again are strong indicators that a sensitive benthic macroinvertebrate community exists here.

Overall assessment for subsample CLT-3C: Very good, supporting a sensitive benthic macroinvertebrate community. The cumulative metric data indicates minimum impairment.

Table 24. Benthic Macroinvertebrate metric results utilized for analysis of tributary site CLT-3C.

METRIC	VALUE	Status*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	28	Mod (↓)	1st Dom. *Paraleptophlebia* sp. 16%	2	Collector
EPT Taxa Richness	13	Mod (↓)	2nd Dom. *Thienemannimyia* sp. 16%	6	Predator
Ephemeroptera Taxa	3	Low (↓)	3rd Dom. *Sweltsa* sp. 9.3%	1	Predator
Plecoptera Taxa	4	Low (↓)	4th Dom. *Paracapnia* sp. 8.6%	1	Shredder
Trichoptera Taxa	6	Low (↓)	5th Dom. *Optioservus* sp. 8.4%	4	Scraper
Diptera Taxa	9	Low (↑)	**METRIC**	**Value**	**Status***
Chironomidae Taxa	6	Low (↓)	Hilsenhoff Biotic Index (HBI)	3.9	Low (↑)
Predator Taxa	7	Low (↑)	ShannonWeiner Diversity (Log 10)	1.18	Mod (↓)
Tolerant Taxa	7	Low (↑)	Biotic Index	19	Mod (↓)
Intolerant Taxa	9	Mod (↓)	% EPT	53	High (↓)
Total Abundance	311	Mod (↓)	% Ephemeroptera	23	Mod (↓)
Extrapolated Abundance	901	Low (↓)	% Plecoptera	22	Mod (↓)
EPT Abundance	166	Mod (↓)	% Trichoptera	8	Low (↓)
Chiro Abundance	71	Mod (↑)	% Hydropsychidae/Trichoptera	11.5	Low (-)
EPT/Chiro Abundance	2.34	High (↓)	% Chironomidae	23	Low (↑)
Gatherer Abundance	78	High (↓)	% Tanytarsini	0.0	Low (↓)
Filterer Abundance	15	Low (↑)	% Diptera	25	Low (↑)
% Shredders	19	Mod (↓)	% Non-Insects	11	Low (↑)
% Grazers+Scrapers	17	Low (↓)	% Oligochaeta	0.0	Low (↑)
% Scraper/Scrapers+Filterers	78	High (↓)	% Intolerant Organisms	45	High (↓)
% Scrapers/Filterers	4	Low (↓)	% Tolerant Organisms	18	Low (↑)
% Omnivores+Scavengers	66	Mod (↑)	% Sediment Tolerant Organisms	31	Mod (↑)
% Predators	34	High (↑)	Overall Assessment:		
% Collector-Gatherers	25	Mod (↓)	Biotic Health: Good to Very good		
% Filterers	5	Low (↑)	Impairment: Minimum to Slight		

* Arrows (↑↓) indicate a metric's response to environmental perturbation and/or impairment.
+ FFG = Functional Feeding Group

A graphical representation of selected metrics is presented below (Figure 19), comparing differences between the three transects (subsamples) of site CLT-3. From the summarized results, we can see a dramatic difference between the subsamples for percent EPT, percent Chironomidae, and percent Intolerant organisms. CLT-3C had the highest percent EPT and Intolerant organisms, while CLT-3A had the lowest values for these metrics. CLT-3A also had a much greater abundance of Chironomidae than the other two transect sites.

Overall, the data appear to indicate that CLT-3A had poorer water quality than the other two, while CLT-3C had the best water quality, with CLT-3B falling midway between the other two. These results also indicate that 3A was likely a pool area, or in other words, a stretch of the reach with deeper, slower flowing water, more sediment, and less oxygen.

Subsample CLT-3C was very likely a riffle area, or in other words, a stretch of the reach with higher oxygen levels due to more rocky cobble, faster flowing water and less sediment.

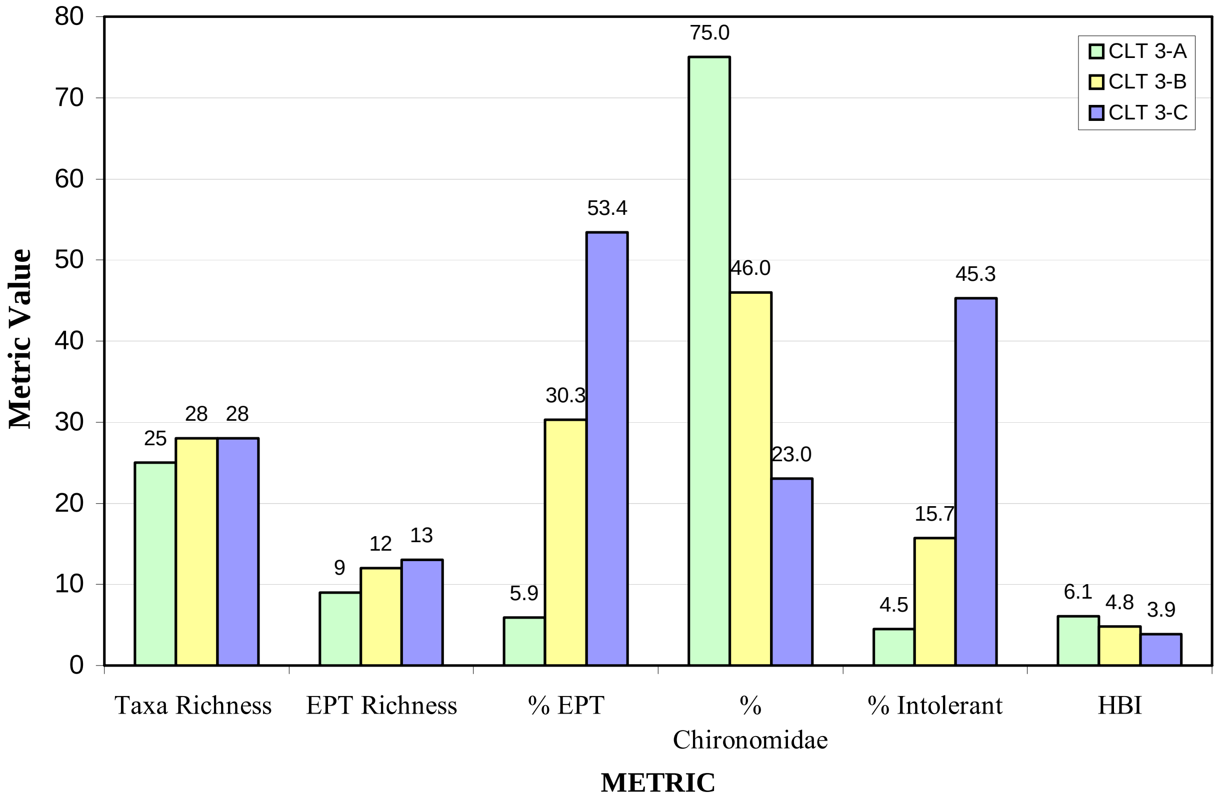


Figure 19. Several metrics demonstrating differences between the three transect sites collected from tributary site CLT-3.

The Taxa Richness for transect subsample CLT-5A was very high, at thirty-nine total taxa (Table 25). The high Taxa Richness was largely due to a large diversity of Diptera, with 16 of the 39 taxa being Diptera, thus causing the taxa richness measure to be somewhat misleading. By itself, Taxa Richness is not a good indicator of community health, because in this case the Diptera occurring here were primarily all very tolerant organisms. The Diptera comprise 58 percent of the total organisms for this sample.

The Chironomidae of the Diptera were the most abundant organisms in this assemblage. The dominant taxon was *Microtendipes pedellus*, a tolerant Chironomid filterer with a tolerance value of 7. All of the dominant taxa in this sample were tolerant Chironomidae and other Diptera, with tolerance values of 6 or higher, with the exception of *Micropsectra* sp., a moderately tolerant collector with a tolerance value of 4.

All measures for EPT, i.e., EPT Richness, EPT abundance, percent EPT and the EPT to Chironomidae ratio, resulted in low values. The following four sensitive taxa were found here, however none were found in abundance: *Paraleptophlebia* sp., an Ephemeropteran with a low tolerance value of 2, immature Chloroperlidae, plecoptera with a very low tolerance value of 1, *Sweltsa* sp. and *Skwala* sp, sensitive plecoptera with low tolerance values of 1 and 2, respectively. There were no sensitive Trichoptera collected. This benthic macroinvertebrate community was dominated by tolerant organisms at 30 percent and sediment tolerant organisms at a very high 60%.

The data suggest that elevated levels of suspended solids, organic enrichment and higher temperatures likely exist here, possibly associated with lower flows, which may be limiting the biotic integrity. From the sampled assemblage, the data suggest that this site has a tolerant benthic macroinvertebrate community overall, particularly to elevated nutrients and sedimentation.

Overall assessment for subsample CLT-5A: Fair biotic condition, supporting a moderately tolerant benthic macroinvertebrate community. Data suggests moderate impairment.

Table 25. Benthic Macroinvertebrate metric results utilized for analysis of tributary site CLT-5A.

METRIC	VALUE	Status*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	39	High (↓)	1st Dom. *Microtendipes pedellus* 17%	7	Filterer
EPT Taxa Richness	11	Mod (↓)	2nd Dom. *Micropsectra* sp. 13.5%	4	Collector
Ephemeroptera Taxa	3	Low (↓)	3rd Dom. Ceratopogoninae (imm.) 7%	6	Predator
Plecoptera Taxa	3	Low (↓)	4th Dom. *Thienemannimyia* sp. 6%	6	Predator
Trichoptera Taxa	5	Low (↓)	5th Dom. *Polypedilum* sp. 5.8%	6	Shredder
Diptera Taxa	16	Mod (↑)	**METRIC**	**Value**	**Status***
Chironomidae Taxa	13	Mod (↓)	Hilsenhoff Biotic Index (HBI)	5.4	Mod (↑)
Predator Taxa	14	Mod (-)	ShannonWeiner Diversity (Log 10)	1.31	Mod (↓)
Tolerant Taxa	11	Low (↑)	Biotic Index	22	Mod (↓)
Intolerant Taxa	7	Low (↓)	% EPT	18	Low (↓)
Total Abundance	311	Mod (↓)	% Ephemeroptera	5	Low (↓)
Extrapolated Abundance	1,829	Mod (↓)	% Plecoptera	4	Low (↓)
EPT Abundance	57	Mod (↓)	% Trichoptera	9	Low (↓)
Chiro Abundance	156	High (↑)	% Hydropsychidae/Trichoptera	18	Low (-)
EPT/Chiro Abundance	0.37	Low (↓)	% Chironomidae	50	High (↑)
Gatherer Abundance	109	High (↓)	% Tanytarsini	0.0	Low (↓)
Filterer Abundance	65	Mod (↑)	% Diptera	58.5	High (↑)
% Shredders	7	Low (↓)	% Non-Insects	13	Low (↑)
% Grazers+Scrapers	11	Low (↓)	% Oligochaeta	1.3	Low (↑)
% Scraper/Scrapers+Filterers	33	Mod (↓)	% Intolerant Organisms	9	Low (↓)
% Scrapers/Filterers	0	Low (↓)	% Tolerant Organisms	30	Mod (↑)
% Omnivores+Scavengers	73	High (↑)	% Sediment Tolerant Organisms	61	High (↑)
% Predators	26	Mod (-)	Overall Assessment:		
% Collector-Gatherers	35	Mod (↓)	Biotic Health: Fair		
% Filterers	21	Mod (↑)	Impairment: Moderate		

* Arrows (↑↓) indicate a metric's response to environmental perturbation and/or impairment.
+ FFG = Functional Feeding Group

Transect subsample CLT-5B appeared somewhat more healthy than the other two transect samples for this site, with several indicators of good biotic health (Table 26). Although the total abundance was not high, the total taxa richness and EPT abundance measures were very high. The percent EPT was modearately high at 30 percent; conversely, the percent Chironomidae was lower, at 12.5 percent. Due to the abundance of EPT and lower numbers of Chironomidae, the EPT to Chironomidae ratio was very high, at 2.37, which is generally considered a reliable indication of better water quality.

An interesting finding was that, contrary to the preceding paragraph, the top five dominant organisms for this site were all very tolerant or marginally tolerant. The dominant organisms were immature Sphaeriidae at 20%, tolerant bivalve filterers with a high tolerance value of 8. The other dominant organisms for this site were all marginal, with tolerance values falling midway between the range of 0 to 10.

The EPT results indicate that this site is very healthy, because the organisms represented, although not the most abundant, all have very low tolerance values. For example, *Paraleptophlebia* sp. was found here, a sensitive Ephemeropteran collector with a very low tolerance value of 2. The following additional sensitive taxa were found at this site (although all were in very low numbers): *Paracapnia* sp., *Sweltsa* sp., *Zapada cinctipes*, and *Skwala* sp., Plecoptera with very low tolerance values of 1, 1, 2 and 2, respectively. Likewise, although not in abundance, *Brachycentrus* sp., *Ceratopsyche morosa*, *Glossosoma* sp., *Micrasema* sp. also were collected here, sensitive Trichoptera with tolerance values of 1, 2, 0 and 2, respectively.

Taking into consideration the presence of these intolerant (sensitive) taxa, this site appears at least moderately capable of supporting a sensitive benthic macroinvertebrate community. The presence of these sensitive taxa may indicate lower suspended solids, healthy nutrient levels, cooler temperatures, and/or a complex substrate.

Overall assessment for subsample CLT-5B: Fair to good, supporting a moderately sensitive benthic macroinvertebrate community, with data suggesting moderate to possibly minimum impairment.

Table 26. Benthic Macroinvertebrate metric results utilized for analysis of tributary site CLT-5B.

METRIC	VALUE	Status*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	37	High (↓)	1st Dom. Sphaeriidae (imm.) 20%	8	Filterer
EPT Taxa Richness	15	Mod (↓)	2nd Dom. *Zaitzevia parvula* 18%	4	Collector
Ephemeroptera Taxa	4	Low (↓)	3rd Dom. *Optioservus* sp. 11%	4	Scraper
Plecoptera Taxa	5	Low (↓)	4th Dom. *Polypedilum* sp. 8.5%	6	Shredder
Trichoptera Taxa	6	Low (↓)	5th Dom. *Cheumatopsyche* sp. 8.5%	5	Filterer
Diptera Taxa	12	Low (↑)	**METRIC**	**Value**	**Status***
Chironomidae Taxa	8	Low (↓)	Hilsenhoff Biotic Index (HBI)	5.1	Mod (↑)
Predator Taxa	8	Low (↑)	ShannonWeiner Diversity (Log 10)	1.17	Mod (↓)
Tolerant Taxa	9	Low (↑)	Biotic Index	25	Mod (↓)
Intolerant Taxa	13	Mod (↓)	% EPT	30	Mod (↓)
Total Abundance	328	Mod (↓)	% Ephemeroptera	10	Low (↓)
Extrapolated Abundance	328	Low (↓)	% Plecoptera	6	Low (↓)
EPT Abundance	97	High (↓)	% Trichoptera	13	Low (↓)
Chiro Abundance	41	Mod (↑)	% Hydropsychidae/Trichoptera	86	High (↑)
EPT/Chiro Abundance	2.37	High (↓)	% Chironomidae	12.5	Low (↑)
Gatherer Abundance	116	High (↓)	% Tanytarsini	0.0	Low (↓)
Filterer Abundance	109	High (↑)	% Diptera	14	Low (↑)
% Shredders	12.5	Low (↓)	% Non-Insects	26	Mod (↑)
% Grazers+Scrapers	13	Low (↓)	% Oligochaeta	3	Low (↑)
% Scraper/Scrapers+Filterers	28	Mod (↓)	% Intolerant Organisms	14	Mod (↓)
% Scrapers/Filterers	0	Low (↓)	% Tolerant Organisms	27	Mod (↑)
% Omnivores+Scavengers	94	High (↑)	% Sediment Tolerant Organisms	18	Mod (↑)
% Predators	6	Low (↑)	Overall Assessment:		
% Collector-Gatherers	35	Mod (↓)	Biotic Health: Borderline fair to good		
% Filterers	33	Mod (↑)	Impairment: Borderline Minimum-moderate		

* Arrows (↑↓) indicate a metric's response to environmental perturbation and/or impairment.
+ FFG = Functional Feeding Group

The third subsample for this site (CLT-5C) exhibited markedly similar results to the first transect for this site. The Taxa Richness was quite high, at thirty-four total taxa (Table 27). As with the first transect subsample, the high Taxa Richness was due to diverse Diptera taxa, with 16 of the 34 taxa being Diptera, thus again causing the taxa richness measure to be misleading. Again, the Diptera occurring here were primarily all very tolerant organisms. The Diptera comprise 58 percent of the total organisms for this sample, and the Chironomidae comprise 53 percent of the total organisms.

The Chironomidae of the Diptera were the most abundant organisms in this assemblage. The dominant taxon was *Polypedilum* sp., a moderately tolerant chironomid with a tolerance value of 6. Other dominant taxa in this sample were the Sphaeriidae (tolerant bivalves with a tolerance value of 8), Tubificidae, (Oligochaeta, or, worms with the highest possible tolerance value of 10), *Micropsectra* sp., a chironomid with a tolerance value of 4, and *Procladius* sp., a chironomid with a high tolerance value of 9. This benthic macroinvertebrate community was dominated by tolerant organisms at 44 percent and sediment tolerant organisms at a very high 64%.

EPT Richness, EPT abundance, percent EPT and the EPT to Chironomidae ratio all resulted in low values. The following sensitive taxa were found here, however they were in extremely low abundance: immature Chloroperlidae, *Sweltsa* sp., *Brachycentrus* sp., *Micrasema* sp., and *Ceratopsyche morosa*.

The average tolerance value for the top five most dominant taxa for this site was 7.4, and the average Hilsenhoff Biotic Index (HBI) for the sampled assemblage was 6.24, again indicating that a tolerant benthic macroinvertebrate community exists here.

Analysis of the entire suite of metrics indicates the possibility of increased sedimentation, higher temperatures and elevated nutrient levels, all of which may be negatively impacting the biota. From the sampled assemblage, the data strongly suggest that this site is supporting a tolerant benthic macroinvertebrate community overall, particularly to increased levels of sedimentation and organic enrichment.

Overall assessment for subsample CLT-5C: Fair biotic condition, with a moderately tolerant benthic macroinvertebrate community dominating this site. Data suggests moderate impairment.

Table 27. Benthic Macroinvertebrate metric results utilized for analysis of tributary site CLT-5C.

METRIC	VALUE	Status*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	34	High (↓)	1st Dom. *Polypedilum* sp. 21%	6	Shredder
EPT Taxa Richness	9	Low (↓)	2nd Dom. Sphaeriidae (imm.) 16%	8	Filterer
Ephemeroptera Taxa	3	Low (↓)	3rd Dom. *Micropsectra* sp. 12%	4	Collector
Plecoptera Taxa	2	Low (↓)	4th Dom. Tubificidae (imm.) 6.6%	10	Collector
Trichoptera Taxa	4	Low (↓)	5th Dom. *Procladius* sp. 6.0%	9	Predator
Diptera Taxa	16	Mod (↑)	**METRIC**	**Value**	**Status***
Chironomidae Taxa	12	Low (↓)	Hilsenhoff Biotic Index (HBI)	6.24	Mod (↑)
Predator Taxa	10	Low (↑)	ShannonWeiner Diversity (Log 10)	1.18	Mod (↓)
Tolerant Taxa	11	Low (↑)	Biotic Index	22	Mod (↓)
Intolerant Taxa	9	Mod (↓)	% EPT	12	Low (↓)
Total Abundance	301	Mod (↓)	% Ephemeroptera	8	Low (↓)
Extrapolated Abundance	1,038	Mod (↓)	% Plecoptera	3	Low (↓)
EPT Abundance	36	Low (↓)	% Trichoptera	2	Low (↓)
Chiro Abundance	160	High (↑)	% Hydropsychidae/Trichoptera	20	Mod (↑)
EPT/Chiro Abundance	0.23	Low (↓)	% Chironomidae	53	High (↑)
Gatherer Abundance	104	High (↓)	% Tanytarsini	0.0	Low (↓)
Filterer Abundance	68	High (↑)	% Diptera	56	High (↑)
% Shredders	23	Mod (↓)	% Non-Insects	27	Mod (↑)
% Grazers+Scrapers	6	Low (↓)	% Oligochaeta	7	Low (↑)
% Scraper/Scrapers+Filterers	20	Mod (↓)	% Intolerant Organisms	8	Low (↓)
% Scrapers/Filterers	4	Low (↓)	% Tolerant Organisms	44	Mod (↑)
% Omnivores+Scavengers	86	High (↑)	% Sediment Tolerant Organisms	63.5	High (↑)
% Predators	14	Mod (↑)	Overall Assessment:		
% Collector-Gatherers	34.5	Mod (↓)	Biotic Health: Poor to fair		
% Filterers	23	Mod (↑)	Impairment: Moderate		

* Arrows (↑↓) indicate a metric's response to environmental perturbation and/or impairment.
+ FFG = Functional Feeding Group

A graphical representation of selected metrics making comparisons of differences between the three CLT-5 subsamples can be found in Figure 20. From the summary of results, we can see a difference between the subsamples for percent EPT, percent Chironomidae, and percent intolerant organisms. CLT-5B had the highest percent EPT and intolerant organisms, while CLT-5C had the lowest values for these metrics. CLT-5C also had a much greater abundance of Chironomidae than the other two transect subsamples.

Overall, the data appear to indicate that CLT-5A and CLT-5C had poorer water quality than CLT-5B, while CLT-5B had the best water quality. These results may indicate that CLT-5A and CLT-5C were pool areas with slower flowing water and more sediment, while CLT-5B was likely a riffle area, with higher oxygen levels, faster flowing water and less sediment.

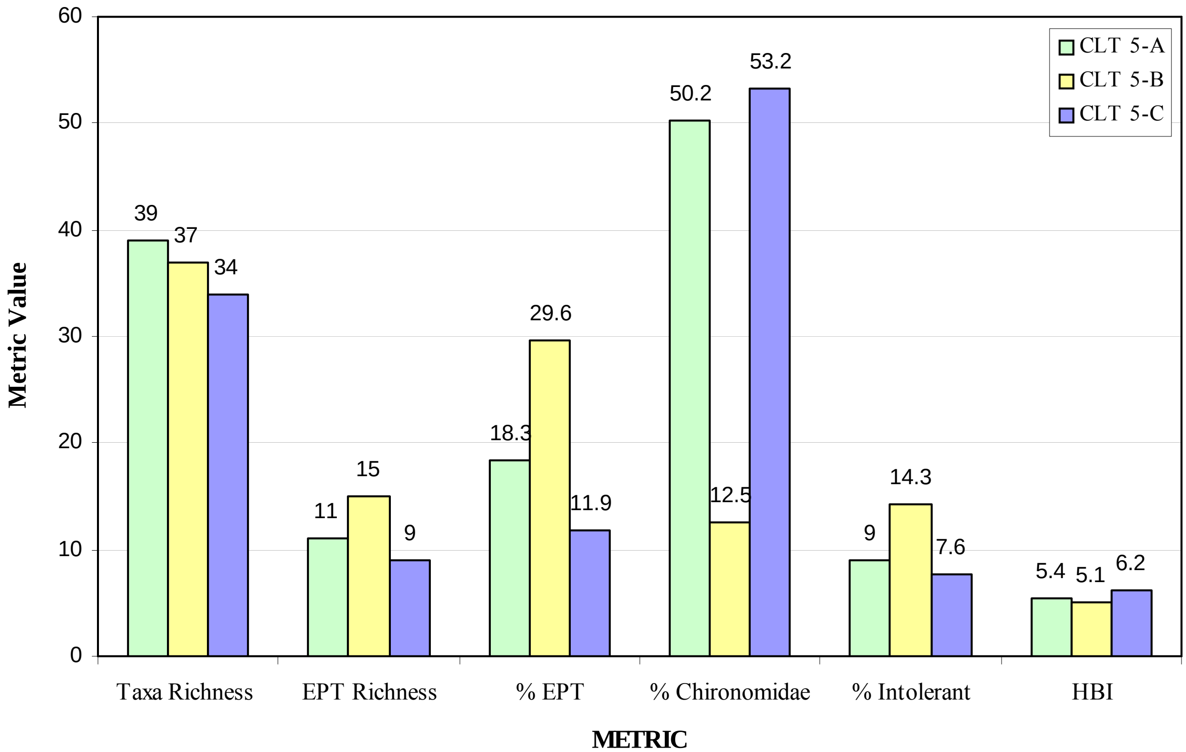


Figure 20. Several metrics demonstrating differences between the three transect samples collected from site CLT-5.

Graphical representations of selected metrics comparing differences between tributary sites CLT-3 and CLT-5 (with individual subsample data averaged for each site) can be found in the following figures (Figure 21-Figure 24).

CLT-3 had significantly higher percent intolerant organisms than CLT-5, (Figure 22), as well as much higher % Ephemeroptera and % Plecoptera (Figure 23). CLT-5 had a much higher total taxa richness than CLT-3, (Figure 24), however, CLT-5 also had much greater diversity and abundance of Diptera and Chironomidae taxa than did CLT-3 (Figure 21). Overall, the cumulative metric data indicate that the inlet tributary site CLT-5 had poorer water quality and greater impairment than tributary site CLT-3.

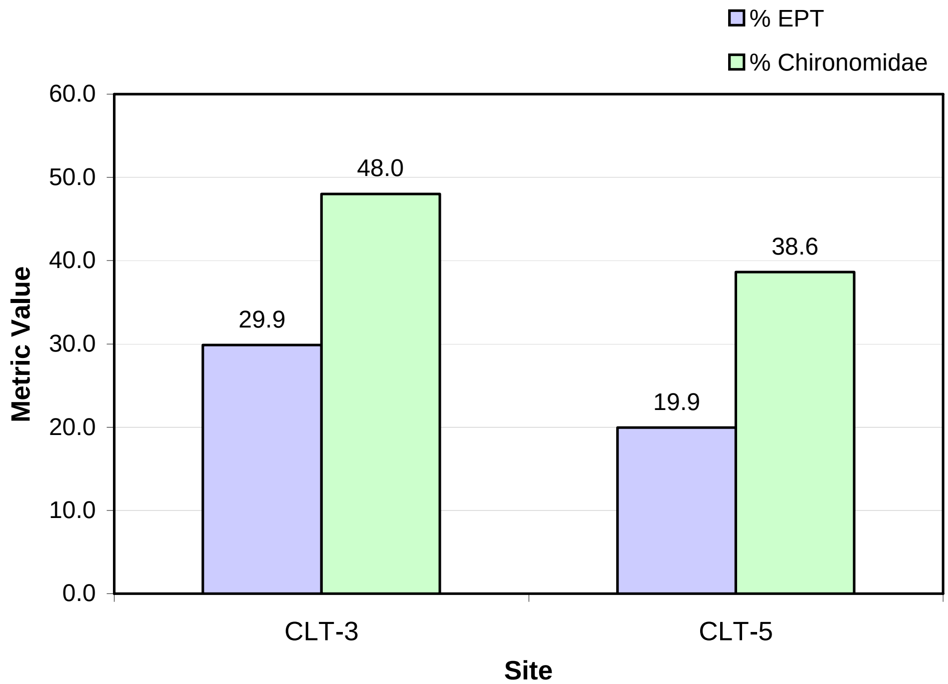


Figure 21. Comparison of percent EPT and percent Chironomidae for sites CLT-3 and CLT-5.

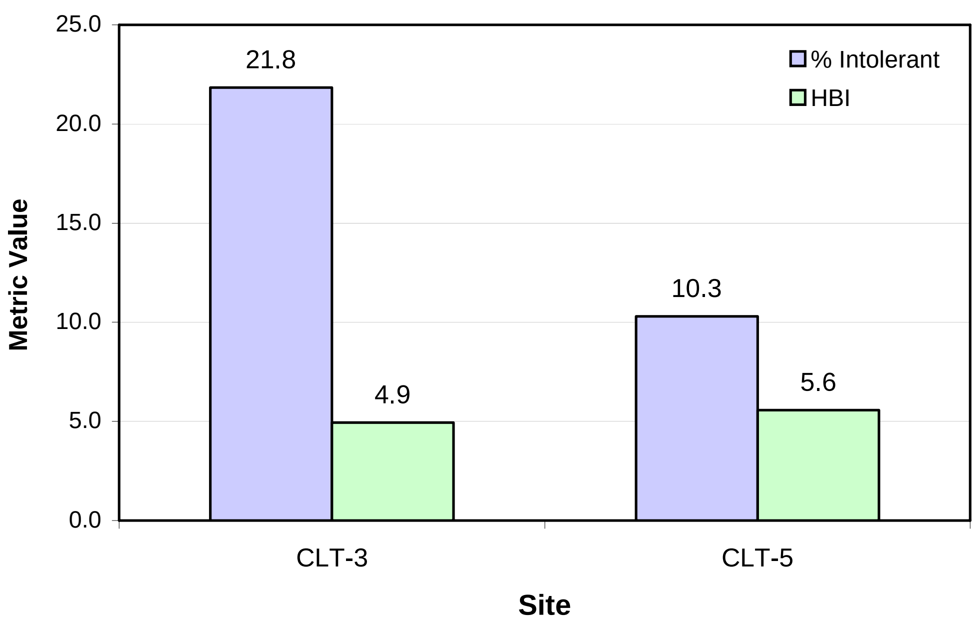


Figure 22. Comparison of the percent Intolerant organisms and the HBI scores for sites CLT-3 and CLT-5.

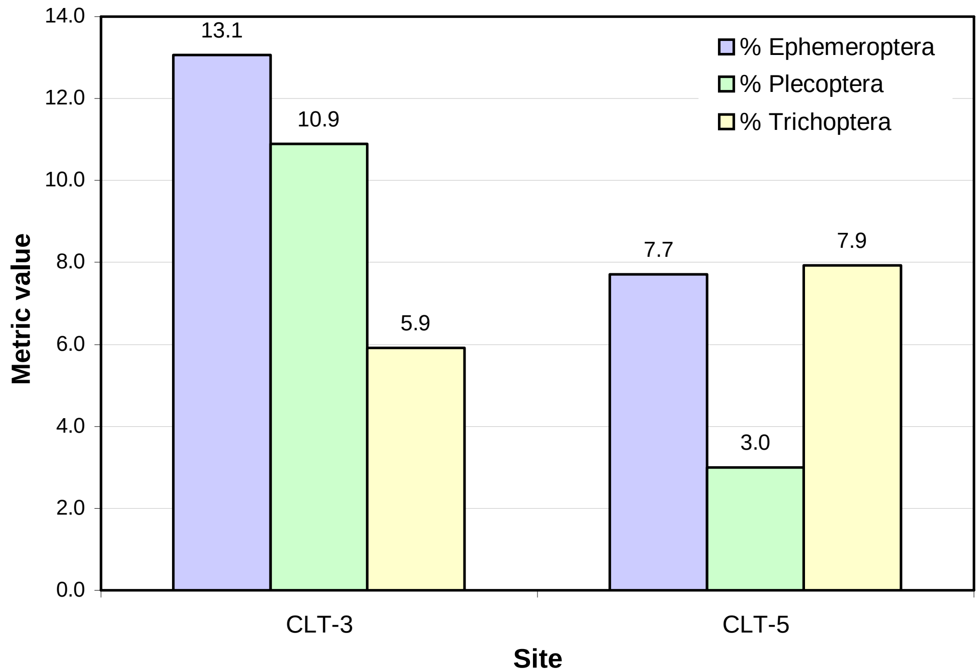


Figure 23. Comparison of Percent Ephemeroptera, Plecoptera and Trichoptera for sites CLT-3 and CLT-5.

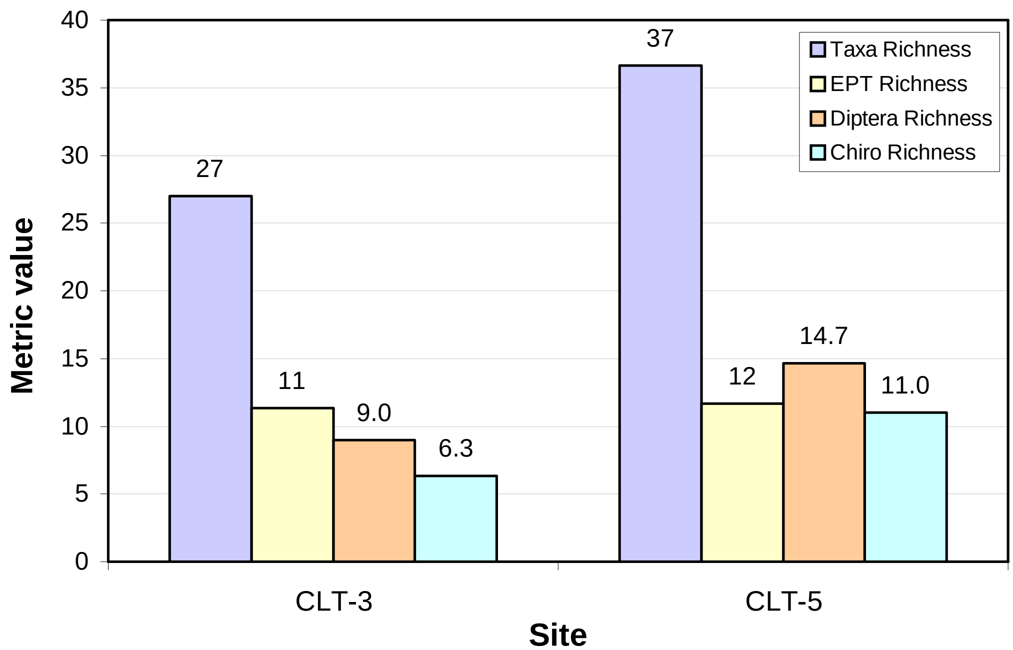


Figure 24. Comparison of Taxa richness, EPT richness, Diptera richness and Chironomidae richness measures for sites CLT-3 and CLT-5.

Center Lake Physical and Chemical Parameters

Water Temperature

Water temperature in Center Lake ranged from 3.4 to 24.1 degrees Celsius (Table 28). State standards require water temperatures to be maintained at or below 18.3 degrees Celsius to support the beneficial use of coldwater permanent fish propagation. Thirty percent of all temperature measurements exceeded the standard. Maximum temperatures were reached in July and August (Figure 25). In August 2001 and 2002, the temperature criterion was exceeded at both surface and bottom depths. Because greater than 10% of the temperature measurements exceeded the temperature criterion, a temperature TMDL is required for Center Lake. The temperature TMDL will be addressed in a separate document.

Table 28. Descriptive statistics of water temperature (degrees Celsius) for Center Lake sites.

Water Temperature, Degrees Celsius

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	13.4	14.2	3.4	24.1	7.85
Bottom	11.4	8.4	3.4	23.8	7.19

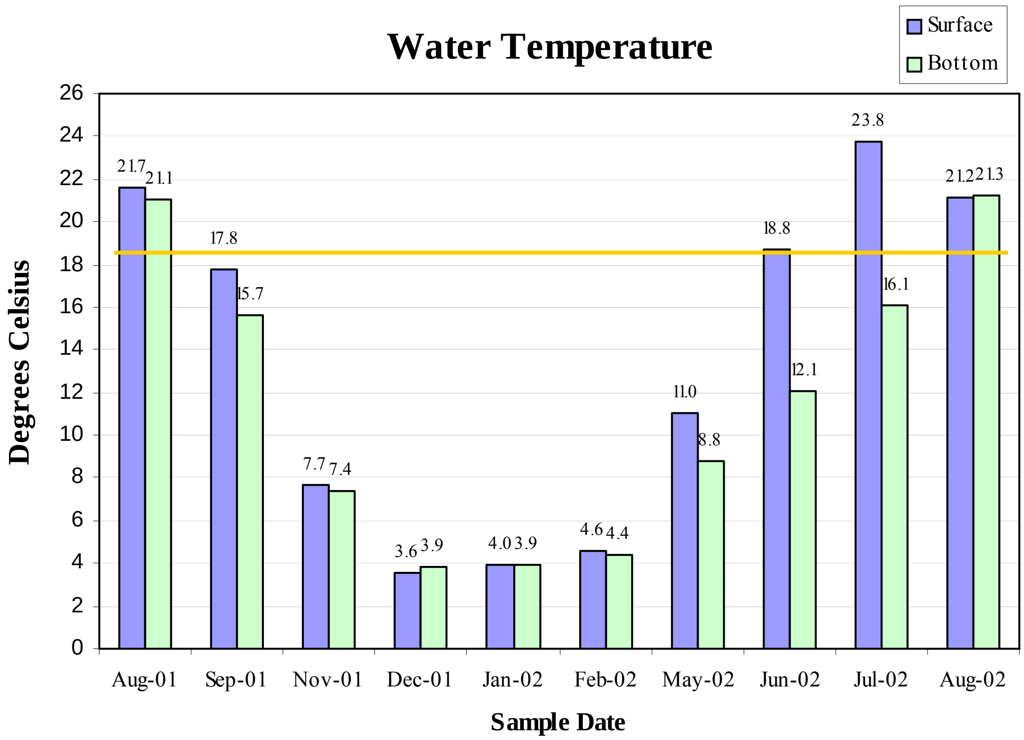


Figure 25. Average surface and bottom water temperatures for Center Lake by sample date. The horizontal line indicates the state standard (18.3 degrees Celsius).

Dissolved Oxygen

Dissolved oxygen (DO) is made available by photosynthetic inputs from algae and other aquatic plants, and through diffusion from the atmosphere. Conversely, microbial degradation of dead algae and aquatic plants consumes oxygen. In eutrophic (productive) lakes, a high rate of production and subsequent decomposition of organic matter can result in low or no oxygen in the hypolimnion (Monson, 2000). This trend was observed during the summer months in Center Lake.

The observed DO values for all sites and depths ranged from 0.26 to 13.48 mg/L (Table 29). The lowest oxygen values were observed in August 2001 and August 2002 (Figure 26). State standards require DO values to be maintained at or above 6.0 mg/L to support the beneficial use of coldwater permanent fish propagation. DO values dropped below state standards (for bottom samples only) in August and September 2001 and in June, July and August 2002.

Because 25% of the DO measurements collected during the study period were below the state standard, a TMDL for the DO impairment is required. This TMDL will be addressed in a future document.

Table 29. Descriptive statistics of dissolved oxygen (mg/L) for Center Lake sites.

Dissolved Oxygen, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	10.14	9.43	7.54	13.48	2.211
Bottom	7.02	7.98	0.26	13.20	4.020

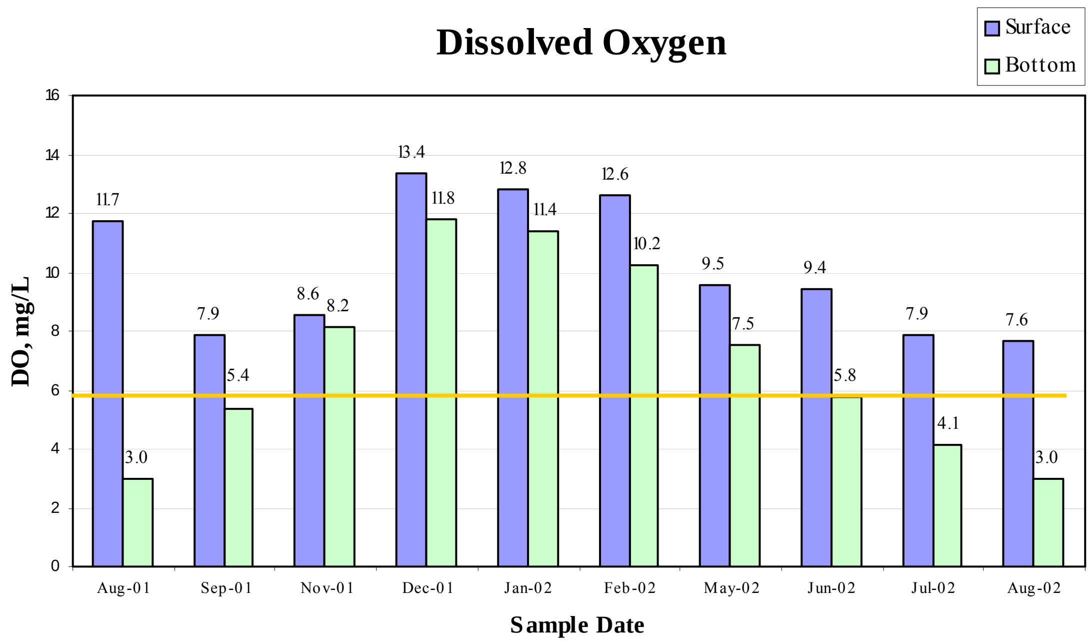


Figure 26. Average surface and bottom dissolved oxygen concentrations for Center Lake by sample date. The horizontal line indicates the state standard (≥ 6.0 mg/L).

Conductivity

Conductivity is a measure of the ability of water to conduct an electric current. This characteristic varies with water temperature and the quantity of dissolved ions present. Conductivity can be correlated to system productivity, since high nutrient waters have high conductivity. However, other factors including non-nutrient salts also influence conductivity. Thus, conductivity is often used as a surrogate measure of salinity. As conductivity/salinity increases, there is a general decrease in aquatic animal diversity. This is due to the tolerance limits of organisms to salinity and to lower levels of dissolved oxygen. The solubility of oxygen decreases with increased salinity (Dodds, 2002).

Conductivity values in Center Lake ranged from 11.5 to 118.9 umhos/cm (Table 30). Highest values (from averages for the two sites) were observed in January 2002 (Figure 27). The conductivity standard for Center Lake is ≤ 7,000 umhos/cm. This criterion was established for the beneficial use of fish and wildlife propagation, recreation, and stock watering. Measurements collected in Center Lake were well below this standard.

Table 30. Descriptive statistics of conductivity (umhos/cm) for Center Lake sites.

Conductivity, umhos/cm

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	105.3	110.5	11.5	117.8	22.51
Bottom	103.5	108.2	11.8	118.9	23.78

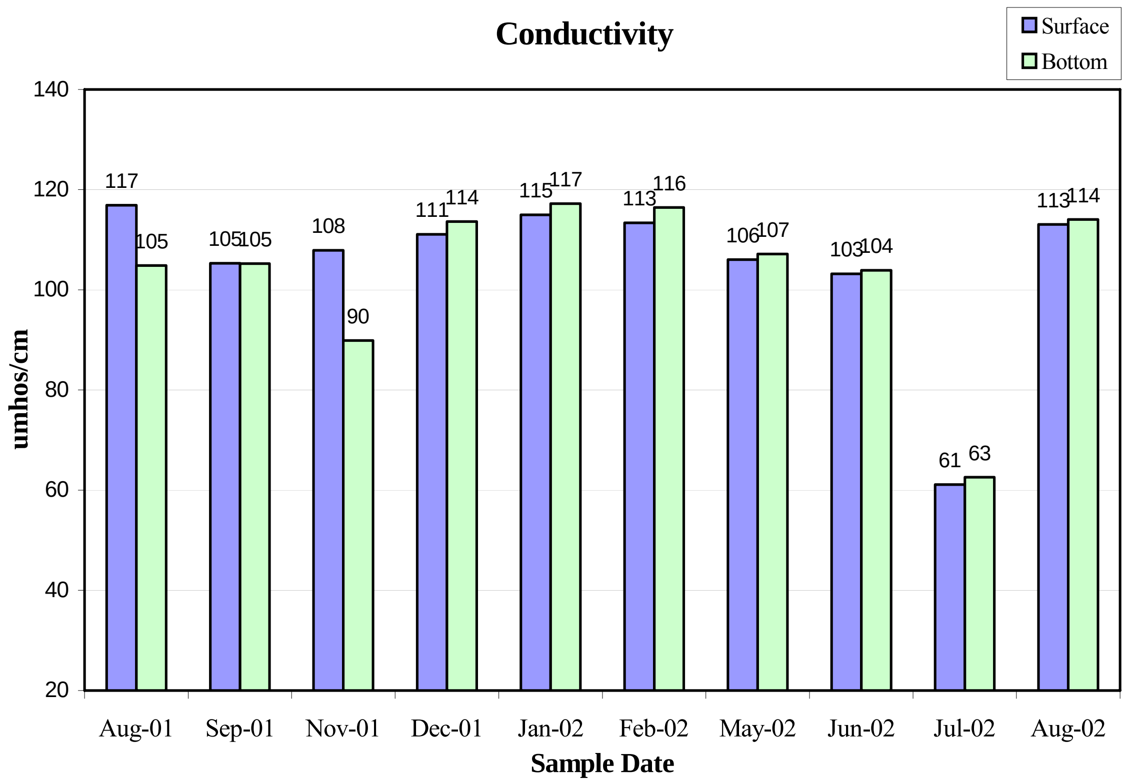


Figure 27. Average surface and bottom conductance by sample date for Center Lake.

Acidification and Alkalinity

In Center Lake, pH values ranged from 6.7 to 9.7 (Table 31). Many measurements (40%) at both sites and both depths exceeded the upper limit of the water quality criterion, which requires pH values to fall within a range of 6.6 to 8.6 for cold water permanent fish propagation (Figure 28). Because greater than 10% of the pH measurements exceeded the criterion, a pH TMDL is required for Center Lake. The TMDL for the pH impairment will be addressed in the future.

Table 31. Descriptive statistics of field pH (standard units) for Center Lake sites.

Field pH

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	8.9	9	7.8	9.7	0.585
Bottom	8.1	8.3	6.7	9.3	0.786

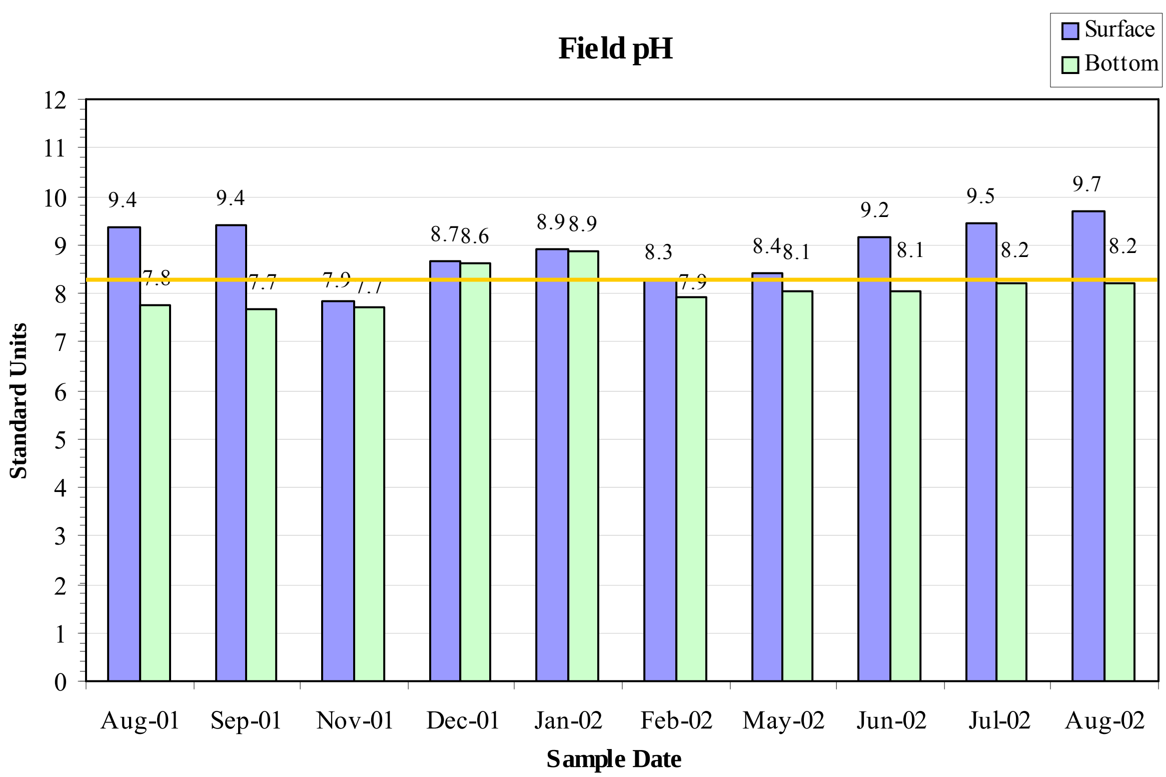


Figure 28. Average surface and bottom pH by sample date for Center Lake. The horizontal line indicates the upper limit of the water quality criterion (≤ 8.6 standard units).

Where igneous rocks and carbonate-poor soils are predominant, waters will have low alkalinity. Considering the geology of the Center Lake watershed (predominantly granite and quartzite) and low alkalinity concentrations observed during this assessment, erosion and natural weathering of the drainage area are not likely sources of the high pH.

The eutrophication of Center Lake is believed to be the largest source of high pH. The vertical distribution of pH in Center Lake is strongly influenced by the photosynthetic utilization of carbon dioxide in the trophogenic zone (the lighted zone where organic matter is synthesized and oxygen generated), which tends to reduce carbon dioxide content and increase pH. Therefore, management practices recommended to reduce phosphorus loads, thereby reducing algae growth, are expected to also reduce the pH of Center Lake.

Alkalinity is a measure of the buffering capacity of a waterbody. Alkalinity measurements in Center Lake were fairly consistent throughout the sampling period, ranging on average from 45.7 to 49.1 mg/L (Table 32). The alkalinity standard for Center Lake is ≤ 1313 mg/L. All sample measurements for Center Lake were far below the state standard (Figure 29).

Table 32. Descriptive statistics of alkalinity (mg/L) for Center Lake sites.

Alkalinity, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	45.7	46	30	56	5.362
Bottom	49.1	48	42	86	9.095

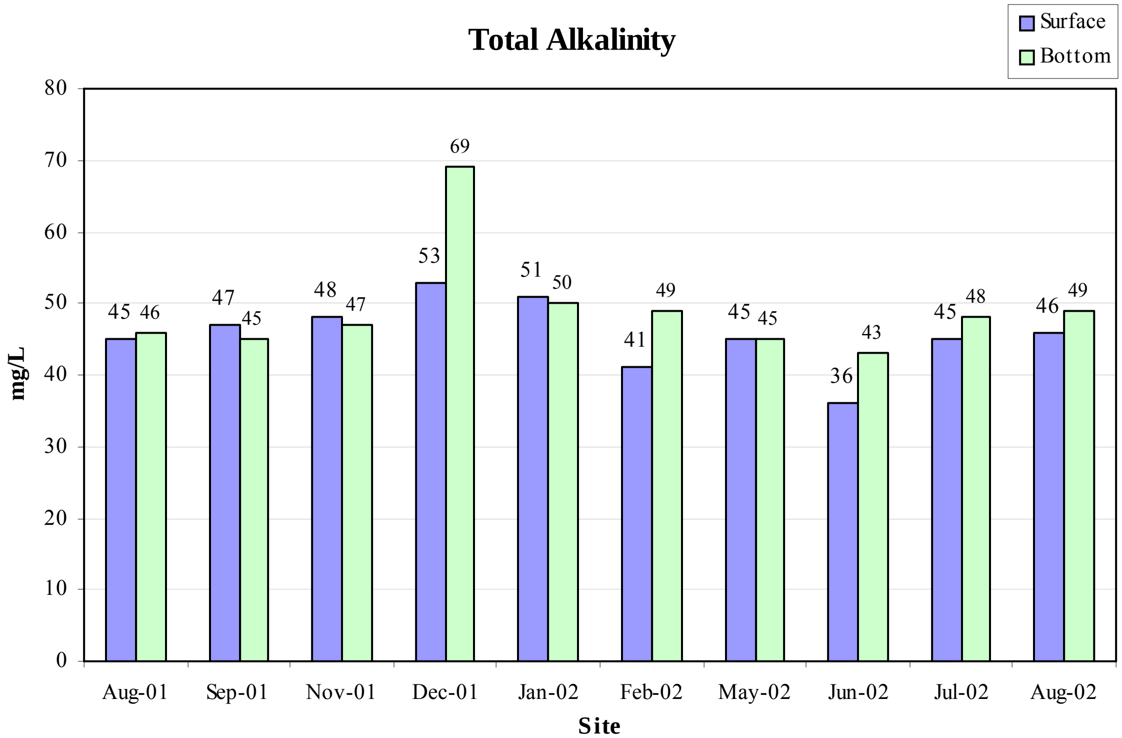


Figure 29. Average alkalinity of surface and bottom samples by sampling date for Center Lake.

Solids

Total solids (suspended and dissolved) in Center Lake ranged from 30 to 160 mg/L (Table 33). Total solids concentrations were fairly consistent across all dates, with the exception of a peak value of 160 mg/L in July 2002. At the present time, a state standard does not exist for total solids (Figure 30).

Table 33. Descriptive statistics of total solids (mg/L) for Center Lake sites.

Total Solids, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	78.8	77	50	160	22.26
Bottom	74.7	78	30	96	15.46

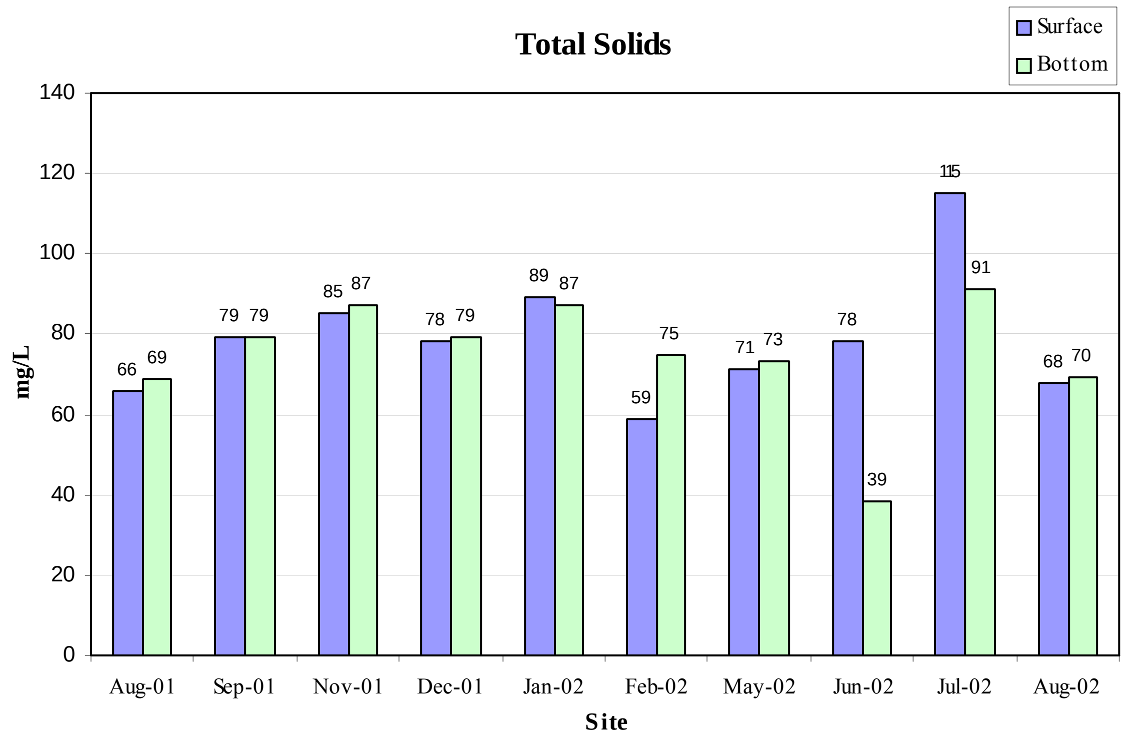


Figure 30. Average surface and bottom concentrations of total solids by sample date for Center Lake.

Dissolved Solids

Typical of most waterbodies, total solids were mostly comprised of dissolved solids. Dissolved solids consist of salts and compounds that increase alkalinity. Like alkalinity, TDS concentrations in Center Lake were low. TDS ranged from 14 to 160 mg/L (Table 34). The TDS standard for Center Lake is ≤ 4,375 mg/L.

Table 34. Descriptive statistics of total dissolved solids (mg/L) for Center Lake sites.

Total Dissolved Solids, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	75.9	74.5	37	160	23.71
Bottom	65.9	74.5	14	88	22.43

Suspended Solids

Total suspended solids (TSS) ranged from less than detection limits to 60 mg/L (Table 35). TSS concentrations need to be maintained at or below 53 mg/L in Center Lake to support its coldwater permanent fishery. The standard was exceeded only once at one sample location (CL-1, bottom), in May 2002, with a concentration of 60 mg/L. This high concentration of TSS was likely caused by the sampler hitting the lake bottom sediment when collecting the lake water sample. Thus, the value is attributed to sampler error and is not representative of actual TSS concentrations in the hypolimnion. Average surface and bottom depth concentrations of total suspended solids by sample date are shown in Figure 31.

Table 35. Descriptive statistics of total suspended solids (mg/L) for Center Lake sites. Note that the minimum values represent half of the detection limit of 5 mg/L.

Total Suspended Solids, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	4.3	2.5	2.5	14.0	3.66
Bottom	9.5	3.7	2.5	60.0	15.33

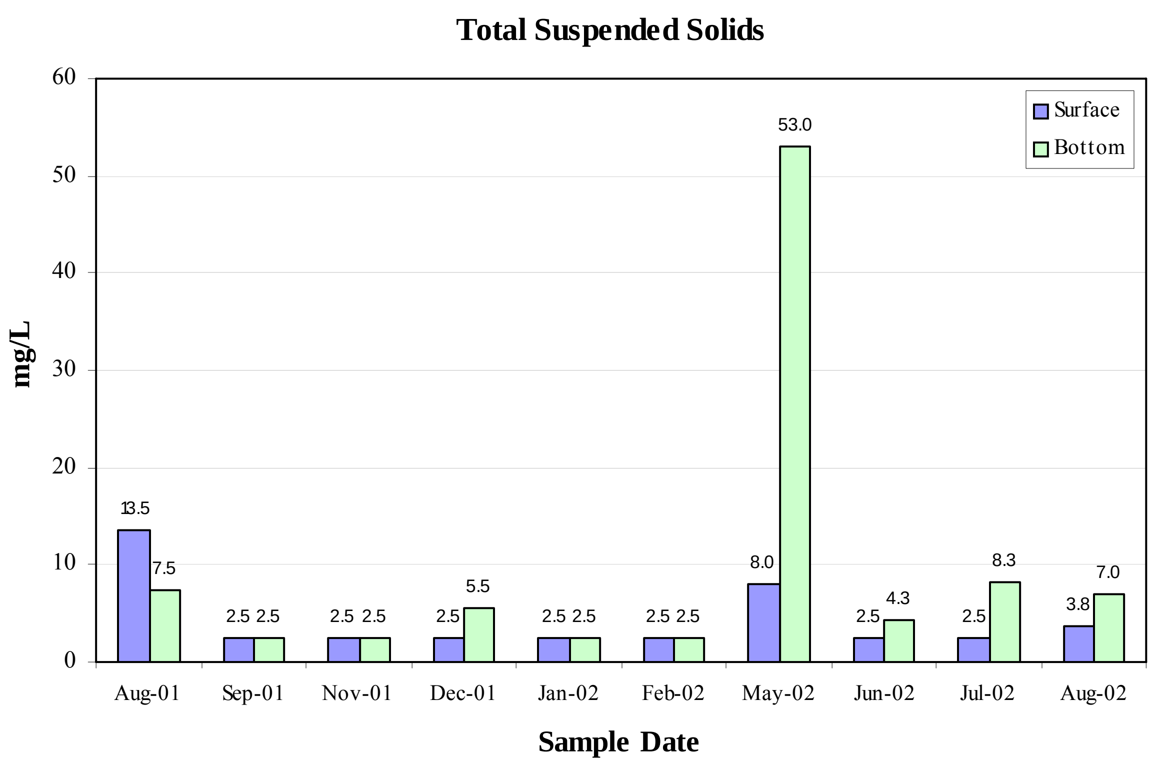


Figure 31. Average surface and bottom concentrations of total suspended solids by sample date for Center Lake.

Nitrogen

Several forms of nitrogen can be found in a waterbody. Natural sources of nitrogen include precipitation, biological processes (i.e. nitrogen fixation), and surface and groundwater drainage. Anthropogenic nitrogen sources include sewage inputs of organic nitrogen and fertilizer applications.

Total Kjeldahl Nitrogen (TKN) is a measure of organic nitrogen plus ammonia. Therefore, organic nitrogen can be calculated by subtracting ammonia from TKN. In Center Lake, the amount of organic nitrogen far exceeded inorganic forms. The calculated average organic nitrogen concentration was 4.89×10^{-4} mg/L. Average inorganic nitrogen (ammonia and nitrate/nitrite) concentration was 1.84×10^{-4} mg/L.

Ammonia is the nitrogen end product of bacterial decomposition of organic matter. This form of nitrogen is most readily available to algae and aquatic plants for uptake and growth. Sources of ammonia may include animal wastes, decayed organic matter, or bacterial conversion of other nitrogen compounds.

For this study, when samples were analyzed for total ammonia, 0.10 mg/L was designated as the detection limit. Total ammonia levels were below the detection limit in 60% of the samples collected in Center Lake. Inorganic forms of nitrogen, including ammonia and nitrate, are quickly consumed by aquatic plants and algae, and can become the limiting factor for growth. Samples with total ammonia levels below the detection limit were assigned values of half the detection limit (0.05 mg/L), assuming that a trace amount was present.

Total ammonia concentrations ranged from less than detection limits to 0.6 mg/L (Table 36). Maximum ammonia concentrations were observed in samples collected in July and August, 2002 (Figure 32). State water quality standards contain total ammonia criteria for the protection of waters classified as fisheries. This criterion is dependent on the pH of the water sample at the time the sample was collected. All ammonia samples were evaluated using the criteria shown in Table 3, and no samples exceeded the total ammonia criteria.

Table 36. Descriptive statistics of ammonia (mg/L) for Center Lake sites. Note that the minimum values represent half of the detection limit of 0.1 mg/L.

Ammonia, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	0.065	0.05	0.05	0.2	0.046
Bottom	0.13	0.05	0.05	0.6	0.144

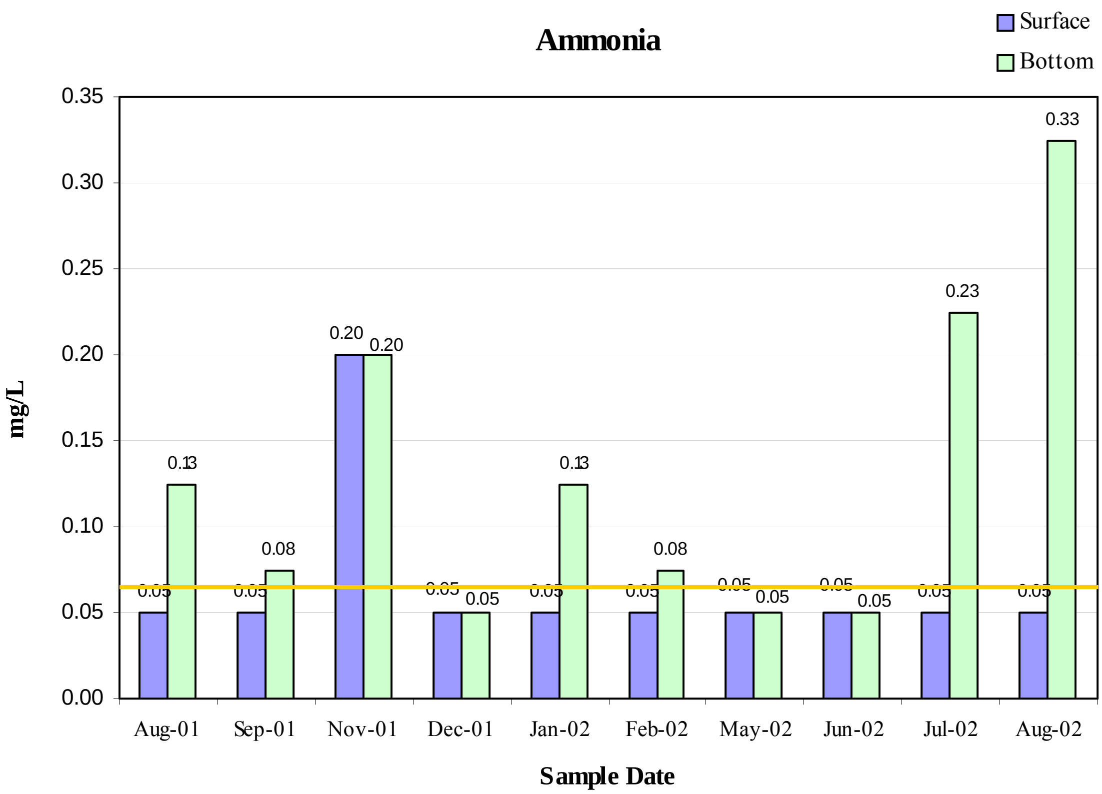


Figure 32. Average surface and bottom concentrations of total ammonia by sample date for Center Lake. Horizontal line indicates the detection limit (0.10 mg/L).

Nitrate + Nitrite concentrations ranged from less than the detection limit to 0.6 mg/L (Table 37). Average surface and bottom concentrations of Nitrate + Nitrite by sample date can be seen in Figure 33, with the concentrations averaged for the two sites. The majority of the samples fell below the detection limit of 0.05 mg/L. Maximum concentrations were observed in samples collected in December, 2001.

Table 37. Descriptive statistics of nitrate + nitrite (mg/L) for Center Lake sites. Note the minimum values represent half of the detection limit of 0.05 mg/L.

Nitrate+Nitrite, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	0.02675	0.025	0.025	0.06	0.007826
Bottom	0.0275	0.025	0.025	0.05	0.007695

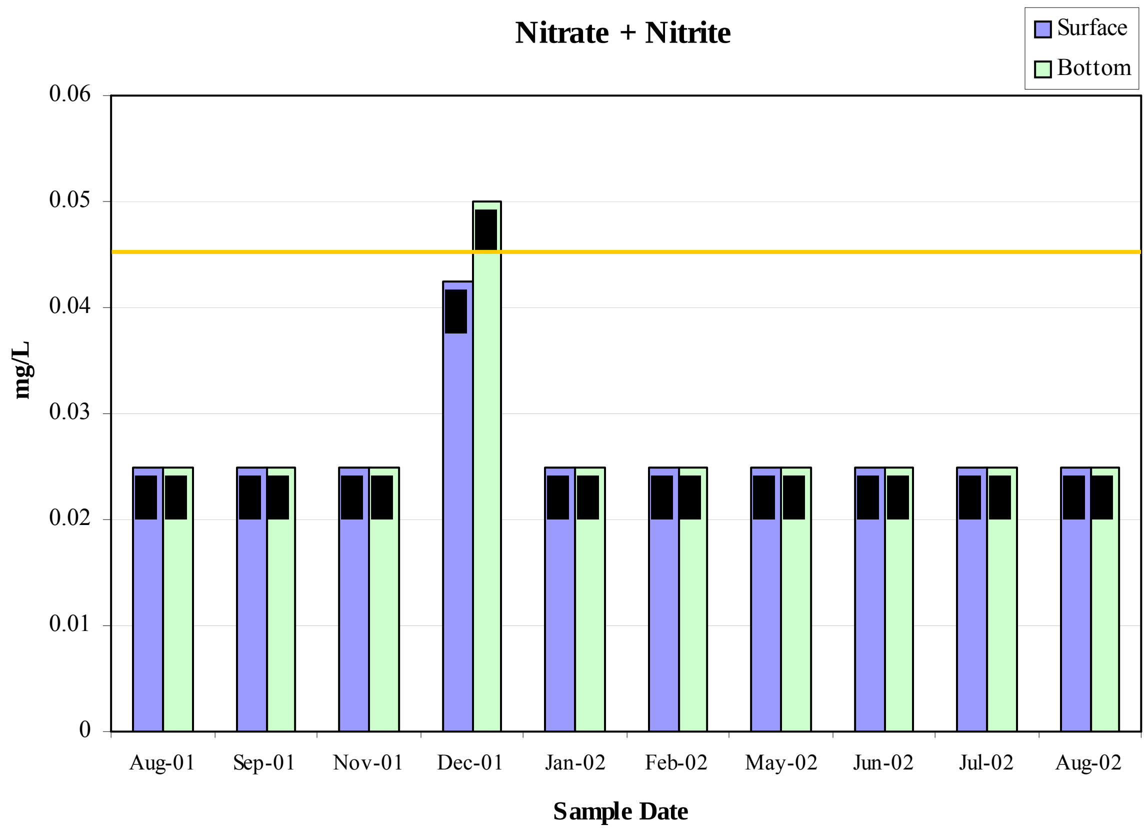


Figure 33. Average surface and bottom concentrations of Nitrate+Nitrite by sample date for Center Lake. Horizontal line indicates the detection limit (0.05 mg/L).

Total Nitrogen can be calculated by adding TKN and nitrate/nitrite concentrations. Total nitrogen values were used to determine whether nitrogen is a limiting nutrient in Center Lake (see limiting nutrient section). Total nitrogen in Center Lake ranged from 0.0825 to 1.525 mg/L (Table 38). Average surface and bottom concentrations of Total Nitrogen by sample date can be seen in Figure 34, with the concentrations averaged for the two sites.

Table 38. Descriptive statistics of Total Nitrogen (mg/L) for Center Lake sites.

Total Nitrogen, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	0.63975	0.625	0.085	1.525	0.368887
Bottom	0.7325	0.825	0.275	1.225	0.282854

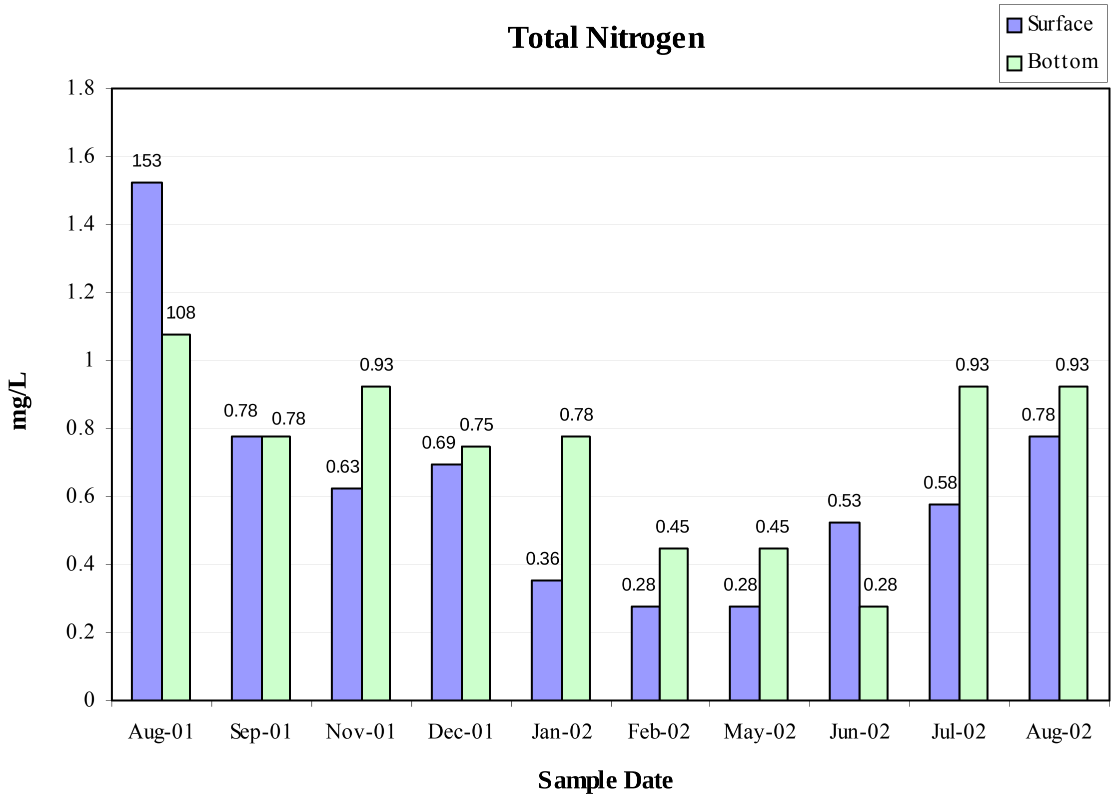


Figure 34. Average surface and bottom concentrations of total nitrogen by sample date for Center Lake.

Phosphorus

Like nitrogen, phosphorus is a biologically active element. It cycles through different states in the aquatic environment, and its concentration in any one state depends on the degree of biological assimilation or decomposition occurring in that system. The predominant inorganic form of phosphorus in lake systems is orthophosphate. Concentrations of orthophosphate were measured as total dissolved phosphorus (TDP) in this study.

Total phosphorus concentrations of non-polluted waters are usually less than 0.1 mg/L (Lind, 1985). Total phosphorus values in Center Lake ranged from 0.01 to 0.13 mg/L (Table 39). Maximum concentrations of phosphorus were observed in August and September, possibly following a large rain event (Figure 35). In conjunction with rain events is the potential for external loading of phosphorus from natural erosional runnoff, as well as runnoff from road maintenance activities. Internal loading may also be contributing, as sediment is disturbed during storm events, which may redistribute phosphorus into the water column as the water becomes more mixed.

Table 39. Descriptive statistics of total phosphorus (mg/L) for Center Lake sites.

Total Phosphorus, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	0.031	0.030	0.010	0.060	0.0135
Bottom	0.049	0.040	0.030	0.130	0.0245

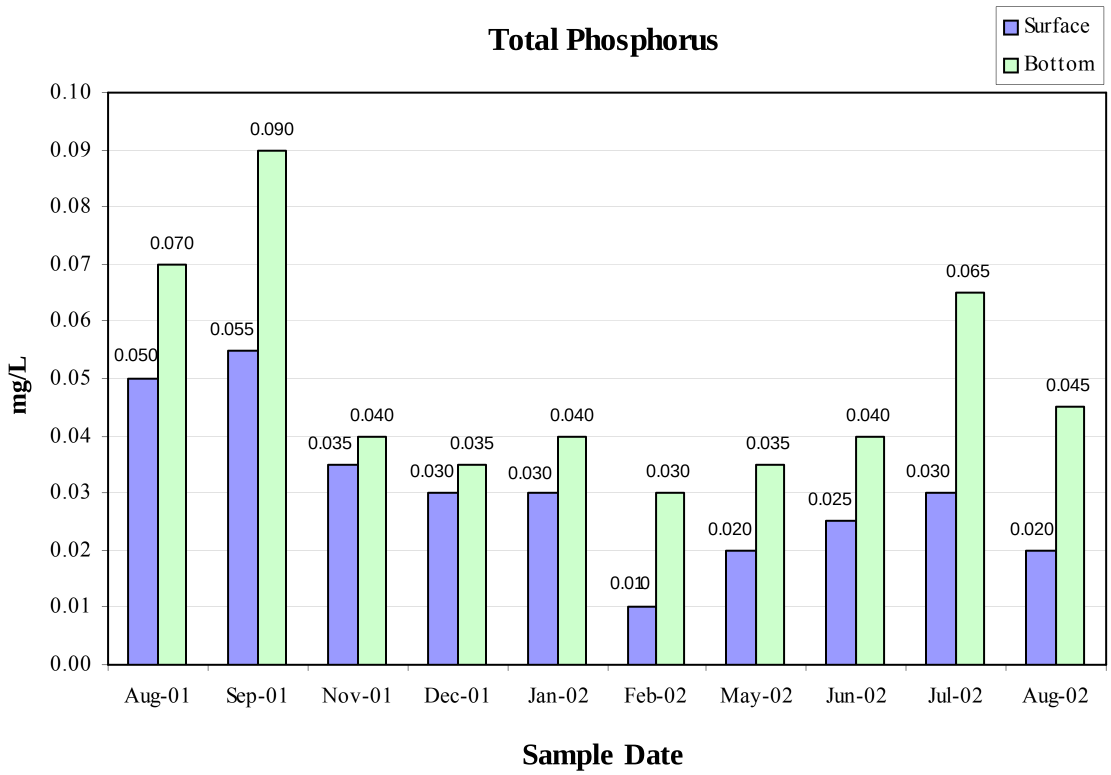


Figure 35. Average surface and bottom concentrations of total phosphorus by sample date for Center Lake.

Phosphorus is often a limiting nutrient to algae and macrophyte production within many aquatic systems. Loading of this nutrient allows for increased eutrophication (primary production). TDP is the portion of total phosphorus that is readily available for aquatic plant or algae utilization. TDP concentrations of non-polluted waters are usually less than 0.01 mg/L (Lind, 1985). TDP concentrations in Center Lake ranged from no detection (< 0.01) to 0.04 mg/L (Table 40). On several sample dates, concentrations exceeded the minimum amount for rapid algal growth, which requires only 0.02 mg/L (Figure 36).

Table 40. Descriptive statistics of total dissolved phosphorus (mg/L) for Center Lake sites.

Total Dissolved Phosphorus, mg/L

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	0.0120	0.0075	0.005	0.030	0.0088
Bottom	0.0125	0.0075	0.005	0.040	0.0101

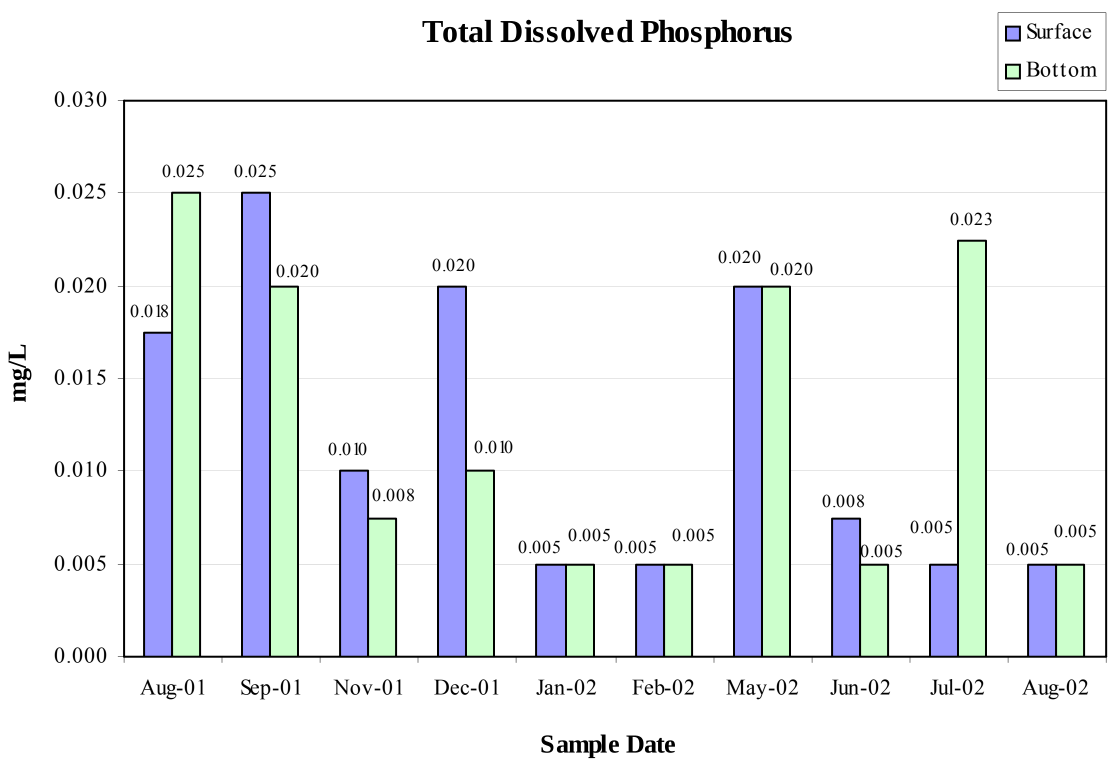


Figure 36. Average surface and bottom concentrations of total dissolved phosphorus by sample date for Center Lake.

Limiting Nutrients

Eutrophication is a term used to describe increased biological production (especially algae and aquatic plants) in lakes due to human impacts (Wetzel, 2001). Great emphasis is placed on regulating nutrient loading to waterbodies to control aquatic productivity. In aquatic systems, the most significant nutrient factors causing the shift from a lesser to a more productive state are phosphorus and nitrogen. Nitrogen is difficult to control because of its highly soluble nature. From a management perspective, phosphorus is easier to manipulate. Consequently, it is most often the nutrient targeted for reduction when attempting to control lake eutrophication.

When either nitrogen or phosphorus reduces the potential for algal growth and reproduction, it is considered the limiting nutrient. Optimal nitrogen and phosphorus concentrations for aquatic plant growth occur at a ratio of 10:1 (N:P ratio). N:P ratios greater than 10:1 indicate a phosphorus-limited system, while N:P ratios less than 10:1 indicate a nitrogen-limited system (USEPA, 1990).

N:P ratios for Center Lake ranged from 2.83 to 41.25 (Table 41). A majority (90%) of the samples collected in Center Lake were phosphorus-limited with N:P ratios above the optimal 10:1 ratio (Figure 37).

Table 41. Descriptive statistics of N:P ratios for Center Lake sites.

N:P Ratio

	Average	Median	Minimum	Maximum	Standard Deviation
Surface	21.9	20.8	2.8	41.2	9.01
Bottom	16.4	18.7	5.5	27.5	6.72

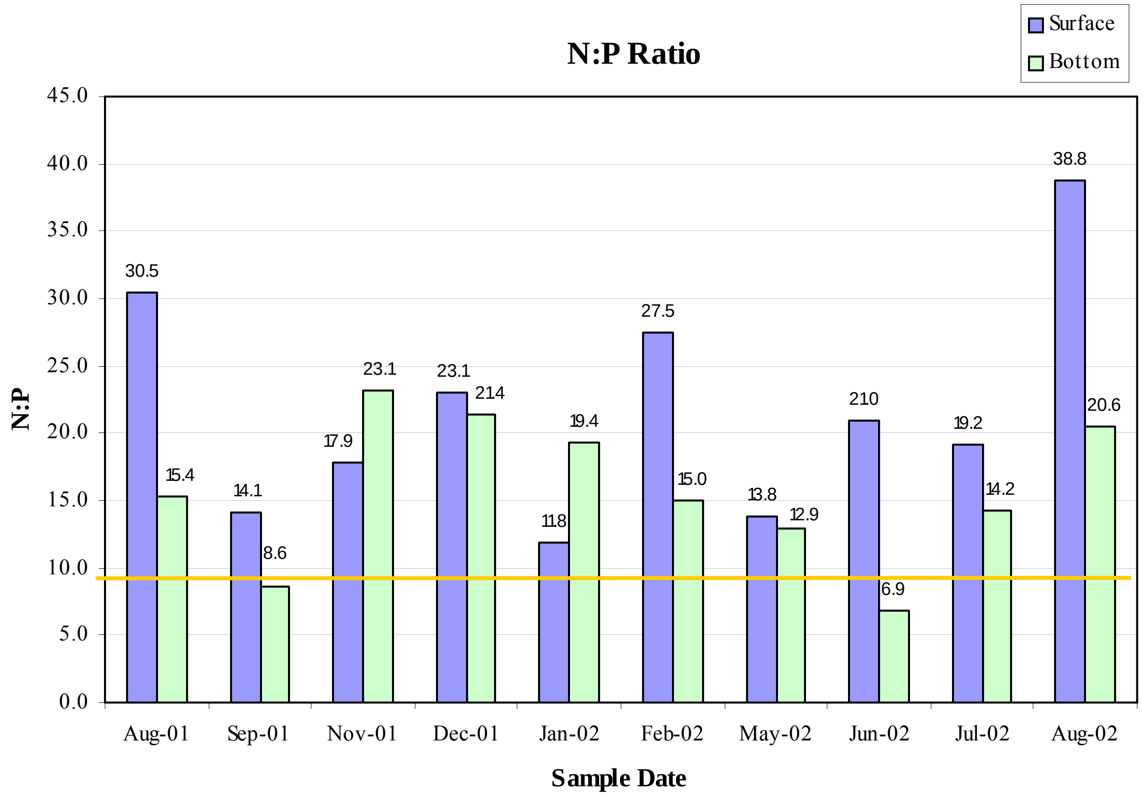


Figure 37. Nitrogen:phosphorus ratios for Center Lake. All except two samples were phosphorus-limited. Values above the horizontal line (N:P > 10) are considered phosphorus limited.

Trophic State

Wetzel (2001) defines 'trophy' of a lake as "the rate at which organic matter is supplied by or to a lake per unit time." Trophic state is often measured as the amount of algal production in a lake, which is one source of organic material. Determinations of trophic state can be made from several different measures including oxygen levels, species composition of lake biota, concentrations of nutrients, and various measures of biomass or production. An index incorporating several of these parameters is best suited to determine trophic state.

The Trophic State Index (TSI) was used to determine the approximate trophic state of Center Lake (Carlson, 1977). This index incorporates measures of Secchi disk transparency, chlorophyll *a*, and total phosphorus into scores ranging from 0 to 100 with each 10-unit increase representing a doubling in algal biomass. Four ranges of index values define Carlson's trophic levels, which include oligotrophic, mesotrophic, eutrophic, and hyper-eutrophic. These levels and their numeric ranges are listed in Table 42 in order of increasing productivity.

Table 42. Carlson's trophic levels and index ranges for each level.

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

TSI values were calculated for two of the three index parameters separately. Unfortunately, chlorophyll samples were inappropriately handled after collection (chlorophyll samples were not promptly shipped to the lab for analysis; all samples were past holding times by the time they were analysed), rendering chlorophyll data unavailable for this report. Actual measurements were only available for phosphorus and Secchi depth. Phosphorus TSI values ranged from 42 to 61 (mean = 52), and Secchi depth TSI values ranged from 44 to 64 (mean = 55) (Table 43). Average and median TSI for both parameters fell in the eutrophic range. The majority of phosphorus and Secchi depth TSI values indicate eutrophic conditions in Center Lake, with a few values indicating mesotrophic conditions.

Table 43. Descriptive statistics for observed trophic state index (TSI) values calculated from direct measurements and samples collected in Center Lake.

	Phosphorus TSI	Secchi TSI
Average	51.6	54.9
Median	53.0	53.0
Minimum	41.9	44.2
Maximum	60.6	64.1
Stan. Deviation	5.41	5.95

Beneficial use attainment for Center Lake was also assessed using TSI values. The SD DENR has recently adopted a TSI methodology to determine support status of a lake's fishery classification based on the median value of Secchi depth and chlorophyll-*a* measurements (Lorenzen, 2005). Numeric TSI criteria are established for each fishery classification. The TSI criterion for Center Lake, a coldwater permanent fishery, is a median chlorophyll-a and Secchi depth TSI value ≤ 48. TSI values during the study period are plotted in Figure 38, showing values exceeding the fishery-based criteria. A median TSI value of 48 is the TMDL goal to achieve fully supporting status.

Reduction Response Model

Inlake reduction response modeling was conducted using BATHTUB, a eutrophication response model designed by the United States Army Corps of Engineers (US ACOE, 1999). The model predicts changes in water quality parameters related to eutrophication (phosphorus, nitrogen, chlorophyll *a*, and transparency) using empirical relationships previously developed and tested for reservoir applications. Lake and tributary sample data were used to calculate existing conditions in Center Lake. Tributary loading data was obtained from the FLUX model output. Inlet phosphorus and nitrogen concentrations were reduced in increments of 10% and modeled to generate an inlake reduction curve.

As anticipated, the predicted inlake phosphorus concentrations and individual parameter (chlorophyll and Secchi depth) TSI values decreased with the reduction of tributary phosphorus load (Table 45). Predicted Secchi TSI values did not respond as rapidly as predicted chlorophyll TSI values to phosphorus load reductions. Predicted chlorophyll and Secchi depth TSI values with no reduction of phosphorus load were 53.4 and 51.5, respectively, which are considered as not supporting beneficial uses. The model indicates an approximate 70% reduction in phosphorus load is required to bring chlorophyll and Secchi depth TSI values into compliance with the fishery-based TSI criterion (Figure 38).

The TMDL goal (70% reduction of total phosphorus loads) was determined based on the load reduction required to achieve a predicted chlorophyll and Secchi TSI value ≤ 48.

Table 44. BATHTUB model-predicted concentrations of total phosphorus and TSI values with successive 10-percent reductions in phosphorus inputs. TSI values are plotted on the following graphs.

Percent Reduction	Total Phosphorus Concentration (ppb)	Predicted TSI value Phosphorus	Predicted TSI value Chlorophyll	Predicted TSI value Secchi Depth
0%	94	56.1	53.4	51.5
10%	84	55.2	52.8	51.1
20%	75	54.2	52.2	50.7
30%	66	53.1	51.4	50.3
40%	56	51.8	50.5	49.7
50%	47	50.3	49.5	49.2
60%	37	48.4	48.2	48.5
70%	28	46.1	46.6	47.8
80%	19	42.9	44.4	46.9
90%	9	37.8	41.0	45.8
100%	0	26.8	33.5	44.2

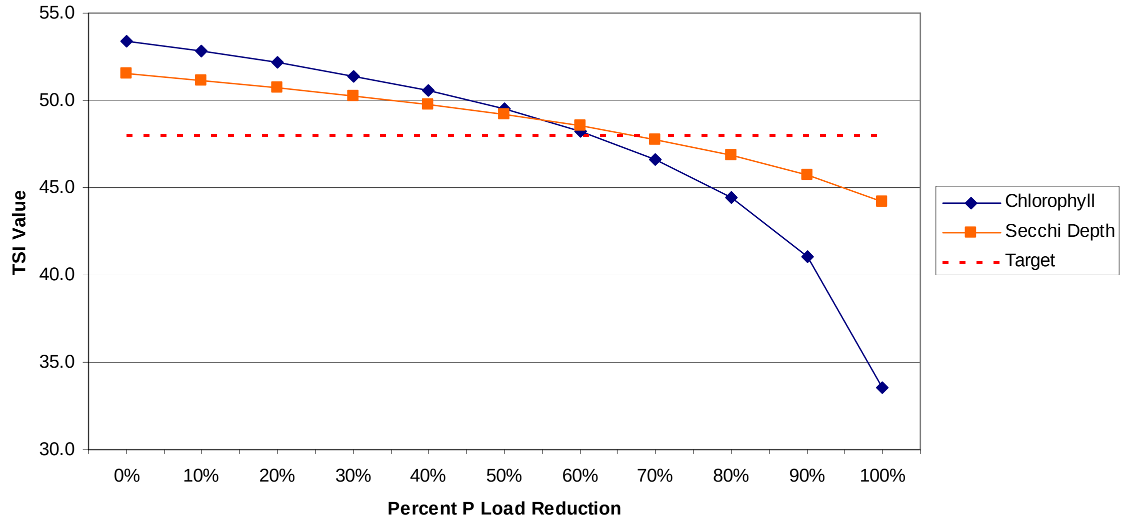


Figure 38. Model-predicted chlorophyll and Secchi depth TSI values with successive 10-percent reductions in nutrient loading. Dotted line represents TMDL target (48).

Lake Biological Parameters

Fishery

The most recent fishery survey was conducted in October, 1994, by the South Dakota Department of Game, Fish and Parks (SDGF&P). Two baby frame nets (one ½" mesh and one 1/4" mesh), three large frame nets (with ¾" mesh and 75 ft. leads), and two 100 ft. seine hauls were used to sample the fish community in Center Lake.

Currently, Center Lake is managed as a rainbow trout fishery, with approximately 8,400 catchable fish stocked annually. Occasionally, adult, post-spawn rainbow trout brood stock are also planted. One stocking of 60 adult brown trout was recorded in 1991. Brook trout are also present, originating from Grace Coolidge Creek.

Hatchery rainbow trout were most abundant in the test netting at 65%, with Brook trout comprising the remainder of the sportfish catch at approximately 15 %. Fourteen white sucker, five fathead minnow and one creek chub also were sampled.

The complete fisheries survey report for Center Lake may be found in Appendix D.

Fecal Coliform Bacteria

Center Lake is designated with the beneficial use of immersion recreation, which requires that no single sample exceed a concentration of 400 colony forming units (CFU) per 100ml of sample, or a 30-day average (five samples) of 200 CFU per 100 ml. None of the lake samples exceeded the state standard. Overall, lake sample concentrations ranged from less than detection limits to 7.5 CFU per 100 ml (Table 46).

Table 45. Descriptive statistics of Fecal Coliform Bacteria (umhos/cm) for Center Lake sites. Values of 1 CFU/100ml represent half of the detection limit of 2 CFU/100ml.

Fecal Coliform Bacteria, CFU/100ml

	Average	Median	Minimum	Maximum	Stdev
Surface	1	1	1	1	0.00
Bottom	1.8	1	1	7.5	2.03

Quality Assurance / Quality Control

Quality assurance/quality control (QA/QC) samples were collected throughout the project period to insure proper laboratory and field sampling methods. Duplicate samples were collected on randomly chosen dates for a minimum of 10 % of all samples collected. All duplicate samples closely matched their paired sample. Please see Appendix E for all replicate and duplicate paired QA/QC sample data.

Other Monitoring

Sediment Survey

Sedimentation continues to be one of the most destructive pollutants of lakes and streams. Increased sedimentation can cause an increase in phosphorus loading, a decrease in the available habitat for invertebrates and fish, and diminished depth of the waterbody. A decrease in water depth poses additional problems, such as increased water temperatures due to less overall water volume and greater sunlight penetration. The shallow depths and warmer water create an environment unsuitable for coldwater permanent fish life propagation, and may also become habitat more suitable for filamentous green and blue-green algae growth.

A sediment survey was conducted by the SDDENR on Center Lake in January 2001. Water depth and sediment depth was measured at approximately 200 locations, through holes drilled in the ice. A steel probe was lowered through the holes and pushed through the soft sediment until solid substrate was reached. Water and sediment depth was recorded at each site with Global Positioning System (GPS) equipment.

Average sediment depth for Center Lake was 2 ft. Sediment depths ranged from 1.0 ft to 6.5 ft. Total sediment volume in Center Lake 70,000 cubic yards (Figure 41).

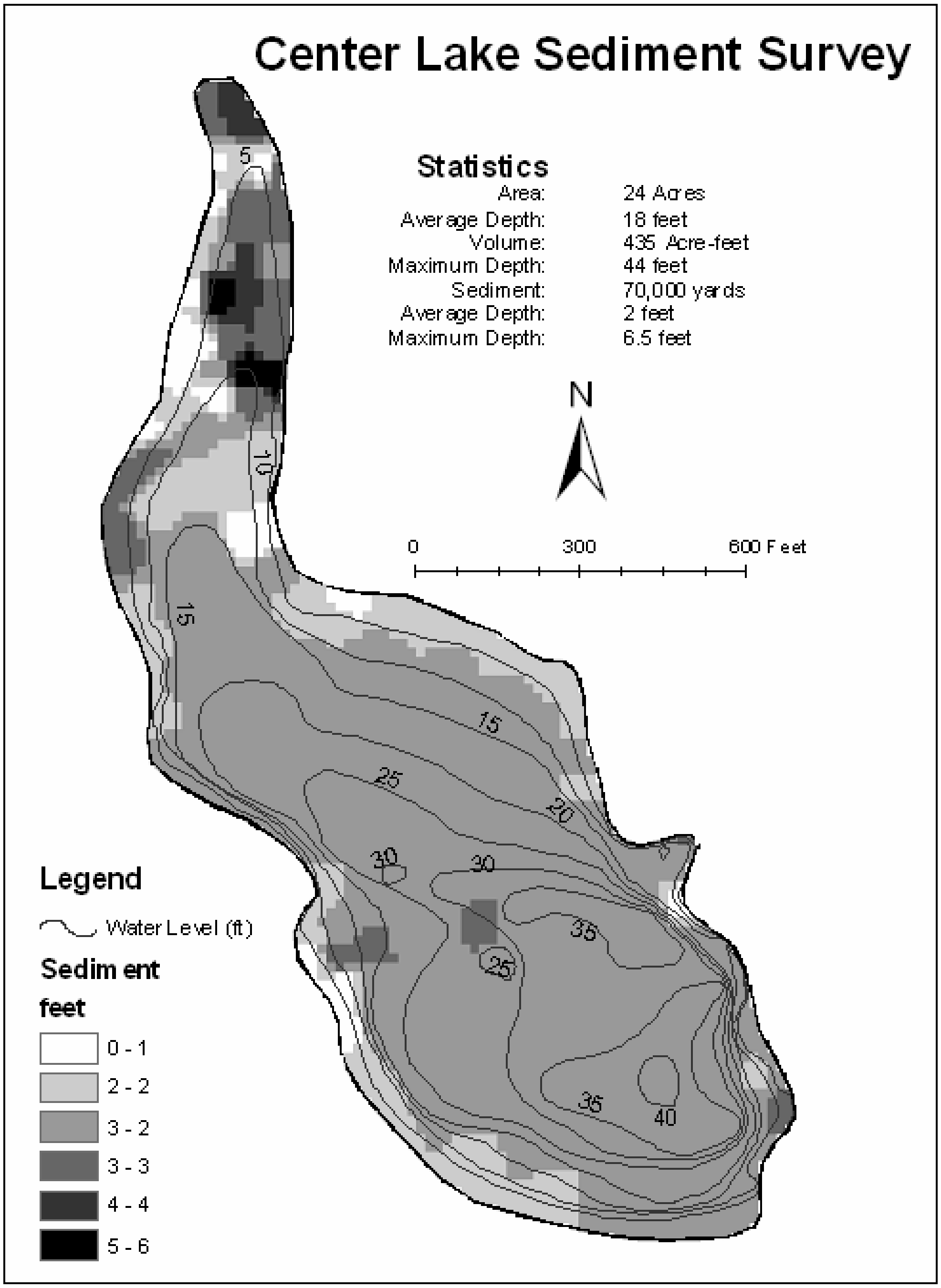


Figure 39. Center Lake sediment depths and water depths.

Watershed Management Recommendations

Natural sources of phosphorus include the leaching of phosphate-bearing rocks and organic matter decomposition. Other potential sources of phosphorus include phosphorus-based detergents, fertilizers, runoff from highway maintenance operations, disturbances from tourism, defective septic systems, improper gray-water (e.g. water used for washing hands, dishes, clothing, etc.) disposal, or other human waste disposal.

The Center Lake watershed is used predominantly by tourists and campers with few permanent residents. Sources of phosphorus most likely affecting Center Lake include: 1) recreational activities resulting in bank and shoreline disturbance, 2) detergents contained in gray-water, 3) road maintenance and use, and 4) septic systems, including the system servicing the Center Lake recreational areas.

Perhaps the most significant sources of phosphorus in the Center Lake watershed are the recreational uses of Center Lake and the surrounding Custer State Park. Stream bank and shoreline disturbance from foot and vehicle traffic increase soil erosion and runoff, thus increasing the sediment and nutrient loads. Pollution in the form of litter and human waste also increase nutrient loads. Additional bathroom facilities, waste receptacles, and fish-cleaning stations are recommended for the Center Lake recreational area. Stream bank and shoreline protection is also recommended to allow sediment and nutrient loads to be filtered and reduced before reaching the receiving waterbody.

Two tent campgrounds and a day-use picnic area are located in close proximity to Center Lake and its tributaries. Limited water services and disposal areas are provided to these areas. It is recommended that water and disposal services be provided to the camping and day-use areas to decrease the likelihood of improper gray-water and other waste disposal in these areas. Literature should be provided to campers or signs posted explaining the importance of proper disposal of their gray-water and other wastes. Additionally, use of phosphorus-free detergents should be encouraged, if not required, of all persons using the campgrounds and the day-use picnic area.

Among all forest activities, roads produce the most sediment. The number of roads constructed in a forested watershed can be minimized through comprehensive road planning with adjacent landowners and by designing roads to the minimum standard necessary to accommodate anticipated use and equipment. Road construction, maintenance and use in the Center Lake watershed have resulted in increased soil erosion and runoff, resulting in increased nutrient loads. It is recommended that all roadways near Center Lake and streams contributing to Center Lake be monitored for erosion and excess weathering. Identified erosional areas should be repaired or stabilized to prevent further erosion.

Septic systems may be another source of phosphorus in the Center Lake watershed. In close proximity to the lake, a drainfield and evapotranspiration field receiving wastewater from the Center Lake recreational areas may be leaching phosphorus. Cetec Engineering Services, Inc. was hired by the S.D. Game, Fish and Parks to analyze the Center Lake water and wastewater systems and suggest possible designs for system renovation. In their report, Cetec stated that the evapo-transpiration disposal system was constructed to replace the overloaded drainfield, however, the evapo-transpiration system has not functioned satisfactorily since construction, and most septic tank effluent is routed to the original drainfield for disposal. Loadings are closely monitored and diverted between the two systems as one or the other becomes overloaded (Cetec, 2004). It is strongly recommended that the water and sewer facilities be upgraded to eliminate substandard facilities, as well as to improve services to all Center Lake recreational areas.

As discussed earlier in this report, export coefficient values were used to make comparisons between subwatersheds represented by sites CLT-3, CLT-4 and the total watershed or site CLT-5. The inlet site (CLT-5) often exhibited higher export coefficient values than CLT-3 and CLT-4; in particular, solids and alkalinity were markedly higher. Total phosphorus export coefficient for CLT-5 was approximately two times higher than those at CLT-3 and CLT-4 (Figure 7). These higher export coefficient values for the inlet site appear to indicate a problem area exists in the portion of the watershed below CLT-3 and CLT-4. Implementation efforts should be focused on this lower subwatershed (CLT-5).

At the present time, Center Lake is not supporting of its beneficial uses as indicated by median chlorophyll and Secchi depth TSI values. The BATHTUB model estimated an approximate 70% reduction in watershed phosphorus loads would be required for Center Lake to meet the fishery-based TSI criterion and TMDL target (median chlorophyll and Secchi depth TSI ≤48). A 70% reduction in phosphorus loads is the TMDL goal and can be attained by implementing the above recommended management practices.

References Cited

Carlson, R.E. 1977. A trophic state index for lakes. *Limnology and Oceanography*. 22(2):361-369.

Carlson, R.E. and J. Simpson. 1996. *A Coordinator's Guide to Volunteer Lake Monitoring Methods*. North American Lake Management Society.

Dodds, Walter K. 2002. *Freshwater Ecology: Concepts and Environmental Applications*. Academic Press, San Diego, SC.

Eaton, A.D., L.S. Clesceri, and A.E. Geenberg (editors). 1995. *Standard Methods for the Examination of Water and Wastewater*, 19th Edition. American Public Health Association, Washington, D.C.

Hauer, R.F. and G.A. Lamberti. 1996. *Methods in Stream Ecology*. Academic Press, San Diego, CA.

Lind, Owen T., 1985. *Handbook of Common Methods used in Limnology*, 2nd Edition. Kendall/Hunt Publishing Company, Dubuque, IA.

Lorenzen, Paul B. 2005. *Targeting Impaired Lakes in South Dakota*. South Dakota Department of Environment and Natural Resources.

Monson, Bruce A. 2000. *A Primer on Limnology*, 2nd Edition. Water Resources Center, University of Minnesota, St. Paul, MN.

Ried G.K. 1961. *Ecology of inland waters and estuaries*. Van Nostrand Reinhold Co., New York.

South Dakota Department of Environment and Natural Resources (SDDENR). 2000. *The 2000 South Dakota Report to Congress*. SDDENR, Pierre, SD.

South Dakota Department of Environment and Natural Resources (SDDENR). 2002. *The 2002 South Dakota Report to Congress*. SDDENR, Pierre, SD.

South Dakota Department of Environment and Natural Resources (SDDENR). 2004. *The 2004 South Dakota Integrated Report for Surface Water Quality Assessment.* SD DENR, Pierre, SD.

South Dakota Department of Environment and Natural Resources (SDDENR). 2006. *The 2006 South Dakota Integrated Report for Surface Water Quality Assessment.* SD DENR, Pierre, SD.

Stueven, Eugene, Alan Wittmuss, and Robert Smith. 2000a. *Standard Operating Procedures for Field Samplers*. South Dakota Department of Environment and Natural Resources, Division of Financial and Technical Assistance, Pierre, SD.

Stueven, E.H., R.L. Smith, A.J. Repsys, and W.C. Stewart. 2000b. *Ecoregion Targeting for Impaired Lakes in South Dakota*. South Dakota Department of Environment and Natural Resources, Water Resource Assistance Program, Pierre, SD.

Stueven, E. and Stewart, W.C. 1996. *1995 South Dakota Lakes Assessment Final Report*. South Dakota Department of Environment and Natural Resources, Watershed Protection Program, Pierre, SD.

United States Army Corps of Engineers (US ACOE). 1999. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual*. US ACOE Waterways Experiment Station. Washington, D.C.

United States Environmental Protection Agency (USEPA). 1990. *Clean Lakes Program Guidance Manual*. EPA-44/4-90-006. Washington, D.C.

Wetzel, Robert G. 2001. *Limnology – Lake and River Ecosystems*, 3rd Edition. Academic Press, San Diego, CA.

Appendix A

Total Maximum Daily Load (TMDL) Summary

Center Lake Trophic State Total Maximum Daily Load

Waterbody Type:	Lake (Impoundment)
303(d) Listing Parameter:	Trophic State Index (TSI)
Designated Uses:	Recreation, Coldwater Permanent Fish Life Propagation Water
Size of Impaired Waterbody:	27 acres
Size of Watershed:	6,270 acres
Water Quality Standards:	Narrative and Numeric
Indicators:	Chlorophyll and Secchi depth TSI values
Analytical Approach:	Models including BATHTUB and FLUX
Location:	HUC Code: 10120109
Goal:	70% reduction of annual average phosphorus loads
Target:	Median chlorophyll and Secchi depth TSI ≤ 48

Objective

A TMDL establishes the total pollutant load a waterbody can receive and still achieve water quality standards. The components of a TMDL include a wasteload allocation (WLA) for point sources and a load allocation (LA) for non-point sources (including natural background) and a margin of safety (MOS) to account for uncertainty.

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

Introduction

Center Lake is a 27-acre impoundment located in the Grace Coolidge Creek basin in northern Custer County, South Dakota (Figure 1). The lake reaches a maximum depth of 40 feet (12 m) and holds a total water volume of 450 acre-ft. Portions of the lake exhibit thermal stratification during spring and summer months.

The 2006 South Dakota 303(d) Waterbody List identifies Center Lake as a high priority waterbody for TMDL development due to elevated trophic state index (TSI) and pH values. Information supporting this listing was derived from statewide lake assessment data.

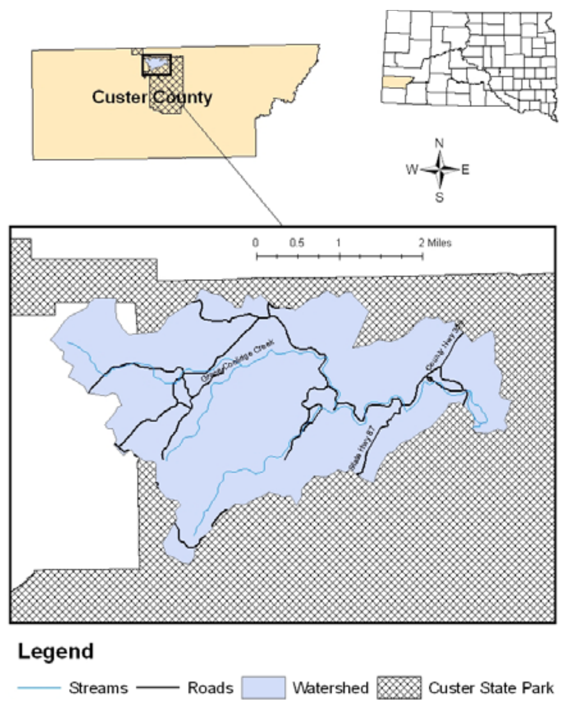


Figure A1. Location of Center Lake and watershed in Custer County, South Dakota.

Problem Identification

Center Lake watershed drains a watershed of 6,270 acres that predominantly consists of evergreen forest and state park camping areas. The streams carry nutrient loads, which at elevated levels, can degrade water quality in the lake and cause eutrophication. Based on the two-year assessment, an estimated 47.7 kg/year of phosphorus enter Center Lake from watershed runoff.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

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

- Coldwater permanent fish propagation
- Immersion recreation
- Limited contact recreation
- Fish and wildlife propagation, recreation and stock watering

Individual parameters, including the lake's trophic state, are used to determine the support of these beneficial uses.

Center Lake experiences phosphorus loading from its watershed, which has caused increased eutrophication. South Dakota has 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 identify impairment. To assess the trophic status of a lake, SD DENR uses metrics of the Trophic State Index or TSI (Carlson 1977). Chlorophyll and Secchi depth measurements are transformed based on regression models to provide a unit-less, standardized index value for both measures.

SD DENR has developed a protocol that establishes desired trophic levels for lakes based on the designated fishery use (Lorenzen, 2005). This protocol was used to assess impairment and determine a numeric target for Center Lake. Center Lake is designated a coldwater permanent fishery. The TSI criterion established for coldwater permanent fisheries is a median chlorophyll and Secchi depth TSI value ≤ 48.

Temperature, dissolved oxygen (DO) and pH criteria, established to support the coldwater permanent fish propagation beneficial use, were also violated during the study period. Approximately 30% of the temperature measurements were above the limit of 18.3° C (65° F), 25% of the DO measurements were below the minimum limit of 6 mg/L, and 40% of the pH measurements exceeded the upper pH limit of 8.6 standard units. However, this document addresses only the trophic state impairments of Center Lake. Temperature, pH, and DO TMDLs will be developed in the future.

Pollutant Assessment

Point Sources

There are no point source discharges of phosphorus in the watershed.

Nonpoint Sources

The source of phosphorus loading from the Center Lake watershed is a combination of septic system failure, recreational uses, vehicle traffic, as well as natural background sources (i.e. wildlife, weathering, etc.). However, degraded water quality in Center Lake is primarily attributed to recreational activity within the watershed. Approximately 90% of the watershed land area is managed by the SD Department of Game, Fish and Parks (Custer State Park), while the remaining 10% is managed by the US Forest Service. Although much of the watershed remains in its natural state, the intense usage of recreational facilities within Custer State Park has degraded the watershed condition.

Additional restroom facilities, waste receptacles, and fish-cleaning stations are recommended for the Center Lake recreational area to reduce the litter and human waste associated with the recreational use of Center Lake. Park managers should also consider alternative wastewater treatment options to replace or enhance the current septic system servicing the Center Lake recreational area.

Roadways near Center Lake and streams contributing to Center Lake should be inspected for erosion and excess weathering. Identified erosional areas should be repaired or stabilized to prevent further erosion. Stream bank and shoreline protection and enhancement are also recommended to allow sediment and nutrient loads to be filtered and reduced before reaching the lake.

Implementation of the management practices recommended above should result in a 70% reduction of the total phosphorus load to Center Lake, which is required to achieve the TMDL target of a median chlorophyll and Secchi depth TSI ≤48.

Linkage Analysis

Water quality data was collected at two lake sites and four stream sites, including the lake's inlet and outlet. 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 Energy Laboratories, Inc. in Rapid City, SD for analysis. Quality Assurance/Quality Control samples were collected on 10% of the samples according to South Dakota's EPA approved Non-point Source Quality Assurance/ Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed in the assessment final report.

Phosphorus export coefficients were calculated for each subwatershed and were used to define critical non-point source (NPS) pollution areas within the watershed (those with higher sediment and phosphorus loads). The CLT-5 subwatershed displayed higher solids (suspended and total) and phosphorus export coefficients than the CLT-3 or CLT-4 subwatersheds. When considering locations for implementation of BMPs to control erosion and nutrient runoff, the CLT-5 subwatershed should be given higher priority. See page 14 of the assessment report for details concerning the export coefficient analysis.

TMDL Allocations

Wasteload Allocation

There are no point source discharges of phosphorus in the watershed. Therefore, the wasteload allocation component of this TMDL is considered a zero value. The TMDL is considered wholly included within the load allocation component.

Load Allocation

According to BATHTUB model results, 70% reduction of watershed phosphorus loads is required to meet the phosphorus TMDL numeric target (i.e. chlorophyll and Secchi depth TSI ≤ 48). Current total phosphorus loads from the watershed are approximately 47.7 kg/yr. A 70% reduction of external phosphorus load to Center Lake may be achieved through the implementation of recommended BMPs, resulting in an annual load of approximately 14.3 kg (Table A1).

Table A1. Load allocation (kg/yr) summary for Center Lake.

TMDL Component	**Allocation (kg/year)**
Wasteload Allocation	0
Load Allocation	14.3
Margin of Safety	Implicit
TMDL	**14.3**

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and landuse. To determine seasonal differences, Center Lake sample data was graphed by month to facilitate viewing seasonal differences. Nearly all parameters assessed in this study displayed seasonal variation. For example, lake total phosphorus concentrations are lowest during the winter months and increase during the spring and summer to a fall maxima. In addition, watershed loading fluxes appear to be driven primarily by seasonal precipitation patterns. See the Annual Loading section of the final report (pg. 10-12).

Margin of Safety

The margin of safety for the phosphorus TMDL is implicit based on conservative estimations of lake model coefficients.

Critical Conditions

The trophic state impairment of Center Lake is most severe during late summer and early fall. This is the result of warm water temperatures and peak algal growth.

It is also important to note that the phosphorus TMDL load represents a measured load and may not represent the long term average load due to recent drought conditions.

Follow-Up Monitoring

Monitoring and evaluation efforts will be targeted toward 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.

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. This will be achieved through the Statewide Lake Assessment program.

Public Participation

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

1. Presentations to local groups on the findings of the Center Lake assessment.
2. 30-day public notice period for public review and comment.

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

Implementation Plan

Funds to implement lake and watershed water quality improvements can be obtained through the SD DENR. SD DENR administers three major funding programs that provide low interest loans and grants for projects that protect and improve water quality in South Dakota. They include: Consolidated Water Facilities Construction program, Clean Water State Revolving Fund (SRF) program, and the Section 319 Nonpoint Source Grants program.

This page intentionally left blank

Appendix B

Benthic Macroinvertebrate Data

Benthic Macroinvertebrates collected from Grace Coolidge Creek, SD.

				Site:	CLT	CLT	CLT	CLT	CLT	CLT
CLASS/ORDER	**FAMILY**	**FINAL DETERMINATION**	Tol. Value	FFG	3-A	3-B	3-C	5-A	5-B	5-C
Amphipoda	Gammaridae	*Gammarus* sp.	4	scavenger	0	0	0	3	0	0
Coleoptera	Elmidae	*Dubiraphia* sp.	6	collector	0	0	0	1	2	2
Coleoptera	Elmidae	*Optioservus* sp. (larvae)	4	scraper	0	41	22	16	34	9
Coleoptera	Elmidae	*Optioservus* sp. (adult)	4	scraper	0	1	4	0	3	0
Coleoptera	Elmidae	*Zaitzevia parvula* (larvae)	4	collector	2	5	5	13	59	3
Coleoptera	Elmidae	*Zaitzevia parvula* (adult)	4	collector	0	0	0	0	1	0
Diptera	Ceratopogonidae	Ceratopogoninae	6	predator	4	4	0	22	1	4
Diptera	Chironomidae	*Ablabesmyia* sp.	8	collector	0	0	0	0	1	14
Diptera	Chironomidae	*Chaetocladius* sp.	6	collector	0	0	0	1	0	0
Diptera	Chironomidae	*Cricotopus* sp.	7	shredder	0	1	0	1	3	0
Diptera	Chironomidae	*Cryptochironomus* sp.	8	predator	0	0	0	0	0	1
Diptera	Chironomidae	*Heterotrissocladius* sp.	4	collector	0	0	0	1	0	1
Diptera	Chironomidae	*Krenopelopia* sp.	unk.	predator	0	0	0	1	0	0
Diptera	Chironomidae	*Larsia* sp.	6	predator	110	85	0	0	0	0
Diptera	Chironomidae	*Micropsectra* sp.	4	collector	25	1	4	42	0	36
Diptera	Chironomidae	*Microtendipes pedellus* gp.	7	filterer	43	1	0	52	2	13
Diptera	Chironomidae	Orthocladiinae (immature)	6	collector	0	0	1	13	0	0
Diptera	Chironomidae	*Parametriocnemus* sp.	3	collector	0	0	1	2	2	1
Diptera	Chironomidae	*Pentaneura* sp.	6	predator	0	0	0	1	0	0
Diptera	Chironomidae	*Polypedilum* sp.	6	shredder	23	23	1	18	28	64
Diptera	Chironomidae	*Procladius* sp.	9	predator	6	1	0	1	0	18
Diptera	Chironomidae	*Radotanypus* sp.	6	collector	0	0	0	0	0	2
Diptera	Chironomidae	Tanypodinae (immature)	7	predator	0	0	14	4	0	3
Diptera	Chironomidae	*Thienemanniella* sp.	6	collector	0	0	0	0	1	0
Diptera	Chironomidae	*Thienemannimyia* gp.	6	predator	56	27	50	19	2	6
Diptera	Simuliidae	*Simulium* sp.	7	filterer	0	0	1	0	1	0
Diptera	Tabanidae	*Chrysops* sp.	7	collector	2	0	0	0	0	2
Diptera	Tipulidae	*Antocha* sp.	3	collector	0	0	0	0	2	0
Diptera	Tipulidae	*Hexatoma* sp.	4	predator	1	4	2	1	1	1
Diptera	Tipulidae	*Tipula* sp.	7	shredder	0	0	5	3	0	1
Ephemeroptera	Baetidae	Baetidae (imm./damaged)	4	collector	2	23	17	3	14	4
Ephemeroptera	Baetidae	*Baetis* sp.	5	collector	0	0	0	0	8	0
Ephemeroptera	Baetidae	*Paracloeodes minutus*	9	scraper	0	0	4	0	0	0
Ephemeroptera	Ephemerellidae	Ephemerellidae (imm.)	1	collector	0	1	0	0	1	0
Ephemeroptera	Leptohyphidae	*Tricorythodes* sp.	4	collector	0	0	0	2	0	11
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia* sp.	2	collector	4	20	50	11	11	8
Gastropoda	Ancylidae	*Ferrissia* sp.	7	scraper	0	0	0	3	3	0
Gastropoda	Planorbidae	*Gyraulus* sp.	8	scraper	0	0	4	10	0	8
Gastropoda	Physellidae	*Physella* sp.	8	scraper	2	2	18	2	2	0
Hirudinea	Glossiphoniidae	*Helobdella stagnalis*	8	predator	7	2	0	0	0	0
Megaloptera	Sialidae	*Sialis* sp.	4	predator	4	0	0	0	0	1
Odonata	Aeshnidae	*Anax* sp.	5	predator	0	2	0	0	0	0
Odonata	Corduliidae	*Epitheca (Tetragoneuria)* sp.	5	predator	1	0	0	0	0	0
Odonata	Gomphidae	Gomphidae (imm.)	1	predator	0	0	0	1	0	1
Odonata	Gomphidae	*Gomphus* sp.	5	predator	0	0	0	0	1	0
Odonata	Gomphidae	*Ophiogomphus* sp.	1	predator	0	0	0	1	0	0
Oligochaeta	Naididae	*Slavina appendiculata*	7	collector	0	0	0	0	1	0

				Site:	CLT	CLT	CLT	CLT	CLT	CLT
CLASS/ORDER	**FAMILY**	**FINAL DETERMINATION**	Tol. Value	FFG	3-A	3-B	3-C	5-A	5-B	5-C
Oligochaeta	Tubificidae	Tubificidae (imm. w/o cc)	10	collector	1	3	0	4	10	20
Oligochaeta	Tubificidae	Tubificidae (imm. w/ cc)	10	collector	1	0	0	0	0	0
Pelecypoda	Sphaeriidae	*Pisidium* sp.	8	filterer	0	0	0	0	0	4
Pelecypoda	Sphaeriidae	Sphaeriidae (imm.)	8	filterer	43	6	11	8	67	49
Plecoptera	Capniidae	*Paracapnia* sp.	1	shredder	2	4	27	0	3	0
Plecoptera	Chloroperlidae	Chloroperlidae (imm.)	1	predator	4	4	7	10	6	4
Plecoptera	Chloroperlidae	*Sweltsa* sp.	1	predator	3	4	29	2	5	4
Plecoptera	Nemouridae	*Zapada cinctipes*	2	shredder	0	12	6	0	5	0
Plecoptera	Perlodidae	*Skwala* sp.	2	predator	0	0	0	1	1	0
Trichoptera	NA	Trichoptera (imm.)	4	shredder	1	0	0	0	0	1
Trichoptera	Brachycentridae	*Brachycentrus* sp.	1	filterer	0	1	0	0	2	1
Trichoptera	Brachycentridae	*Micrasema* sp.	2	shredder	0	0	0	0	2	1
Trichoptera	Glossosomatidae	*Glossosoma* sp.	0	scraper	0	0	1	0	1	0
Trichoptera	Hydropsychidae	*Ceratopsyche morosa* gp. (imm.)	2	filterer	0	0	0	0	6	1
Trichoptera	Hydropsychidae	*Ceratopsyche slossonae*	4	filterer	0	11	1	0	3	0
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	5	filterer	0	9	2	0	28	0
Trichoptera	Hydropsychidae	*Hydropsyche* sp.	6	filterer	0	0	0	5	0	0
Trichoptera	Hydroptilidae	Hydroptilidae (partial pupa)	4	scraper	0	0	0	1	0	0
Trichoptera	Leptoceridae	Leptoceridae (immature)	4	collector	0	0	0	12	0	0
Trichoptera	Leptoceridae	*Mystacides* sp.	4	collector	0	0	0	4	3	0
Trichoptera	Leptoceridae	*Oecetis* sp.	8	predator	2	1	0	6	0	0
Trichoptera	Lepidostomatidae	*Lepidostoma* sp.	3	shredder	1	1	18	0	0	2
Trichoptera	Limnephilidae	*Limnephilus* sp.	3	shredder	2	0	2	0	0	0
Trichoptera	Polycentropodidae	*Polycentropus* sp.	5	predator	0	0	2	0	0	0
Trombidiformes		Acari	5	predator	0	0	2	10	2	0
				total:	**352**	**300**	**311**	**311**	**328**	**301**

Benthic Macroinvertebrate Metrics Analysis Results

	Metric 1	Metric 2	Metric 3	Metric 4	Metric 5	Metric 6
SITE	Taxa Richness	EPT Taxa	Ephemeroptera Taxa	Trichoptera Taxa	Plecoptera Taxa	Diptera Taxa
CLT 3-A	25	9	2	4	3	9
CLT 3-A (dup)	27	8	2	3	3	10
CLT 3-B	28	12	3	5	4	9
CLT 3-C	28	13	3	6	4	9
CLT 5-A	39	11	3	5	3	16
CLT 5-B	37	15	4	6	5	12
CLT 5-C	34	9	3	4	2	16

	Metric 7	Metric 8	Metric 9	Metric 10	Metric 11	Metric 12
SITE	Chironomidae Taxa	EPT Abund	Chiro Abund	EPT/Chiro Abundance	% EPT	% Ephemeroptera
CLT 3-A	6	21	263	0.08	5.97	1.70
CLT 3-A (dup)	7	25	244	0.10	7.84	1.25
CLT 3-B	7	91	139	0.65	30.33	14.67
CLT 3-C	6	166	71	2.34	53.38	22.83
CLT 5-A	13	57	156	0.37	18.33	5.14
CLT 5-B	8	97	41	2.37	29.57	10.37
CLT 5-C	12	36	160	0.23	11.96	7.64

	Metric 13	Metric 14	Metric 15	Metric 16	Metric 17	Metric 18
SITE	% Plecoptera	% Trichoptera	% Chironomidae	% Tanytarsini	% Diptera	% Non-Insects
CLT 3-A	2.56	1.70	74.72	0.00	76.70	15.34
CLT 3-A (dup)	4.08	2.51	76.49	0.00	78.37	10.34
CLT 3-B	8.00	7.67	46.33	0.00	49.00	4.33
CLT 3-C	22.19	8.36	22.83	0.00	25.40	11.25
CLT 5-A	4.18	9.00	50.16	0.00	58.52	12.86
CLT 5-B	6.10	13.11	12.50	0.00	14.02	25.91
CLT 5-C	2.66	1.66	53.16	0.00	55.81	26.91

	Metric 19	Metric 20			Metric 21	Metric 22
SITE	% Oligochaeta	ShanWeiner (e)	ShanWeiner (2)	ShanWeiner (10)	Intolerant Taxa	% Intolerant
CLT 3-A	0.57	2.23	3.22	0.97	6	4.55
CLT 3-A (dup)	0.63	2.36	3.40	1.02	6	5.96
CLT 3-B	1.00	2.51	3.62	1.09	8	15.67
CLT 3-C	0.00	2.71	3.91	1.18	9	45.34
CLT 5-A	1.29	3.02	4.36	1.31	7	9.00
CLT 5-B	3.35	2.69	3.88	1.17	13	14.33
CLT 5-C	6.64	2.72	3.93	1.18	9	7.64

SITE	Metric 23 No. Tolerant Taxa	Metric 24 % Tolerant Organisms	Metric 25 % Sediment Tolerant	Metric 26 % 1st Dominant	Metric 27 Hilsenhoff Biotic Index
CLT 3-A	7	28.41	77.27	31.25	6.07
CLT 3-A (dup)	8	31.03	81.19	24.76	5.97
CLT 3-B	7	5.00	49.33	28.33	4.84
CLT 3-C	7	18.33	30.87	16.08	3.99
CLT 5-A	11	30.23	61.09	16.72	5.37
CLT 5-B	9	27.44	17.99	20.43	5.12
CLT 5-C	11	44.19	63.46	21.26	6.24

SITE	Metric 28 Biotic Index	Metric 29 % Hydropsychidae/Trich.	Metric 30 Total Abundance	Extrap. Abundance	Metric 31 No. Predator Taxa
CLT 3-A	16	0.00	352	1,408	11
CLT 3-A (dup)	16	0.00	319	958	11
CLT 3-B	19	86.96	300	1,200	10
CLT 3-C	19	11.54	311	901	7
CLT 5-A	22	17.86	311	1,829	14
CLT 5-B	25	86.05	328	328	8
CLT 5-C	22	20.00	301	1,038	10

SITE	Metric 32 % Omnivore+Scavenger	Metric 33 % Gatherers+Filterers	Metric 34 % Gatherers	Metric 35 % Filterers	Metric 36 % Grazers+Scrapers
CLT 3-A	43.75	34.9	10.51	24.43	0.57
CLT 3-A (dup)	47.96	34.8	9.09	25.71	1.88
CLT 3-B	55.33	27.0	17.67	9.33	14.67
CLT 3-C	65.92	29.9	25.08	4.82	17.04
CLT 5-A	73.31	55.9	35.05	20.90	10.29
CLT 5-B	94.21	68.6	35.37	33.23	13.11
CLT 5-C	85.71	57.1	34.55	22.59	5.65

SITE	Metric 37 Scrapers / Filterers	Metric 38 %Scraper / (Scraper+Filterer)	Metric 39 % Predators	Metric 40 % Shredders	Metric 41 % Clingers
CLT 3-A	0	2.27	56.25	8.24	0.57
CLT 3-A (dup)	0	6.82	52.04	11.29	1.25
CLT 3-B	2	61.11	44.67	13.67	3.33
CLT 3-C	4	77.94	34.08	18.97	1.61
CLT 5-A	0	32.99	25.72	7.07	3.86
CLT 5-B	0	28.29	5.79	12.50	9.45
CLT 5-C	0	20.00	14.29	22.92	0.66

Appendix C

Lake Assessment Data

Center Lake Field Data

Station	Date	TALKA	TSOL	TDSOL	TSSOL	TKN	AMMO	NIT
CL1a	23-Aug-01	44	50	37	13	1.5	0.05	0.025
CL1a	26-Sep-01	46	70	67.5	2.5	0.9	0.05	0.025
CL1a	1-Nov-01	48	82	79.5	2.5	0.6	0.2	0.025
CL1a	27-Dec-01	50	76	73.5	2.5	0.6	0.05	0.025
CL1a	31-Jan-02	54	84	81.5	2.5	0.06	0.05	0.025
CL1a	27-Feb-02	44	62	59.5	2.5	0.25	0.05	0.025
CL1a	13-May-02	44	74	68	6	0.25	0.05	0.025
CL1a	6-Jun-02	42	76	73.5	2.5	0.5	0.05	0.025
CL1a	1-Jul-02	46	160	157.5	2.5	0.5	0.05	0.025
CL1a	5-Aug-02	46	58	55.5	2.5	0.8	0.05	0.025
CL1a	5-Aug-02	46	72	69.5	2.5	0.8	0.1	0.025

Station	Date	TALKA	TSOL	TDSOL	TSSOL	TKN	AMMO	NIT
CL1b	23-Aug-01	44	56	49	7	0.9	0.2	0.025
CL1b	26-Sep-01	46	78	75.5	2.5	0.6	0.1	0.025
CL1b	1-Nov-01	46	90	87.5	2.5	0.9	0.2	0.025
CL1b	27-Dec-01	52	78	72	6	0.8	0.05	0.05
CL1b	31-Jan-02	50	86	83.5	2.5	0.6	0.2	0.025
CL1b	27-Feb-02	50	78	75.5	2.5	0.6	0.1	0.025
CL1b	13-May-02	44	74	14	60	0.6	0.05	0.025
CL1b	6-Jun-02	44	47	44.5	2.5	0.25	0.05	0.025
CL1b	1-Jul-02	50	86	83.5	2.5	0.8	0.4	0.025
CL1b	5-Aug-02	50	69	64	5	1	0.6	0.025

Station	Date	TALKA	TSOL	TDSOL	TSSOL	TKN	AMMO	NIT
CL2a	23-Aug-01	46	82	68	14	1.5	0.05	0.025
CL2a	26-Sep-01	48	88	85.5	2.5	0.6	0.05	0.025
CL2a	1-Nov-01	48	88	85.5	2.5	0.6	0.2	0.025
CL2a	27-Dec-01	56	80	77.5	2.5	0.7	0.05	0.06
CL2a	31-Jan-02	48	94	91.5	2.5	0.6	0.05	0.025
CL2a	27-Feb-02	38	56	53.5	2.5	0.25	0.05	0.025
CL2a	13-May-02	46	68	58	10	0.25	0.05	0.025
CL2a	13-May-02	42	64	54	10	0.25	0.05	0.025
CL2a	6-Jun-02	30	80	77.5	2.5	0.5	0.05	0.025
CL2a	1-Jul-02	44	70	67.5	2.5	0.6	0.05	0.025
CL2a	5-Aug-02	46	78	73	5	0.7	0.05	0.025

Station	Date	TALKA	TSOL	TDSOL	TSSOL	TKN	AMMO	NIT
CL2b	23-Aug-01	48	82	74	8	1.2	0.05	0.025
CL2b	26-Sep-01	44	80	77.5	2.5	0.9	0.05	0.025
CL2b	1-Nov-01	48	84	81.5	2.5	0.9	0.2	0.025
CL2b	27-Dec-01	86	80	75	5	0.6	0.05	0.05
CL2b	31-Jan-02	50	88	85.5	2.5	0.9	0.05	0.025
CL2b	27-Feb-02	48	71	68.5	2.5	0.25	0.05	0.025
CL2b	13-May-02	46	72	26	46	0.25	0.05	0.025
CL2b	6-Jun-02	42	30	24	6	0.25	0.05	0.025
CL2b	1-Jul-02	46	96	82	14	1	0.05	0.025
CL2b	5-Aug-02	48	70	61	9	0.8	0.05	0.025

Center Lake Field Data

Station	Date	INORGNIT	ORGNIT	TOTNIT	TP	TDP
CL1a	23-Aug-01	0.075	1.45	1.525	0.05	0.03
CL1a	26-Sep-01	0.075	0.85	0.925	0.05	0.03
CL1a	1-Nov-01	0.225	0.4	0.625	0.03	0.01
CL1a	27-Dec-01	0.075	0.55	0.625	0.03	0.02
CL1a	31-Jan-02	0.075	0.01	0.085	0.03	0.005
CL1a	27-Feb-02	0.075	0.2	0.275	0.01	0.005
CL1a	13-May-02	0.075	0.2	0.275	0.02	0.02
CL1a	6-Jun-02	0.075	0.45	0.525	0.02	0.01
CL1a	1-Jul-02	0.075	0.45	0.525	0.03	0.005
CL1a	5-Aug-02	0.075	0.75	0.825	0.02	0.005
CL1a	5-Aug-02	0.125	0.7	0.825	0.02	0.005
Station	Date	INORGNIT	ORGNIT	TOTNIT	TP	TDP
CL1b	23-Aug-01	0.225	0.7	0.925	0.08	0.02
CL1b	26-Sep-01	0.125	0.5	0.625	0.05	0.02
CL1b	1-Nov-01	0.225	0.7	0.925	0.04	0.005
CL1b	27-Dec-01	0.1	0.75	0.85	0.04	0.01
CL1b	31-Jan-02	0.225	0.4	0.625	0.04	0.005
CL1b	27-Feb-02	0.125	0.5	0.625	0.03	0.005
CL1b	13-May-02	0.075	0.55	0.625	0.03	0.02
CL1b	6-Jun-02	0.075	0.2	0.275	0.03	0.005
CL1b	1-Jul-02	0.425	0.4	0.825	0.08	0.04
CL1b	5-Aug-02	0.625	0.4	1.025	0.06	0.005
Station	Date	INORGNIT	ORGNIT	TOTNIT	TP	TDP
CL2a	23-Aug-01	0.075	1.45	1.525	0.05	0.005
CL2a	26-Sep-01	0.075	0.55	0.625	0.06	0.02
CL2a	1-Nov-01	0.225	0.4	0.625	0.04	0.01
CL2a	27-Dec-01	0.11	0.65	0.76	0.03	0.02
CL2a	31-Jan-02	0.075	0.55	0.625	0.03	0.005
CL2a	27-Feb-02	0.075	0.2	0.275	0.01	0.005
CL2a	13-May-02	0.075	0.2	0.275	0.02	0.02
CL2a	13-May-02	0.075	0.2	0.275	0.03	0.03
CL2a	6-Jun-02	0.075	0.45	0.525	0.03	0.005
CL2a	1-Jul-02	0.075	0.55	0.625	0.03	0.005
CL2a	5-Aug-02	0.075	0.65	0.725	0.02	0.005
Station	Date	INORGNIT	ORGNIT	TOTNIT	TP	TDP
CL2b	23-Aug-01	0.075	1.15	1.225	0.06	0.03
CL2b	26-Sep-01	0.075	0.85	0.925	0.13	0.02
CL2b	1-Nov-01	0.225	0.7	0.925	0.04	0.01
CL2b	27-Dec-01	0.1	0.55	0.65	0.03	0.01
CL2b	31-Jan-02	0.075	0.85	0.925	0.04	0.005
CL2b	27-Feb-02	0.075	0.2	0.275	0.03	0.005
CL2b	13-May-02	0.075	0.2	0.275	0.04	0.02
CL2b	6-Jun-02	0.075	0.2	0.275	0.05	0.005
CL2b	1-Jul-02	0.075	0.95	1.025	0.05	0.005
CL2b	5-Aug-02	0.075	0.75	0.825	0.03	0.005

Parameter Abbreviations

ALKA = alkalinity
TSOL = total solids
TSSOL = total suspended solids
TDSOL = total dissolved solids
AMMO = ammonia
NIT = nitrate+nitrite
TKN = total Kjeldahl nitrogen

TOTNIT = total nitrogen
ORGNIT = organic nitrogen
INORGNIT = inorganic nitrogen
TP = total phosphorus
TDP = total dissolved phosphorus

NOTE: all data units are mg/L

Center Lake Physical and Fecal Coliform Data

Date:	Water Temp, C		DO, mg/L		pH, units		Conductivity		Fecal Coliforms, CFU/100ml	
	CL-1s	CL-1b	CL-1s	CL-1b	CL-1s	CL-1b	CL-1s	CL-1b	CL-1s	CL-1b
23-Aug-01	21.6	21.6	11.78	0.54	9.4	6.7	117.8	104.1	1	2
26-Sep-01	17	15.1	7.97	2.68	9.5	6.9	105.2	106.3	1	1
1-Nov-01	7.8	7.4	8.63	7.98	7.8	7.6	107.9	71.6	1	1
27-Dec-01	3.4	3.4	13.48	10.36	8.7	8.6	110.3	114.3	1	1
31-Jan-02	3.8	3.8	12.66	9.8	8.9	8.8	114.5	118.9	1	1
27-Feb-02	4.6	4.5	12.57	7.98	8.3	7.6	113.2	118.4	1	1
13-May-02	10.6	7.2	9.6	5.63	8.4	7.7	106.4	108.3	1	1
6-Jun-02	18.7	8.5	9.38	3.08	9.2	7.6	103.4	105.4	1	1
1-Jul-02	23.5	8.3	8.02	0.41	9.4	7.1	11.5	113.3	1	1
5-Aug-02	21.1	21.1	7.75	0.26	9.7	7.1	113.1	114.9	1	1

Date:	Water Temp, C		DO, mg/L		pH, units		Conductivity		Fecal Coliforms, CFU/100ml	
	CL-2s	CL-2b	CL-2s	CL-2b	CL-2s	CL-2b	CL-2s	CL-2b	CL-2s	CL-2b
23-Aug-01	21.7	20.5	11.68	5.42	9.3	8.8	116	105.6	1	2
26-Sep-01	18.5	16.2	7.8	8.04	9.3	8.4	105.4	104.1	1	1
1-Nov-01	7.6	7.4	8.5	8.33	7.9	7.8	107.8	108.1	1	1
27-Dec-01	3.8	4.3	13.25	13.2	8.6	8.6	111.8	113	1	1
31-Jan-02	4.1	4	13	13	8.9	8.9	115.4	115.6	1	1
27-Feb-02	4.6	4.3	12.71	12.43	8.3	8.2	113.5	114.4	1	1
13-May-02	11.4	10.3	9.46	9.43	8.4	8.4	105.6	106	1	1
6-Jun-02	18.8	15.6	9.41	8.42	9.1	8.5	103	102.4	1	2
1-Jul-02	24.1	23.8	7.68	7.81	9.5	9.3	110.7	11.8	1	1
5-Aug-02	21.2	21.4	7.54	5.67	9.7	9.3	113	113.2	1	14

Abbreviations:
S = Surface, B = Bottom
CFU/100ml = Colony forming units/100ml (fecal coliform bacteria)

Center Lake TSI Data

Measured TSI Data

Date:	Total Phosphorus CL1-s	CL1-b	Total Phosphorus CL2-s	CL2-b	Total Phosphorus Surface	Bottom	TP Avg Total P	Measured TP TSI
23-Aug-01	0.05	0.08	0.05	0.06	0.05	0.07	0.06	44.72
26-Sep-01	0.05	0.05	0.06	0.13	0.055	0.09	0.0725	41.99
1-Nov-01	0.03	0.04	0.04	0.04	0.035	0.04	0.0375	51.50
27-Dec-01	0.03	0.04	0.03	0.03	0.03	0.035	0.0325	53.56
31-Jan-02	0.03	0.04	0.03	0.04	0.03	0.04	0.035	52.49
27-Feb-02	0.01	0.03	0.01	0.03	0.01	0.03	0.02	60.56
13-May-02	0.02	0.03	0.02	0.04	0.02	0.035	0.0275	55.97
6-Jun-02	0.02	0.03	0.03	0.05	0.025	0.04	0.0325	53.56
1-Jul-02	0.03	0.08	0.03	0.05	0.03	0.065	0.0475	48.09
5-Aug-02	0.02	0.06	0.02	0.03	0.02	0.045	0.0325	53.56

Date:	Secchi Depth CL1-s	CL2-s	Secchi Depth Average	Measured Secchi TSI
23-Aug-01	0.75	0.75	0.75	64.15
26-Sep-01	0.75	2.5	1.625	53.00
1-Nov-01	0.75	2.5	1.625	53.00
27-Dec-01			0	60.00
31-Jan-02			0	60.00
27-Feb-02			0	60.00
13-May-02	3	3	3	44.17
6-Jun-02	1.75	1.75	1.75	51.94
1-Jul-02	2	2	1.875	50.94
5-Aug-02	1.5	1.5	1.75	51.94

BATHTUB Estimated TSI Data

% Reduction	0%		10%		20%		30%		40%		50%	
Variable	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
TOTAL P MG/M3	22.4	0.21	21.2	0.21	20.1	0.21	19.0	0.21	18.0	0.20	17.0	0.20
TOTAL N MG/M3	0.6	0.66	0.6	0.66	0.6	0.66	0.6	0.66	0.6	0.66	0.6	0.66
C.NUTRIENT MG/M3	0.8	0.00	0.8	0.00	0.8	0.00	0.8	0.00	0.8	0.00	0.8	0.00
CHL-A MG/M3	7.9	0.40	7.3	0.40	6.7	0.40	6.2	0.40	5.7	0.39	5.3	0.39
SECCHI M	3.6	0.31	3.8	0.30	4.0	0.29	4.2	0.29	4.5	0.28	4.7	0.27
ORGANIC N MG/M3	343.0	0.24	329.2	0.23	316.4	0.23	304.7	0.22	293.8	0.21	283.9	0.21
TP-ORTHO-P MG/M3	11.8	0.50	10.8	0.50	9.8	0.51	8.9	0.52	8.0	0.53	7.2	0.54
(N - 150) / P	0.4	0.21	0.5	0.21	0.5	0.21	0.5	0.21	0.6	0.21	0.6	0.21
INORGANIC N / P	0.1	0.40	0.1	0.38	0.1	0.35	0.1	0.33	0.1	0.31	0.1	0.29
TURBIDITY 1/M	0.1	0.20	0.1	0.20	0.1	0.20	0.1	0.20	0.1	0.20	0.1	0.20
ZMIX * TURBIDITY	0.6	0.23	0.6	0.23	0.6	0.23	0.6	0.23	0.6	0.23	0.6	0.23
ZMIX / SECCHI	2.2	0.33	2.1	0.32	2.0	0.32	1.9	0.31	1.8	0.30	1.7	0.30
CHL-A * SECCHI	28.5	0.16	27.8	0.17	27.1	0.17	26.4	0.18	25.7	0.19	24.9	0.19
CHL-A / TOTAL P	0.4	0.28	0.3	0.28	0.3	0.28	0.3	0.28	0.3	0.28	0.3	0.28
FREQ(CHL-a>10) %	24.5	0.83	20.6	0.89	17.1	0.95	14.1	1.01	11.4	1.08	9.1	1.14
FREQ(CHL-a>20) %	3.5	1.42	2.6	1.49	1.9	1.56	1.4	1.63	1.0	1.71	0.7	1.78
FREQ(CHL-a>30) %	0.7	1.81	0.5	1.88	0.3	1.95	0.2	2.02	0.1	2.10	0.1	2.17
FREQ(CHL-a>40) %	0.2	2.09	0.1	2.16	0.1	2.23	0.0	2.31	0.0	2.38	0.0	2.46
FREQ(CHL-a>50) %	0.1	2.31	0.0	2.38	0.0	2.46	0.0	2.53	0.0	2.61	0.0	2.68
FREQ(CHL-a>60) %	0.0	2.49	0.0	2.57	0.0	2.64	0.0	2.72	0.0	2.80	0.0	2.87
CARLSON TSI-P	49.0	0.06	48.2	0.06	47.4	0.06	46.6	0.06	45.8	0.06	45.0	0.07
CARLSON TSI-CHLA	50.9	0.08	50.1	0.08	49.3	0.08	48.5	0.08	47.7	0.08	47.0	0.08
CARLSON TSI-SEC	41.5	0.11	40.7	0.11	39.9	0.11	39.2	0.11	38.4	0.11	37.7	0.10

% Reduction	60%		70%		80%		90%		100%	
Variable	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
TOTAL P MG/M3	16.1	0.20	15.3	0.20	14.5	0.20	13.7	0.20	13.0	0.20
TOTAL N MG/M3	0.6	0.66	0.6	0.66	0.6	0.66	0.6	0.66	0.6	0.66
C.NUTRIENT MG/M3	0.8	0.00	0.8	0.00	0.8	0.00	0.8	0.00	0.8	0.00
CHL-A MG/M3	4.9	0.39	4.5	0.39	4.2	0.39	3.9	0.39	3.6	0.39
SECCHI M	4.9	0.27	5.2	0.26	5.4	0.26	5.7	0.25	5.9	0.25
ORGANIC N MG/M3	274.7	0.20	266.3	0.19	258.5	0.19	251.4	0.18	244.9	0.18
TP-ORTHO-P MG/M3	6.5	0.55	5.9	0.56	5.3	0.58	4.7	0.60	4.2	0.62
(N - 150) / P	0.6	0.20	0.7	0.20	0.7	0.20	0.7	0.20	0.8	0.20
INORGANIC N / P	0.1	0.28	0.1	0.26	0.1	0.25	0.1	0.24	0.1	0.23
TURBIDITY 1/M	0.1	0.20	0.1	0.20	0.1	0.20	0.1	0.20	0.1	0.20
ZMIX * TURBIDITY	0.6	0.23	0.6	0.23	0.6	0.23	0.6	0.23	0.6	0.23
ZMIX / SECCHI	1.6	0.29	1.5	0.29	1.5	0.28	1.4	0.28	1.4	0.27
CHL-A * SECCHI	24.2	0.20	23.4	0.21	22.7	0.21	21.9	0.22	21.2	0.23
CHL-A / TOTAL P	0.3	0.28	0.3	0.28	0.3	0.28	0.3	0.28	0.3	0.28
FREQ(CHL-a>10) %	7.2	1.21	5.6	1.28	4.3	1.34	3.3	1.41	2.5	1.48
FREQ(CHL-a>20) %	0.5	1.85	0.3	1.92	0.2	1.99	0.2	2.06	0.1	2.13
FREQ(CHL-a>30) %	0.1	2.24	0.0	2.32	0.0	2.39	0.0	2.46	0.0	2.54
FREQ(CHL-a>40) %	0.0	2.53	0.0	2.61	0.0	2.68	0.0	2.76	0.0	2.83
FREQ(CHL-a>50) %	0.0	2.76	0.0	2.83	0.0	2.91	0.0	2.99	0.0	3.06
FREQ(CHL-a>60) %	0.0	2.95	0.0	3.02	0.0	3.10	0.0	3.18	0.0	3.25
CARLSON TSI-P	44.2	0.07	43.5	0.07	42.7	0.07	41.9	0.07	41.1	0.07
CARLSON TSI-CHLA	46.2	0.08	45.4	0.08	44.7	0.09	43.9	0.09	43.1	0.09
CARLSON TSI-SEC	37.0	0.10	36.3	0.10	35.7	0.10	35.0	0.10	34.4	0.10

Parameter Abbreviations

TOT CHL = total chlorophyll (mg/cm^3)
CHL A = chlorophyll *a* (mg/cm^3)
TP TSI = phosphorus trophic state index
CHL TSI = chlorophyll trophic state index
SEC TSI = secchi depth trophic state index
MEAN TSI = mean trophic state index

Appendix D

Tributary Assessment Data

Tributary Field Data, Center Lake

Station	Date	FLOW	ALKA	TSOL	TDS	TSS	TKN	AMMO
CLT3	23-Aug-01	0.023	40	66	63.5	2.5	0.25	0.05
CLT3	27-Sep-01	0.063	40	60	57.5	2.5	0.25	0.05
CLT3	10-Oct-01	0.108	38	74	71.5	2.5	0.25	0.05
CLT3	31-Oct-01	0.036	38	80	77.5	2.5	0.25	0.05
CLT3	18-Apr-02	0.115	28	59	56.5	2.5	0.25	0.05
CLT3	23-Apr-02	0.12	26	76	73.5	2.5	0.25	0.05
CLT3	02-May-02	0.14	30	78	75.5	2.5	0.25	0.05
CLT3	26-Jun-02	0.05	38	76	73.5	2.5	0.25	0.05
CLT3	21-Jul-02	0.54	34	96	91	5	0.7	0.05
CLT3	12-Aug-02	0.28	40	70	67.5	2.5	0.25	0.05
CLT4	23-Aug-01	0.008	24	56	48	8	0.25	0.05
CLT4	27-Sep-01	0.009	22	48	45.5	2.5	0.25	0.05
CLT4	10-Oct-01	0.036	22	50	47.5	2.5	0.25	0.05
CLT4	31-Oct-01	0.03	22	66	63.5	2.5	0.25	0.05
CLT4	18-Apr-02	0.19	18	45	42.5	2.5	0.25	0.05
CLT4	23-Apr-02	0.18	16	63	60.5	2.5	0.6	0.05
CLT4	02-May-02	0.23	16	94	91.5	2.5	0.25	0.05
CLT4	26-Jun-02	0.035	22	51	48.5	2.5	0.25	0.05
CLT4	21-Jul-02	0.03	24	64	61.5	2.5	0.25	0.05
CLT4	12-Aug-02	0.02	22	32	29.5	2.5	0.25	0.05
CLT5	23-Aug-01	0.543	48	74	71.5	2.5	0.25	0.05
CLT5	27-Sep-01	0.5	52	78	75.5	2.5	0.25	0.05
CLT5	10-Oct-01	0.67	52	78	75.5	2.5	0.25	0.05
CLT5	31-Oct-01	0.53	46	84	81.5	2.5	0.25	0.05
CLT5	18-Apr-02	0.77	50	78	73	5	0.25	0.05
CLT5	23-Apr-02	0.6	38	73	64	9	0.25	0.05
CLT5	02-May-02	0.5	62	86	83.5	2.5	0.25	0.05
CLT5	26-Jun-02	0.25	34	76	73.5	2.5	0.25	0.05
CLT5	21-Jul-02	0.65	48	81	78.5	2.5	0.25	0.05
CLT5	12-Aug-02	1.3	52	100	88	12	0.25	0.05
CLO6	23-Aug-01	0.37	58	70	65	5	0.25	0.1
CLO6	26-Sep-01	0.6	62	94	91.5	2.5	0.6	0.1
CLO6	18-Apr-02	0.45	50	74	71.5	2.5	0.25	0.05
CLO6	23-Apr-02	0.38	20	100	91	9	0.25	0.05
CLO6	02-May-02	0.58	48	68	65.5	2.5	0.25	0.05
CLO6	26-Jun-02	0.39	58	84	81.5	2.5	0.25	0.05
CLO6	21-Jul-02	0.53	54	94	86	8	0.5	0.1
CLO6	12-Aug-02	0.21	76	86	83.5	2.5	0.25	0.2

Tributary Field Data, Center Lake

Station	Date	NIT	INIT	ONIT	TNIT	TP	TDP
CLT3	23-Aug-01	0.025	0.075	0.2	0.275	0.06	0.06
CLT3	27-Sep-01	0.025	0.075	0.2	0.275	0.06	0.05
CLT3	10-Oct-01	0.025	0.075	0.2	0.275	0.07	0.05
CLT3	31-Oct-01	0.025	0.075	0.2	0.275	0.06	0.03
CLT3	18-Apr-02	0.49	0.54	0.2	0.74	0.13	0.07
CLT3	23-Apr-02	0.025	0.075	0.2	0.275	0.04	0.02
CLT3	02-May-02	0.025	0.075	0.2	0.275	0.04	0.01
CLT3	26-Jun-02	0.025	0.075	0.2	0.275	0.05	0.05
CLT3	21-Jul-02	0.025	0.075	0.65	0.725	0.13	0.09
CLT3	12-Aug-02	0.025	0.075	0.2	0.275	0.04	0.03
CLT4	23-Aug-01	0.025	0.075	0.3	0.375	0.1	0.05
CLT4	27-Sep-01	0.025	0.075	0.3	0.375	0.09	0.07
CLT4	10-Oct-01	0.025	0.075	0.3	0.375	0.09	0.07
CLT4	31-Oct-01	0.025	0.075	0.3	0.375	0.1	0.06
CLT4	18-Apr-02	0.025	0.075	0.3	0.375	0.12	0.07
CLT4	23-Apr-02	0.025	0.075	0.65	0.725	0.05	0.03
CLT4	02-May-02	0.025	0.075	0.3	0.375	0.05	0.02
CLT4	26-Jun-02	0.025	0.075	0.3	0.375	0.05	0.05
CLT4	21-Jul-02	0.06	0.11	0.3	0.41	0.1	0.08
CLT4	12-Aug-02	0.025	0.075	0.3	0.375	0.05	0.04
CLT5	23-Aug-01	0.025	0.075	0.2	0.275	0.1	0.06
CLT5	27-Sep-01	0.025	0.075	0.2	0.275	0.09	0.07
CLT5	10-Oct-01	0.025	0.075	0.2	0.275	0.07	0.07
CLT5	31-Oct-01	0.025	0.075	0.2	0.275	0.15	0.12
CLT5	18-Apr-02	0.025	0.075	0.2	0.275	0.06	0.04
CLT5	23-Apr-02	0.025	0.075	0.2	0.275	0.1	0.08
CLT5	02-May-02	0.025	0.075	0.2	0.275	0.04	0.04
CLT5	26-Jun-02	0.025	0.075	0.2	0.275	0.03	0.02
CLT5	21-Jul-02	0.025	0.075	0.2	0.275	0.1	0.08
CLT5	12-Aug-02	0.025	0.075	0.2	0.275	0.12	0.08
CLO6	23-Aug-01	0.09	0.19	0.15	0.34	0.19	0.08
CLO6	26-Sep-01	0.07	0.17	0.5	0.67	0.17	0.07
CLO6	18-Apr-02	0.05	0.1	0.2	0.3	0.14	0.11
CLO6	23-Apr-02	0.025	0.075	0.2	0.275	0.12	0.04
CLO6	02-May-02	0.025	0.075	0.2	0.275	0.07	0
CLO6	26-Jun-02	0.11	0.16	0.2	0.36	0.28	0.07
CLO6	21-Jul-02	0.55	0.65	0.4	1.05	0.19	0.05
CLO6	12-Aug-02	0.025	0.225	0.05	0.275	0.15	0.06

Parameter Abbreviations

ALKA = alkalinity
TSOL = total solids
TSS = total suspended solids
TDS = total dissolved solids
TP = total phosphorus
TDP = total dissolved phosphorus
AMMO = ammonia
NIT = nitrate + nitrite
TKN = total Kjeldahl nitrogen
INIT = inorganic nitrogen
ONIT = organic nitrogen
TNIT = total nitrogen

Tributary Data, Physical parameters

	Water Temperature, C				DO, mg/L			
Date	CLT-3	CLT-4	CLT-5	CLO-6	CLT-3	CLT-4	CLT-5	CLO-6
23-Aug-01	16.4	14.8	17.5	17.3	9.06	8.25	8.1	5.28
26-Sep-02	9.6	8.2	14.2	13.3	9.95	9.94	8.37	5.28
10-Oct-01	7.1	6.6	7.8		11.1	10.63	10.1	
31-Oct-01	8.4	8.3	9.2		9.78	9.19	8.9	
18-Apr-02	4.2	4.5	9.2	8.15	9.91	10.19	8.9	10.6
23-Apr-02	7.7	7.4	12.1	12	9.18	8.7	7.9	7.32
2-May-02	3.3	4.8	5.2	9.5	10.94	10.05	10.43	7.78
26-Jun-02	18.2	16	19.1	20.1	7.67	7.94	7.13	5.17
21-Jul-02	17.3	14.9	17.9	18.2	6.15	5.66	5.96	4.7
12-Aug-02	13	12.2	13.4	13.6	8.15	8.46	7.8	5.34

	pH, standard units				Conductivity, umhos/cm			
Date	CLT-3	CLT-4	CLT-5	CLO-6	CLT-3	CLT-4	CLT-5	CLO-6
23-Aug-01	7.3	7.4	7	7.1	90.6	54	111.9	126.3
26-Sep-02	7.6	7.1	11.8	12.4	93.9	58.1	117.4	134.8
10-Oct-01	7.5	7	7.3		94.8	56.7	109.8	
31-Oct-01	7.7	7.6	7.8		88.6	53.9	115.6	
18-Apr-02	7.6	7.7	7.9	7.7	50.1	79.8	95.5	115.1
23-Apr-02	7.7	7.6	8	7.7	77.1	48.7	94.3	118.8
2-May-02	7.9	7.8	8.1	7.9	80.2	48.2	87.3	114
26-Jun-02	7.8	7.7	7.8	7.6	29.8	53.9	108.2	131.5
21-Jul-02	8.2	8.1	8.2	8.2	86.9	63.1	113.8	130.6
12-Aug-02	8	8.3	8	7.6	88.4	54.6	130	157.6

Tributary Data, Fecal Coliform Bacteria, CFU/100ml

Sample Date:	CLT-3	CLT-4	CLT-5	CLO-6
23-Aug-01	10	6	38	64
27-Sep-01	3	2	56	7
10-Oct-01	8	2	48	
31-Oct-01	14	1	10	
18-Apr-02	1	1	7	1
23-Apr-02	1	1	1	1
2-May-02	1	1	1	1
26-Jun-02	12	44	12	18
21-Jul-02	2000	1000	62	490
12-Aug-02	24	16	1700	4

Appendix E

Center Lake Fishery Survey Report
Prepared by South Dakota Department of Game, Fish, and Parks

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102 - F21-R-28

Name: Center County(ies): Custer
Legal description: T3S, R6E, Sec.8&9

Location from nearest town: 8E, 3N, 1/2E Custer
(Custer State Park)

Dates of present survey: 18-19 October 1994
Date last surveyed: 5-6 August 1980
Most recent lake management plan: F-21-R-26 Date: 1992
Management classification: Coldwater Permanent
Contour mapped: Yes Date: 1987

Primary Species: (game and forage)
1. Hatchery Rainbow Trout
2. Brook Trout
3. Creek Chub
4. Fathead Minnow
5.
6.
7.
8.
9.

Secondary and other species:
1. White Sucker
2.
3.
4.
5.
6.
7.
8.
9.

PHYSICAL CHARACTERISTICS

Surface Area: 26.5 ac. (10.7 ha.); Watershed: 4,992 ac. (2,021.8 ha.)
Maximum depth: 40 ft. (12.2 m); Mean depth: 17 ft. (5.2 m)
Lake elevation at survey (from known benchmark): 4,636 ft. (1,413 m)

1. Describe ownership of lake and adjacent lakeshore property:

The Parks Division of the South Dakota Game, Fish and Parks (SDGFP) owns and maintains the lake and adjacent shoreline.

2. Describe watershed condition and percentages of land use:

The watershed above Center Lake is primarily public timberland administered by SDGFP. A small portion of the upper end of the watershed lies outside Custer State Park boundaries and is administered by the U. S. Forest Service. A campground, private cabins and a summer theater are located immediately above the lake. A swimming beach is located on the southwest shoreline. Grace Coolidge Creek, a tributary of Battle Creek, is the main water source for Center Lake. A walk in fishery is located downstream on Grace Coolidge Creek and its associated lowhead dams.

3. Describe aquatic vegetative condition:

Emergent vegetation in the form of cattail and bulrush exists in the inlet region. Submergent forms are evident in littoral areas along much of the shoreline excluding the spillway area.

4. Describe pollution problems:

Moderate pollution and sedimentation likely occurs due to camping activities and adjacent roads. Some silt was removed in 1973 after drawing down the reservoir level prior to nongame fish eradication. The construction of a hard surfaced road and camping pads in 1973-1974 appear to have lessened the impacts of erosion.

5. Describe condition of all structures, i.e. spillway, level regulators, boatramps, etc.:

Center Lake was constructed in the 1930s by the Civilian Conservation Corps. The dam and spillway appear to be structurally sound. The control structure was repaired in 1965 after a draw down prior to fish eradication. Custer State Park officials may have records of recent inspections. One improved boat ramp and dock exist on the north shore.

CHEMICAL DATA

1. Describe general water quality characteristics:

Conductivity of water in Center Lake was quite low at 78 umhos/cm³. Low conductivity values are common in this region where waters originate in granitic substrate. Dissolved oxygen was supersaturated at the surface on the survey date. No hypolimnetic samples were taken to determine if oxygen was lacking in that region of the water column. Low water clarity indicated a moderate algae bloom.

2. Thermocline: Yes __ No _X_; location from surface _NA_ ft.

Slightly over three degrees centigrade existed between the surface and bottom. Most waters in this region undergo thermal mixing at this time of year.

3. Secchi disc reading: _3.9 ft. (1.2 m)_

4. Stations for water chemistry located on attached lake map: Yes _X_ No _

See Figure 1.

Table 1. Water chemistry results from Center Lake, Custer County, 18 October 1994.

Depth Meters	Temp °C	pH	DO ppm	Conductivity umhos/cm³
0 (Surface)	10.1	7.8	10.0	78
2	9.9			
4	9.9			

6	9.9
8	9.0
10	8.3
11 (Bottom)	7.0

BIOLOGICAL DATA

1. Describe fish collection methods:

The following gear types were used to collect fish:

2 (24 hr) baby frame net sets, (1) at 1/2" and (1) at 1/4" mesh.
3 (24 hr) large frame net sets with 3/4" mesh and 75 ft. leads.
2 (1/4 arc) seine hauls with 100' seine.

Table 2. Total catch of two, 24 hour baby frame net sets at Center Lake, Custer County, 19 October 1994.

Species	Total Number	%	Total Weight (grams)	%	Mean Weight (grams)	Mean Length (mm)	Catch per Effort
Brook Trout	2	25.0	50	6.6	25.0	144	1.0
Hatch. Rainbow	1	12.5	154	20.3	154.0	269	0.5
Creek Chub	1	12.5	71	9.4	71.0	192	0.5
Fathead Minnow	2	25.0	3	0.4	1.5	56	1.0
White Sucker	2	25.0	480	63.3	240.0	232	1.0
Totals	8	100.0	758	100.0			

Table 3. Total catch of three, 24 hour large frame net sets at Center Lake, Custer County, 19 October 1994.

Species	Total Number	%	Total Weight (grams)	%	Mean Weight (grams)	Mean Length (mm)	Catch per Effort
Hatch. Rainbow	59	75.6	4,932	69.9	*123.3	246.2	19.67
Brook Trout	8	10.3	NA	NA	NA	225.0	2.67
White Sucker	11	14.1	2,125	30.1	**212.5	272.2	3.67
Totals	78	100.0	7,057	100.0			

* based on a 40 fish sample
** based on a 10 fish sample

Table 4. Total catch of two, quarter arc seine hauls at Center Lake, Custer County, 19 October 1994.

Species	Young of Year	Age 1 or Older	Total Number Caught	% of Total	Catch per Unit Effort (CPUE)
Hatch. Rainbow	0	7	7	43.75	3.5
Brook Trout	0	5	5	31.25	2.5
Fathead Minnow	1	2	3	18.75	1.5
White Sucker	0	1	1	6.25	0.5
Totals	1	15	16	100.00	

2. Brief narrative describing status of fish sampled.

Center lake was last rehabilitated in 1973 due to an overabundance of white sucker. Currently, the Lake is managed exclusively as a rainbow trout fishery by the stocking of approximately 8,400 catchables annually (APPENDIX Table 1). Occasional plants of adult, post-spawn rainbow trout brood stock are also planted in Center Lake. In addition, one plant of 60 adult brown trout was recorded in 1991. Brook trout inhabit the lake as well, originating from Grace Coolidge Creek.

Hatchery rainbow trout were most abundant in the test netting, accounting for slightly over 65 percent of the total catch. Brook trout comprised the remainder of the sportfish catch at approximately 15 percent. Mean total lengths were 225.0 mm and 246.2 mm, respectively, for brook and rainbow trout (Table 3).

Fourteen age 1 or older white sucker were collected, ranging in size from 135-352 mm. A mean total length of 272.2 mm was calculated for those individuals collected by large frame nets (Table 3). No YOY white sucker were sampled.

Numerous YOY cyprinids were observed along the shoreline on the survey dates, although gear types were ineffective in capturing these fishes. Two cyprinid species, represented by five fathead minnow and one creek chub were sampled. One fathead was YOY, while all other cyprinids were estimated to be age 1 or older (Table 4).

Length-frequencies for brook trout, hatchery rainbow trout, fathead minnow and white sucker are presented in APPENDIX Figures 2-5.

RECOMMENDATIONS

1. Continue stocking rainbow catchables at a rate of 8,400 annually in six plants from April-August.

2. Evaluate data from 1994-1995 Black Hills Angler Use and Preference Study to determine if an adjustment to stocking is necessary.

2. Survey again in 1998 to monitor size of white sucker population.

APPENDIX

Table 1. Stocking record for Center Lake, Custer County, 1984-1993.

Species	Year	Number	Size
Rainbow Trout	1984	9,300	Catchable
Rainbow Trout	1985	8,400	Catchable
Rainbow Trout	1986	160	Adult
Rainbow Trout	1986	8,400	Catchable
Rainbow Trout	1987	42	Adult
Rainbow Trout	1987	9,435	Catchable
Rainbow Trout	1988	10,400	Catchable
Rainbow Trout	1988	8,500	Fingerling
Rainbow Trout	1989	500	Adult
Rainbow Trout	1989	8,403	Catchable
Rainbow Trout	1990	200	Adult
Rainbow Trout	1990	8,400	Catchable
Brown Trout	1991	60	Adult
Rainbow Trout	1991	140	Adult
Rainbow Trout	1991	9,540	Catchable
Rainbow Trout	1992	270	Adult
Rainbow Trout	1992	8,400	Catchable
Rainbow Trout	1993	8,400	Catchable

Appendix F

Quality Assurance/Quality Control (QA/QC) Data

QA/QC data for duplicate sample pairs

Site	Date	Depth	Type	Fecal	Alka	Cond	TSol	TSS	Amm	Un-Amm	Nit	TKN	TDP	TP
CLT-3	31-Oct-01	S	Rep	14	38	90	80	2.5	<0.1	<0.1	<0.05	<0.5	0.03	0.06
CLT-3	31-Oct-01	S	Dup	12	34	91	74	2.5	<0.1	<0.1	<0.05	0.6	0.03	0.06
Percent Difference:				7.7%	5.5%	0.5%	3.9%	0.0%	0.0%	0.0%	0.0%	9.1%	0.0%	0.0%
CLT-3	18-Apr-02	S	Rep	<2	28	82	59	2.5	<0.1	<0.1	0.49	<0.5	0.07	0.13
CLT-3	18-Apr-02	S	Dup	<2	30	79	70	2.5	<0.1	<0.1	<0.05	<0.5	0.12	0.13
Percent Difference:				0.0%	3.4%	1.9%	8.5%	0.0%	0.0%	0.0%	81.5%	0.0%	26.3%	0.0%
CLT-3	2-May-02	S	Rep	<2	30	82	78	2.5	<0.1	<0.1	<0.05	<0.5	0.01	0.04
CLT-3	2-May-02	S	Dup	<2	26	84	83	2.5	<0.1	<0.1	<0.05	<0.5	0.01	0.05
Percent Difference:				0.0%	7.1%	1.2%	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.1%
CLT-5	23-Aug-01	S	Rep	38	48	105	74	2.5	<0.1	<0.1	<0.05	<0.5	0.06	0.1
CLT-5	23-Aug-01	S	Dup	56	58	126	88	2.5	<0.1	<0.1	<0.05	<0.5	0.04	0.06
Percent Difference:				19.1%	9.4%	9.1%	8.6%	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	25.0%
CL-2	13-May-02	S	Rep	<2	46	104	68	10	<0.1	<0.1	<0.05	<0.5	0.02	0.02
CL-2	13-May-02	S	Dup	<2	42	104	64	10	<0.1	<0.1	<0.05	<0.5	0.03	0.03
Percent Difference:				0.0%	4.5%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	20.0%

Appendix G

Response to Comments

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Center Lake**
Submitted by:	**Gene Stueven, SD DENR**
Date Received:	**March 20, 2007**
Review Date:	**April 27, 2007**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Informal – Public notice**

This document provides a standard format for EPA Region 8 to provide comments to the South Dakota Department of Environment and Natural Resources on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 12 review criteria:

1. Water Quality Impairment Status
2. Water Quality Standards
3. Water Quality Targets
4. Significant Sources
5. Technical Analysis
6. Margin of Safety and Seasonality
7. Total Maximum Daily Load
8. Allocation
9. Public Participation
10. Monitoring Strategy
11. Restoration Strategy
12. Endangered Species Act Compliance

Each of the 12 review criteria are described below to provide the rational for the review, followed by EPA's comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Water Quality Impairment Status

Criterion Description – Water Quality Impairment Status
TMDL documents must include a description of the listed water quality impairments. While the 303(d) list identifies probable causes and sources of water quality impairments, the information contained in the 303(d) list is generally not sufficiently detailed to provide the reader with an adequate understanding of the impairments. TMDL documents should include a thorough description/summary of all available water quality data such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and/or appropriate water quality standards.

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☒ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Center Lake is a 27 acre man-make impoundment located in the Cheyenne River basin, Middle Cheyenne-Spring sub-basin, Custer County, South Dakota. It is listed on SD's 2006 303(d) list as impaired for trophic state index (TSI) and pH due to nonpoint sources and is ranked as priority 1 (i.e., high priority) for TMDL development. The watershed is approximately 6,270 acres and drains predominantly forested land which is heavy used for recreational activities. The mean TSI during the period of the project assessment was 50, and is not currently meeting its designated beneficial use for coldwater permanent fish life propagation. Data collected during the assessment show that Center Lake is also impaired for dissolved oxygen and temperature. The document only addresses the TSI impairment of Center Lake. Temperature, pH and dissolved oxygen TMDLs will be developed in the future.

COMMENTS – It is not clear from the nitrogen section (pp. 57-59, Figure 32) whether the ammonia concentration data collected during the assessment exceed the applicable water quality standard. Please clarify.

RESPONSE – The following paragraph was added to p. 57: "State water quality standards contain total ammonia criteria for the protection of waters classified as fisheries. This criterion is dependent on the pH of the water sample at the time the sample was collected. All ammonia samples were evaluated using the criteria shown in Table 3, and no samples exceeded the total ammonia criteria."

2. Water Quality Standards

Criterion Description – Water Quality Standards
The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Center Lake is impaired for dissolved oxygen, pH, temperature and TSI. TSI is a surrogate measure used to determine whether the narrative standards are being met. South Dakota has applicable narrative standards that may be applied to the undesirable eutrophication of lakes. Data from Center Lake indicates problems with nutrient enrichment and nuisance algal blooms, which are typical signs of the eutrophication process. The narrative standards being implemented in this TMDL are:

> "*Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair a beneficial use or create a human health problem.*" (See ARSD §74:51:01:09)

> "*All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*" (See ARSD §74:51:01:12)

The Center Lake impairments of pH, dissolved oxygen and temperature will be addressed in a future TMDL document.

Other applicable water quality standards are included in the water quality standards section of the assessment report. See pages 3 – 5.

3. Water Quality Targets

Criterion Description – Water Quality Targets

Quantified targets or endpoints must be provided to address each listed pollutant/water body combination. Target values must represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the TMDL target. For pollutants with narrative standards, the narrative standard must be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of

☒ Satisfies Criterion

☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In June 2005, SD DENR published *Targeting Impaired Lakes in South Dakota*. This document proposed targeted median growing season Secchi disk/chlorophyll *a* Trophic State Index (TSI) values for each beneficial use designation category. Using this approach the coldwater permanent fish life median chlorophyll-a and Secchi disk TSI target is ≤ 48.

In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met.

The overall mean TSI for Center Lake during the period of the assessment was 50. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 70% or more reduction in the total phosphorous loading from the watershed would is necessary to meet the beneficial use-based beneficial use TSI target of 48 or less.

The proposed water quality target for this TMDL is: **maintain a median annual TSI (Chl-*a*/SD) at or below 48.0**.

4. Significant Sources

Criterion Description – Significant Sources

TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☒ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL identifies the major sources of phosphorous as coming from nonpoint sources within the watershed. The watershed is approximately 6,270 acres and drains predominantly forested land which is heavy used for recreational activities. The watershed is used by tourists and campers with few permanent residents. Sources of phosphorous most likely affecting Center Lake include: 1) recreational activities resulting in bank and shoreline disturbance; 2) detergents contained in grey-water; 3) road maintenance and use; and 4) septic systems. There are no point sources of phosphorous of concern in the watershed.

COMMENTS – The statement on page 77 says "There are no point sources of pollutants of concern in this watershed." Does that mean there are point sources contributing phosphorous upstream of Center Lake? If so, what are the wasteload allocations from each facility? Why are they not concerns?

This TMDL and all future TMDLs should address point sources directly by: 1) listing all permitted point sources that cause or contribute to the impairment(s) addressed in the TMDL; 2) include the wasteload allocations from these point sources in the TMDL; and 3) include a more detailed explanation of how these loads will/will not be reduced as indicated in the TMDL (including why they are not significant sources if applicable). If there are no permitted point sources in the watershed we recommend a statement similar to "There are no point source discharges of [insert pollutant(s)] in the watershed."

RESPONSE – Throughout the report, the statement "There are no point sources of pollutants of concern in this watershed" was replaced with the following statement: "There are no point source discharges of phosphorus in the watershed."

5. Technical Analysis

Criterion Description – Technical Analysis

*TMDLs must be supported by an appropriate level of technical analysis. It applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of technical analysis.*

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 70% reduction in average annual total phosphorous loads to Center Lake. Using the loads measured during the period of the assessment the total phosphorous load should be 14.3 kg/yr to achieve the desired TSI target. This reduction is based in large part on the BATHTUB mathematical modeling of the lake and its predicted response to nutrient load reductions.

The FLUX model was used to develop nutrient and hydrologic budgets for Center Lake. Seasonal and annual loads for each measured parameter (nutrients and solids) were also calculated using the FLUX model. This information was used to derive export coefficients for nutrients and sediment to target areas within the watershed with excessive loads of these pollutants.

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety and Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required.

Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered when establishing TMDLs , targets, and allocations.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

7. TMDL

Criterion Description – Total Maximum Daily Load

TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL established for Center Lake is a 14.3 kg/yr total phosphorus load to the lake (70% reduction in annual total phosphorus load). This is the "measured load" which is based on the flow and concentration data collected during the period of the assessment. Since the annual loading varies from year-to-year, this TMDL is considered a long term average percent reduction in phosphorous loading.

8. Allocation

Criterion Description – Allocation

TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources. Every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles.

In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Center Lake. The allocation for the TMDL is a "load allocation" attributed to nonpoint sources. There are no significant point source contributions in this watershed. The source allocations for phosphorous are assigned to nonpoint source runoff from recreational activities (i.e., recreational activities resulting in bank and shoreline disturbance; detergents contained in grey-water; road maintenance and use; and septic systems) in the watershed.

9. Public Participation

Criterion Description – Public Participation

The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA..

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through presentations to local groups on the assessment report findings, and widespread solicitation of comments on the draft TMDL. Also, the draft TMDL was posted on the State's internet site to solicit comments during the public notice period. The level of public participation is found to be adequate.

10. Monitoring Strategy

Criterion Description – Monitoring Strategy *TMDLs may have significant uncertainty associated with selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL documents to articulate the means by which the TMDL will be evaluated in the field, and to provide supplemental data in the future to address any uncertainties that may exist when the document is prepared.*

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Center Lake will continue to be monitored through the statewide lake assessment project. Post-implementation monitoring will be necessary to assure the TMDL has been reached and maintenance of the beneficial use occurs.

11. Restoration Strategy

Criterion Description – Restoration Strategy *At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality <u>is not</u> currently a regulatory requirement, but is considered a value added component of a TMDL document.*

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The South Dakota DENR will work with the SD Department of Game, Fish and Parks, U.S. Forest Service and local interested parties in the watershed to develop an implementation plan for Center Lake.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance

EPA's approval of a TMDL may constitute an action subject to the provisions of Section 7 of the Endangered Species Act (ESA). EPA will consult, as appropriate, with the US Fish and Wildlife Service (USFWS) to determine if there is an effect on listed endangered and threatened species pertaining to EPA's approval of the TMDL. The responsibility to consult with the USFWS lies with EPA and is not a requirement under the Clean Water Act for approving TMDLs. States are encouraged, however, to participate with USFWS and EPA in the consultation process and, most importantly, to document in its TMDLs the potential effects (adverse or beneficial) the TMDL may have on listed as well as candidate and proposed species under the ESA.

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – EPA will request ESA Section 7 concurrence from the FWS for this TMDL.

13. Miscellaneous Comments/Questions

Appendix H

TMDL Approval Letter and
Final Review Checklist

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
1595 Wynkoop Street
DENVER, CO 80202-1129
Phone 800-227-8917
http://www.epa.gov/region08

August 8, 2007

Ref: 8EPR-EP

Steven M. Pirner, Secretary
Department of Environment & Natural Resources
Joe Foss Building
523 East Capitol
Pierre, SD 57501-3181

Re: TMDL Approvals
Bear Butte Creek; SD-BF-R-BEAR_BUTTE_02
Burke Lake; SD-MI-L-BURKE_01
Center Lake; SD-CH-L-CENTER_01
Richmond Lake; SD-JA-L-RICHMOND_01

Dear Mr. Pirner:

We have completed our review, and have received Endangered Species Act Section 7 concurrence from the U.S. Fish and Wildlife Service, on the total maximum daily loads (TMDLs) as submitted by your office for the waterbodies listed in the enclosure to this letter. In accordance with the Clean Water Act (33 U.S.C. 1251 *et. seq*.), we approve all aspects of the TMDLs as developed for the water quality limited waterbodies as described in Section 303(d)(1). Based on our review, we feel the separate elements of the TMDLs listed in the enclosed table adequately address the pollutants of concern as given in the table, taking into consideration seasonal variation and a margin of safety.

Some of the TMDLs listed in the enclosed table may be for waters not found on the State's current Section 303(d) waterbody list. EPA understands that such waters would have been included on the list had the state been aware, at the time the list was compiled, of the information developed in the context of calculating these TMDLs. This information demonstrates that the non-listed water is in fact a water quality limited segment in need of a TMDL. The state need not include these waters that have such TMDLs associated with them on its next Section 303(d) list for the pollutant covered by the TMDL.

Printed on Recycled Paper

Thank you for submitting these TMDLs for our review and approval. If you have any questions, the most knowledgeable person on my staff is Vern Berry and can be reached at (303) 312-6234.

Sincerely,

signed by Terry Anderson, Acting ARA

Carol Rushin
Assistant Regional Administrator
Office of Ecosystems Protection and Remediation

Enclosures

APPROVED TMDLS

4 Pollutant TMDLs completed
6 causes addressed from the 2006 303(d) list
0 Determinations made that no pollutant TMDL was needed

Waterbody Name & AU ID	TMDL Parameter/ Pollutant (303(d) list cause)	Water Quality Goal/Endpoint	TMDL WLA / LA / MOS	Section 303(d)1 or 303(d)3 TMDL	Supporting Documentation (not an exhaustive list of supporting documents)
Bear Butte Creek (from Strawberry Creek to mouth)* SD-BF-R-BEAR_BUTTE_02	Total Suspended Solids (TSS)	TSS ≤ 158 mg/L in any one sample	2,400 tons/yr TSS (61% reduction in average annual TSS loads) LA = 2,400 tons/yr WLA = 0 tons/yr MOS = implicit	Section 303(d)(1)	? Section 319 Nonpoint Source Pollution Control Program Assessment/Planning Project Final Report, Bear Butte Creek Watershed Assessment, (SD DENR, 2007)
Burke Lake* SD-MI-L-BURKE_01	Phosphorus (TSI, pH, dissolved oxygen**)	Maintain a mean annual Secchi disk-chlorophyll-a TSI at or below 63.4; dissolved oxygen ≥ 5.0; pH 6.5 ≥ - ≤ 9.0	7 kg/yr total phosphorous (88% reduction in average annual total phosphorous loads) LA = 7 kg/yr WLA = 0 MOS = implicit	Section 303(d)(1)	? Watershed Assessment Final Report, Burke Lake, Gregory County, South Dakota (SD DENR, April 2006)
Center Lake* SD-CH-L-CENTER_01	Phosphorus (TSI) Impairment causes pH, water temperature and dissolved oxygen will be addressed in another document.	Maintain a mean annual Secchi disk-chlorophyll-a TSI at or below 48.0	14.3 kg/yr total phosphorous (70% reduction in average annual total phosphorous loads) LA = 14.3 kg/yr WLA = 0 MOS = implicit	Section 303(d)(1)	? Section 319 Nonpoint Source Pollution Control Program Assessment/Planning Project Final Report, Center Lake Watershed Assessment Final Report and TMDL, (SD DENR, Oct. 2006)
Richmond Lake* SD-JA-L-RICHMOND_01	Phosphorus (TSI)	Maintain a mean annual Secchi disk-chlorophyll-a TSI at or below 61.5	557.6 kg/yr total phosphorous (20% reduction in average annual total phosphorous loads) LA = 557.6 kg/yr WLA = 0 MOS = implicit	Section 303(d)(1)	? Watershed Assessment Final Report, Richmond Lake, Brown County, South Dakota (SD DENR, July 2006)

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

** Improvements in the dissolved oxygen concentration of the lake can be achieved through reduction of organic loading to the lake as a result of proposed BMP implementation. The TMDL contains a linkage analysis between phosphorous loading and low dissolved oxygen in lakes and reservoirs.

Enclosure 4

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Center Lake**
Submitted by:	**Gene Stueven, SD DENR**
Date Received:	**June 12, 2007**
Review Date:	**June 27, 2007**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Formal – Final Approval**

This document provides a standard format for EPA Region 8 to provide comments to the South Dakota Department of Environment and Natural Resources on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 12 review criteria:

13. Water Quality Impairment Status
14. Water Quality Standards
15. Water Quality Targets
16. Significant Sources
17. Technical Analysis
18. Margin of Safety and Seasonality
19. Total Maximum Daily Load
20. Allocation
21. Public Participation
22. Monitoring Strategy
23. Restoration Strategy
24. Endangered Species Act Compliance

Each of the 12 review criteria are described below to provide the rational for the review, followed by EPA's comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Water Quality Impairment Status

Criterion Description – Water Quality Impairment Status
TMDL documents must include a description of the listed water quality impairments. While the 303(d) list identifies probable causes and sources of water quality impairments, the information contained in the 303(d) list is generally not sufficiently detailed to provide the reader with an adequate understanding of the impairments. TMDL documents should include a thorough description/summary of all available water quality data such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and/or appropriate water quality standards.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Center Lake is a 27 acre man-make impoundment located in the Cheyenne River basin, Middle Cheyenne-Spring sub-basin, Custer County, South Dakota. It is listed on SD's 2006 303(d) list as impaired (SD-CH-L-CENTER_01) for trophic state index (TSI) and pH due to nonpoint sources and is ranked as priority 1 (i.e., high priority) for TMDL development. The watershed is approximately 6,270 acres and drains predominantly forested land which is heavy used for recreational activities. The mean TSI during the period of the project assessment was 50, and is not currently meeting its designated beneficial use for coldwater permanent fish life propagation. Data collected during the assessment show that Center Lake is also impaired for dissolved oxygen and temperature. The document only addresses the TSI impairment of Center Lake. Temperature, pH and dissolved oxygen TMDLs will be developed in the future.

2. Water Quality Standards

Criterion Description – Water Quality Standards
The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Center Lake is impaired for dissolved oxygen, pH, temperature and TSI. TSI is a surrogate measure used to determine whether the narrative standards are being met. South Dakota has applicable narrative standards that may be applied to the undesirable eutrophication of lakes. Data from Center Lake indicates problems with nutrient enrichment and nuisance algal blooms, which are typical signs of the eutrophication process. The narrative standards being implemented in this TMDL are:

> "*Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair a beneficial use or create a human health problem.*" (See ARSD §74:51:01:09)
>
> "*All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*" (See ARSD §74:51:01:12)

The Center Lake impairments of pH, dissolved oxygen and temperature will be addressed in a future TMDL document.

Other applicable water quality standards are included in the water quality standards section of the assessment report. See pages 3 – 5.

3. Water Quality Targets

Criterion Description – Water Quality Targets

Quantified targets or endpoints must be provided to address each listed pollutant/water body combination. Target values must represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the TMDL target. For pollutants with narrative standards, the narrative standard must be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In June 2005, SD DENR published Targeting Impaired Lakes in South Dakota. This document proposed targeted median growing season Secchi disk/chlorophyll a Trophic State Index (TSI) values for each beneficial use designation category. Using this approach the coldwater permanent fish life median chlorophyll-a and Secchi disk TSI target is < 48. In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met.

The overall mean TSI for Center Lake during the period of the assessment was 50. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 70% or more reduction in the total phosphorus loading from the watershed would is necessary to meet the beneficial use-based beneficial use TSI target of 48 or less.

The water quality target for this TMDL is: **maintain a median annual TSI (Chl-a/SD) at or below 48.0.**

4. Significant Sources

Criterion Description – Significant Sources
TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL identifies the major sources of phosphorus as coming from nonpoint sources within the watershed. The watershed is approximately 6,270 acres and drains predominantly forested land which is heavy used for recreational activities. The watershed is used by tourists and campers with few permanent residents. Sources of phosphorus most likely affecting Center Lake include: 1) recreational activities resulting in bank and shoreline disturbance; 2) detergents contained in grey-water; 3) road maintenance and use; and 4) septic systems. There are no point source discharges of phosphorus in the watershed.

5. Technical Analysis

Criterion Description – Technical Analysis

*TMDLs must be supported by an appropriate level of technical analysis. It applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of technical analysis.*

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The technical analysis addresses the needed phosphorus reduction to achieve the desired water quality. The TMDL recommends a 70% reduction in average annual total phosphorus loads to Center Lake. Using the loads measured during the period of the assessment the total phosphorus load should be 14.3 kg/yr to achieve the desired TSI target. This reduction is based in large part on the BATHTUB mathematical modeling of the lake and its predicted response to nutrient load reductions.

The FLUX model was used to develop nutrient and hydrologic budgets for Center Lake. Seasonal and annual loads for each measured parameter (nutrients and solids) were also calculated using the FLUX model. This information was used to derive export coefficients for nutrients and sediment to target areas within the watershed with excessive loads of these pollutants.

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety and Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required.

Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered when establishing TMDLs , targets, and allocations.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.

☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

7. TMDL

Criterion Description – Total Maximum Daily Load

TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL established for Center Lake is a 14.3 kg/yr total phosphorus load to the lake (70% reduction in annual total phosphorus load). This is the "measured load" which is based on the flow and concentration data collected during the period of the assessment. Since the annual loading varies from year-to-year, this TMDL is considered a long term average percent reduction in phosphorus loading.

For parameters such as phosphorus, for which narrative water quality criteria often apply, attainment of WQS cannot always be judged on a daily basis. Assessment of cumulative loading impacts is necessary to understand how to achieve WQS and to estimate the allowable loading capacity; therefore identifying long-term allocations for such situations is appropriate and informative from a management perspective. For TMDLs in which it is determined that a non-daily allocation is more meaningful in understanding the pollutant/waterbody dynamics, EPA recommends that practitioners identify and include such an allocation, as well as a daily load expression with the final TMDL submission. Unfortunately, EPA's draft technical guidance for developing daily loads was not released until after the final Center Lake TMDL was submitted for approval.

The TMDL targets, calculations and loads developed by SD DENR for the Center Lake TMDL are based on an annual timeframe rather than a "daily" load. EPA recognizes that, under the specific circumstances, the state may deem this the most appropriate timeframe (i.e., the TSI water quality target is based on an interpretation of narrative water quality standards which naturally does not include an averaging period). EPA notes that the Center Lake TMDL calculations for phosphorus can be readily approximated to a daily format through simple division of the annual loads by the number of days in a year**.** For Center Lake this would be a daily load of 0.04 kg/day of phosphorus. However, simply dividing an annual load by 365 would produce an "average" daily load that would not match the actual phosphorus load reaching the lake on a given day. EPA's draft technical guidance for developing daily loads mentions that because many TMDLs are developed for precipitation-driven parameters, one number will often not represent an adequate daily load value. Instead, the guidance recommends that a range of values might need to be presented to account for allowable differences in loading due to seasonal or flow-related conditions (e.g., daily maximum and daily median).

8. Allocation

Criterion Description – Allocation

TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources. Every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles.

In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Center Lake. The allocation for the TMDL is a "load allocation" attributed to nonpoint sources. There are no significant point source contributions in this watershed. The source allocations for phosphorus are assigned to nonpoint source runoff from recreational activities (i.e., recreational activities resulting in bank and shoreline disturbance; detergents contained in grey-water; road maintenance and use; and septic systems) in the watershed.

9. Public Participation

Criterion Description – Public Participation

The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through presentations to local groups on the assessment report findings, and widespread solicitation of comments on the draft TMDL. Also, the draft TMDL was posted on the State's internet site to solicit comments during the public notice period. The level of public participation is found to be adequate.

10. Monitoring Strategy

Criterion Description – Monitoring Strategy

TMDLs may have significant uncertainty associated with selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL documents to articulate the means by which the TMDL will be evaluated in the field, and to provide supplemental data in the future to address any uncertainties that may exist when the document is prepared.

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Post-implementation monitoring will be necessary to assure the TMDL has been reached and maintenance of the beneficial use occurs.

11. Restoration Strategy

Criterion Description – Restoration Strategy

At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document.

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The South Dakota DENR administers three major funding programs that provide low interest loans and grants for projects that protect and improve water quality in South Dakota. Interested parties should contact SD DENR for information on developing an implementation plan for Center Lake.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance

EPA's approval of a TMDL may constitute an action subject to the provisions of Section 7 of the Endangered Species Act (ESA). EPA will consult, as appropriate, with the US Fish and Wildlife Service (USFWS) to determine if there is an effect on listed endangered and threatened species pertaining to EPA's approval of the TMDL. The responsibility to consult with the USFWS lies with EPA and is not a requirement under the Clean Water Act for approving TMDLs. States are encouraged, however, to participate with USFWS and EPA in the consultation process and, most importantly, to document in its TMDLs the potential effects (adverse or beneficial) the TMDL may have on listed as well as candidate and proposed species under the ESA.

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – EPA has received ESA Section 7 concurrence from the FWS for this TMDL.

Twenty-five copies of this document were printed by the South Dakota Department of Environment and Natural Resources at a cost of $3.87 per copy.