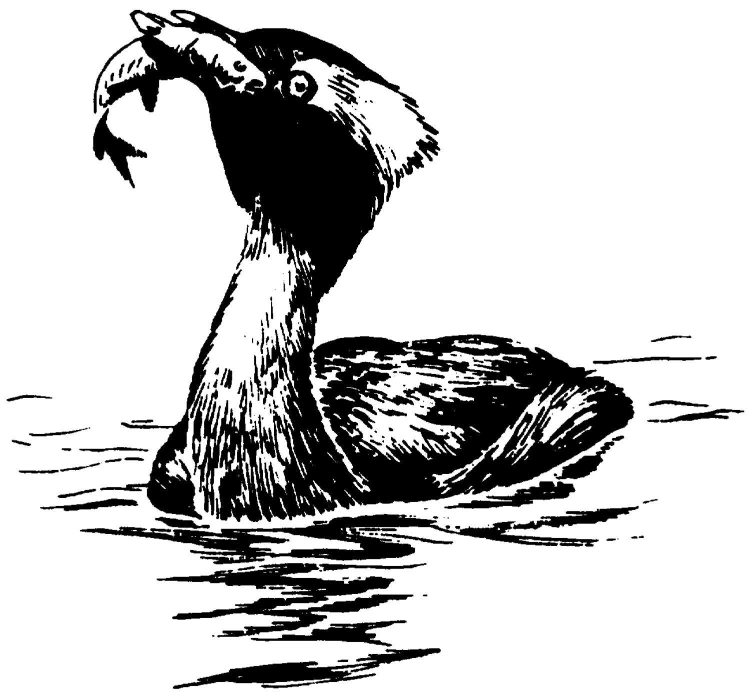
Draft updated 6/2/03

PHASE I
WATERSHED ASSESSMENT AND TMDL
FINAL REPORT

LAKE HANSON/ PIERRE CREEK,
HANSON COUNTY, SOUTH DAKOTA



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

December, 2002

SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM

Draft updated 6/2/03

ASSESSMENT/PLANNING PROJECT FINAL REPORT

LAKE HANSON AND PIERRE CREEK WATERSHED ASSESSMENT AND TMDL FINAL REPORT

By

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Sponsor

Hanson County Conservation District

12/31/02

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Hanson Lake Association

John Deppe, Lower James RC&D

Natural Resource Conservation Service

SD DENR – Water Resource Assistance Program

SD Department of Game, Fish and Parks

Table of Contents

Abbreviations

AFOs	Animal Feeding Operations
AGNPS	Agricultural Non-Point Source
BMPs	Best Management Practices
CPUE	Catch per Unit Effort
CV	Coefficient of Variance
DC	District Conservationist
DO	Dissolved Oxygen
GPS	Global Positioning System
GLS	Great Little Sampler
IJC	International Joint Commission
NPS	Nonpoint Source
NRCS	Natural Resource Conservation Service
NTU	Nephelometric Turbidity Units
Q WTD C	Flow Weighted Concentration
SD DENR	South Dakota Department of Environment and Natural Resources
SD GF&P	South Dakota Department of Game, Fish & Parks
SU	Standard Units
TKN	Total Kjeldahl Nitrogen
TSI	Trophic State Index
µmhos/cm	micrmohos/centimeter
USGS	United States Geologic Survey

Executive Summary

PROJECT TITLE: Lake Hanson/ Pierre Creek Watershed Assessment
START DATE: April, 2001 COMPLETION DATE: December, 2002

FUNDING: TOTAL BUDGET: $73,510.00

TOTAL 106 GRANT:	$58,808.00
TOTAL EXPENDITURES OF 106 FUNDS	$45,044.27
TOTAL MATCH ACCRUED	$14,170.00
BUDGET REVISIONS	None
TOTAL EXPENDITURES	$59,214.27

SUMMARY ACCOMPLISHMENTS

The Lake Hanson/ Pierre Creek Watershed Assessment was developed as a result of Lake Hanson's listing on the state 303 (d) list and due to local interest in lake improvements and dredging potential. Through the use of section 106 EPA funds, the project was initiated through the Hanson County Conservation District in the spring of 2001 at which point data collection began and continued through the summer of 2002. Analysis of the data and the final report were completed in December of 2002. The milestones for the project were completed in an acceptable fashion (with the exception of blank QA/QC samples) after all of the data was collected and returned to SDDENR for analysis.

The primary goal of this project was to determine sources of impairment to the lake and provide sufficient background data to drive a section 319 implementation project. Lake Hanson was listed on the 1998 303 (d) list for high TSI values. Additional data collected since the listing, including the project data indicate that the lakes trophic state is low enough to support its beneficial uses but will benefit from work in the watershed.

The greatest impairment to the beneficial uses of Lake Hanson has been the loss of useable lake acres as a result of sedimentation. Sedimentation rates in the Lake Hanson watershed have declined through the years as a result of conservation practices. Continued promotion of these activities as well as limiting livestock access to the perennial portions of Pierre Creek will provide sufficient protection of this water body to justify a dredge project.

A potential for bacterial contamination to the lake was determined during the assessment. Protection from fecal contamination will be attained through the implementation of the mitigation activities targeting both livestock along the creek and those located in the two animal feeding operations identified in the AnnAGNPs section of the report in addition to limiting livestock access at the lake and elimination of septic contamination of the lake from residences located along it.

Introduction

Purpose

The long term goal of the Lake Hanson Assessment Project is to locate and document sources of nonpoint source pollution in the watershed. Feasible restoration recommendations will be produced in order to provide adequate background information needed to drive a watershed implementation project to reduce sedimentation and nutrients impacting the lake and its tributaries, and to produce a TMDL report for Lake Hanson.

General Lake Description

Lake Hanson is a 60 acre reservoir in central Hanson County, South Dakota (see Figure 1). The reservoir receives runoff from agricultural operations and the creek in the watershed and the lake have experienced declining water quality according to the state 303 (d) report. The Lake Hanson Watershed is approximately 48,000 acres in size. The land use in thewatershed is predominately agricultural consisting of cropland and grazing.

Lake Identification and Location

Lake Name: Lake Hanson	State: South Dakota
County: Hanson	Township: 102N
Range: 58W	Sections: 21
Nearest Municipality: Alexandria	Latitude: 43.623341
Longitude: -97.797272	EPA Region: VIII
Primary Tributary: Pierre Creek	Receiving Body of Water: Pierre Creek
HUC Code: 10160011	HUC Name: Middle James

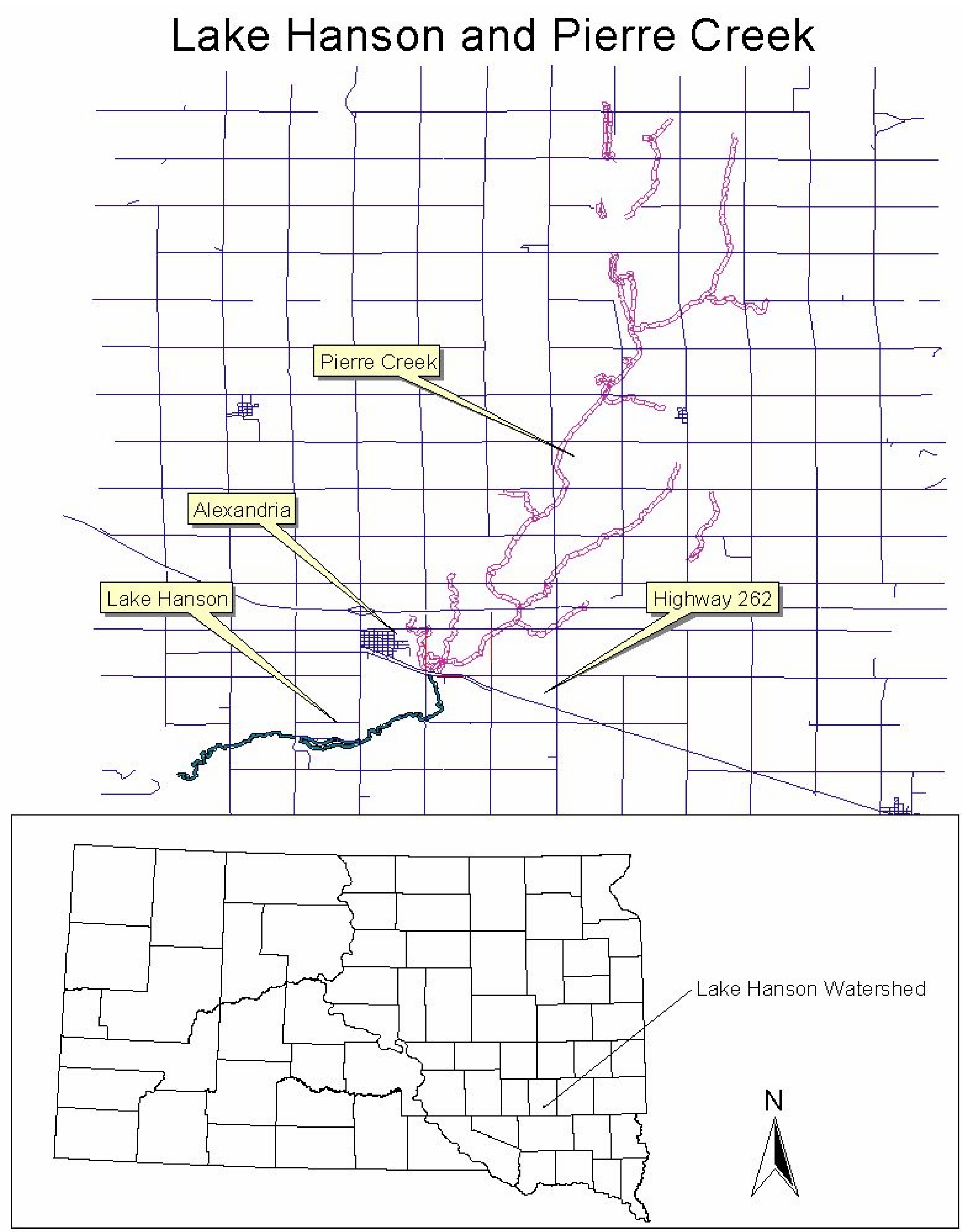


Figure 1. Lake Hanson, Hanson County South Dakota

Trophic Status Comparison

The trophic state of a lake is a numerical value that ranks its relative productivity. Developed by Carlson (1977), the Trophic State Index, or TSI, allows a lake's productivity to be easily quantified and compared to other lakes. Higher TSI values correlate with higher levels of primary productivity. A comparison of Lake Hanson to other reservoirs in the Northern Glaciated Plains Ecoregion (Table 1) shows a wide range of productivity's in the ecoregion. Lake Hanson has an average to lower than average mean TSI value for its ecoregion. The values provided in Table 1 were generated from the most recent statewide lake assessment final report (Stueven and Stewart, 1996). The TSI for Lake Hanson will vary slightly in this report due to the use of additional new data gathered during this assessment.

Table 1. Comparison of Mean Trophic States for Lakes Located in the Northern Glaciated Plains Ecoregion

Lake	County	TSI	Mean Trophic State
Mitchell	Davison	61.34	Eutrophic
Hanson	**Hanson**	**63.92**	**Eutrophic**
Jones	Hand	64.45	Eutrophic
Elm	Brown	69.84	Hyper-eutrophic
Richmond	Mcpherson	66.86	Hyper-eutrophic
Amsden	Day	66.24	Hyper-eutrophic
Faulkton	Faulk	70.63	Hyper-eutrophic
Mina	Edmunds	71.91	Hyper-eutrophic
Cresbard	Edmunds	70.06	Hyper-eutrophic
Louise	Hand	70.57	Hyper-eutrophic
Redfield	Spink	77.02	Hyper-eutrophic

Beneficial Uses

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

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

Individual parameters as well as the lake's TSI value determine the support of these beneficial uses. Lake Hanson is identified in *Ecoregion Targeting for Impaired Lakes in South Dakota* (Stueven et al, 2000) as not supporting its beneficial uses.

Recreational Use

The South Dakota Department of Game, Fish, and Parks provides a list of existing public facilities that are maintained at area lakes (Table 2). Lake Hanson has a small recreation area developed on the north side of the lake including a beach, boat ramp, public dock shore fishing, and public toilets. There are also several permanent residences and several seasonal homes located along the north side of the lake.

Table 2. Comparison of Recreational Uses and Facilities for Area Lakes

Lake	Beach	Boat Ramp	Camp Ground	Public Docks	Handicapped Access	Shore Fishing	Public Toilets	County
Lake Hanson	**X**	**X**		**X**		**X**	**X**	**Hanson**
Fulton Lake						X		Hanson
Lake Mitchell	X	X		X		X	X	Davison
Ethan Dam		X				X		Hanson
Menno Dam		X	X	X	X	X	X	Hutchinson
Dimock		X		X		X	X	Hutchinson
Silver		X				X		Hutchinson
Lyons Lake						X		McCook
Forsh Lake						X		McCook

Project Goals, Objectives, and Activities

Planned and Actual Milestones, Products, and Completion Dates

Objective 1. Lake Sampling
The project coordinator began collecting samples in May of 2001. A total of four samples were collected from Lake Hanson from May through September 2001. Unsafe ice conditions persisted throughout the winter preventing any sampling through the ice. While sampling was less than proposed in the contract, utilization of collected data as well as historic data should be adequate to describe the general water quality of the lake.

Objective 2. Tributary Sampling
The local coordinator and DENR staff began collecting tributary data in April of 2001. A total of 34 tributary samples were collected during the project from the four monitoring stations on Pierre Creek. The sample set provided enough data to develop nutrient and sediment loadings for Lake Hanson.

Objective 3. Quality Assurance/ Quality Control (QA/QC)
There were only three duplicate samples collected from the tributary and no blank samples. Missing blank samples were not discovered until after the project was completed. The duplicate samples were adequate to determine some level of precision, however the lack of blank samples prevents any determination of effectiveness of rinsing and sample contamination.

Objective 4. Watershed Modeling
Collection of the data required to execute the AnnAGNPS model was conducted during the spring and summer of 2002 and reached completion during early fall of 2002. Execution of the AnnAGNPS model was completed in a timely manner and restoration alternatives were determined.

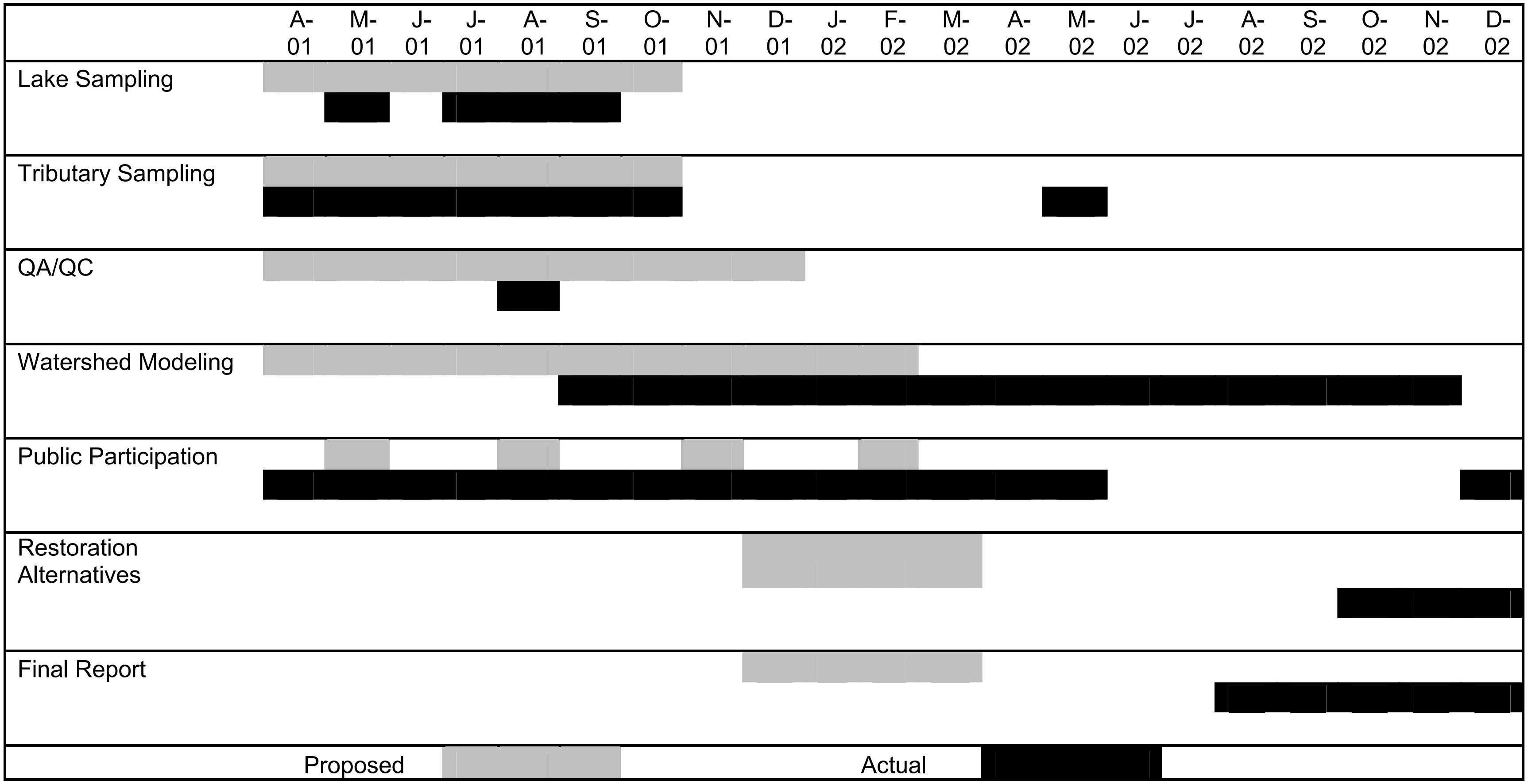
Objective 5. Public Participation
The public was involved throughout the project. The coordinator attended various conservation district and lake association meetings as well as having individual contact with land owners.

Objectives 6 and 7. Restoration Alternatives and Final Report
The restoration alternatives and the final report were completed by the end of 2002, after the proposed completion date of March 2002.

Evaluation of Goal Achievements

With the exception of the number of lake samples and the QA/QC data, all of the objectives were met in an acceptable time frame. Completion of the final report and restoration alternatives should have been planned for after the project completion in the spring of 2002.

Table 3. Proposed and Actual Objective Completion Dates



Monitoring Results

Surface Water Chemistry (Pierre Creek)

Flow Calculations

A total of four (three tributary and one outlet) monitoring sites were selected along Pierre Creek, which is the primary tributary to Lake Hanson. The sites were selected to determine which portions of the watershed were contributing the greatest amount of nutrient and sediment load to the lake. All of the sites were equipped with Stevens Type F stage recorders. Water stages were monitored and recorded to the nearest $1/100^{th}$ of a foot for each of the four sites. A Marsh-McBirney Model 210D flow meter was used to determine flows at various stages. The stages and flows were then used to create a stage-to-discharge table for each site. Stage-to-discharge tables may be found in Appendix A.

Load Calculations

Total nutrient and sediment loads were calculated with the use of the Army Corps of Engineers eutrophication model known as FLUX. FLUX uses individual sample data in correlation with daily average discharges to develop six loading calculations for each parameter. As recommended in the application sequence, a stratification scheme and method of calculation was determined using the total phosphorus load. This stratification scheme is then used for each of the additional parameters. Sample data collected for Pierre Creek may be found in Appendix B.

Tributary Sampling Schedule

Samples were collected at selected sites during the spring of 2001 through the spring of 2002. Most samples were collected using a suspended sediment sampler. Water samples were filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD. The laboratory then assessed the following parameters:

Fecal Coliform Counts
Total Solids
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus
E. coli Bacteria Counts
Alkalinity
Total Dissolved Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Volatile Total Suspended Solids
Un-ionized Ammonia

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

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

Parameters measured in the field by sampling personnel were:

Water Temperature
Dissolved Oxygen
Air Temperature
Field pH

South Dakota Water Quality Standards

The State of South Dakota assigns at least two of the eleven beneficial uses to all bodies of water in the state. Fish and wildlife propagation, recreation and stock watering as well as irrigation are assigned to all streams and rivers. All portions of Pierre Creek located within the Lake Hanson watershed must maintain the criteria that support these uses. In order for the creek to support these uses, there are seven standards that must be maintained. These standards, as well as the water quality values that must be met, are listed in Table 4.

Table 4. State Water Quality Standards

Parameter	Criterion
Nitrate	≤ 50 mg/L (mean) ≤ 88 mg/L (single sample)
Alkalinity	≤ 750 mg/L (mean) ≤ 1,313 mg/L (single sample)
pH	≥ 6.0 and ≤ 9.5 su
Total Dissolved Solids	≤ 2,500 mg/L for a 30-day geometric mean ≤ 4,375 mg/L daily maximum for a grab sample
Conductivity	≤ 2,500µmhos (mean) ≤ 4,375µmhos (single sample)
Total Petroleum Hydrocarbon Oil and Grease	≤ 10 mg/L ≤ 10 mg/L
Sodium Adsorption Ratio	≤ 10 mg/L

The portion of Pierre Creek located downstream from Section 11, Township 102 North and 58 West (Approximately the point where the creek crosses highway 262) to the James River, with the exception of Lake Hanson, is classified for the beneficial uses of 5 and 8 which are warmwater semipermanent fish life propagation and limited-contact recreation. These additional classifications add water quality parameters that must be maintained to support these beneficial uses. The parameters found in Table 5 must be maintained in addition to those listed in Table 4. Site LHT1 is located approximately one mile downstream from the point of classification change. This is the only watershed site above the lake that must maintain the additional standards.

Site LHT2 is located slightly upstream from the point of classification change. While it does not need to maintain the same standards, water quality data at this site does have a direct impact on the portion of the stream classified as a fishery and for limited contact recreation. Due to its close proximity and impact on the classified portion of the stream, this site will be addressed as having a fishery standard.

Table 5. State Beneficial Use Standards for Portions of Pierre Creek

Parameters	**mg/L (except where noted)**	**Beneficial Use Requiring this Standard**
Coliform, fecal *(per 100 mL)* May 1 to Sept 30	≤ 1000 mg/L *(mean)* ≤ 2000 mg/L *(single sample)*	Limited Contact Recreation
Nitrogen, un-ionized ammonia as N (mg/L)	≤ 0.04 mg/L *(mean)* ≤ 1.75 times the applicable limit *(single sample)*	Warmwater Semi-permanent Fish Propagation
Oxygen, dissolved (mg/L)	≥ 5.0 mg/L	Limited Contact Recreation Warmwater Semi-permanent Fish Propagation
pH *(standard units)*	6.0 - 9.0	Warmwater Semi-permanent Fish Propagation
Solids, suspended (mg/L)	≤ 90 mg/L *(mean)* ≤ 158 mg/L *(single sample)*	Warmwater Semi-permanent Fish Propagation
Temperature	≤ 32 ^{o}C	Warmwater Semi-permanent Fish Propagation

Watershed Overview and Water Budget

Pierre Creek drainage was divided into four individual subwatersheds with a gauging station located at the outlet to each one (See Figure 2). Stage and discharge data were collected from each subwatershed as well as water chemistry samples, which were combined to calculate a load from each of these subwatersheds.

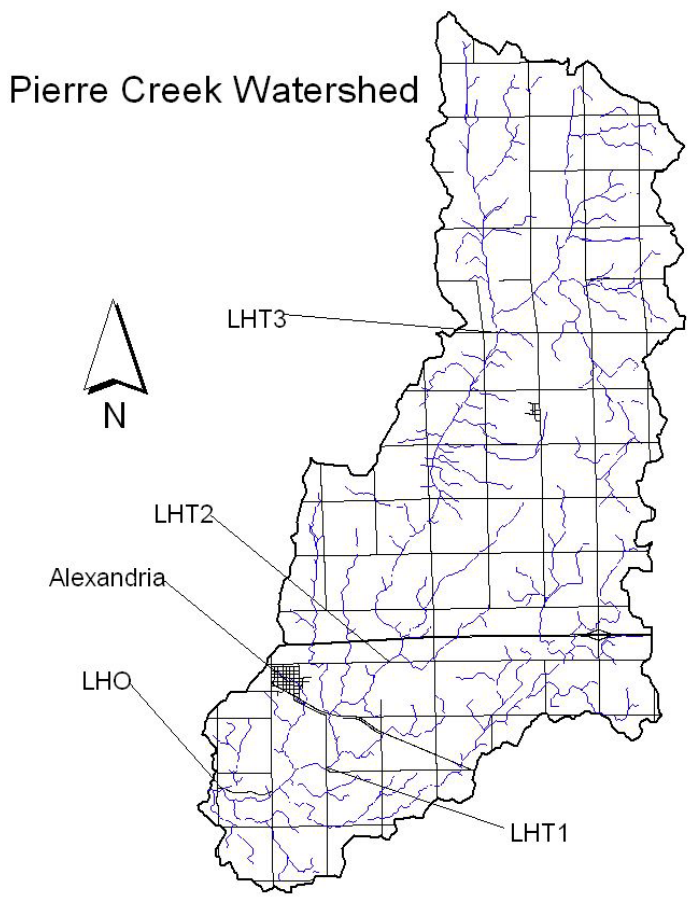


Figure 2. Pierre Creek Monitoring Stations

Discharge from Pierre Creek, ground water, and rainfall are the primary sources of water entering Lake Hanson. Ground water does significantly affect Lake Hanson. Discharge measurements recorded at sites LHT2 and LHT1 indicate that some recharging of the underlying aquifer occurs during high flows and that this water is then released during low flows, see Figure 3. The geology of the stream basin consists of an alluvium deposit with the potential to hold and release water (DENR staff, 2002)

Recharge occurred during May and June with equilibrium occurring towards the end of June. An average loss of 4.9 cfs was measured from May 11, 2001 through June 16, 2002. The large spikes (both positive and negative) in the average line are due to rainstorm events that impacted the upstream site prior to impacting the downstream site. Discharge from the aquifer exceeded recharge from late July through the end of the project. Average groundwater discharge into the stream from July 30, 2001 through November 19, 2001 measured 5.7 CFS.

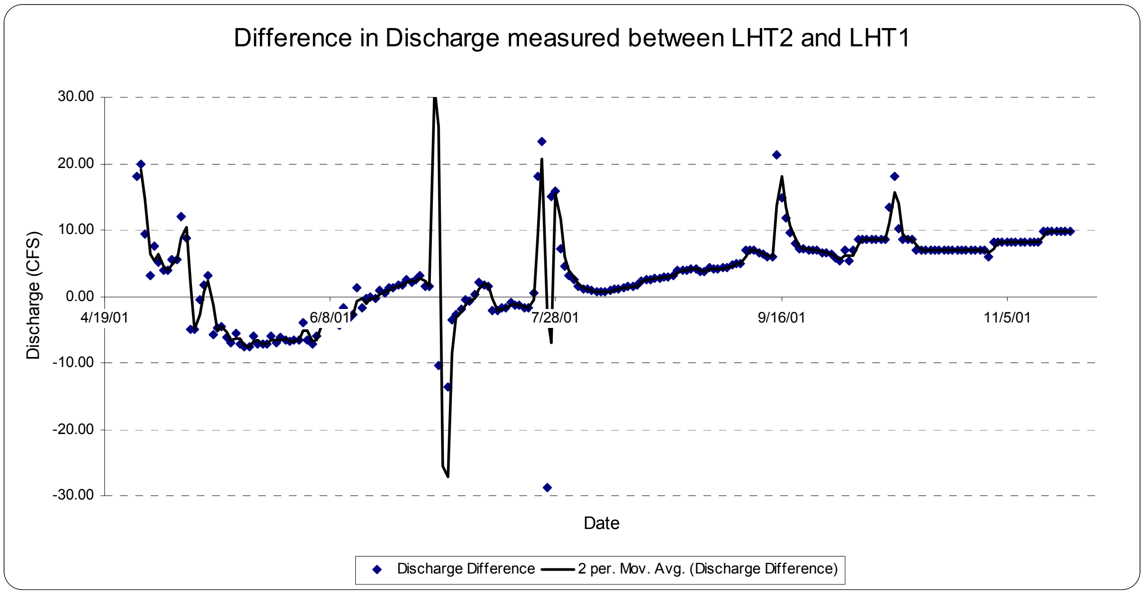


Figure 3. Difference in Discharge Measured Between LHT2 and LHT1

Due to difficulties gauging the outlet to Lake Hanson, developing a water budget encompassing the impacts of ground water and rain water is not possible. Some accurate generalizations regarding the water budget for Lake Hanson can be made. The majority of the water entering Lake Hanson comes from the watershed. The lake experiences some groundwater influences. It is likely that this water comes from the alluvial deposits that line the Pierre Creek basin and are recharged when the level in the creek rises. The Alexandria Aquifer underlies the area; however it is too deep to be a likely candidate for the springs discharging to the lake and Pierre Creek.

Annual and Seasonal Loadings

To calculate the current and future water quality in an impoundment, BATHTUB (Army Corps of Engineers eutrophication model) utilizes phosphorus and nitrogen loads entering the impoundment. These loads and their standard errors (CV) are calculated through the use of FLUX (Army Corps of Engineers loading model) for the primary inlets to the lake.

Due to the nature of Pierre Creek and the varying impacts the seasons have on nutrients and sediments delivered to this lake from the watershed, seasonal and annual loadings will be discussed in detail for each parameter.

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the waste of warm-blooded animals. Some common types of bacteria are *E. coli*, S*almonella,* and *Streptococcus,* which are associated with livestock, wildlife, and human waste (Novotny, 1994). Most of the samples indicated the presence of *E. coli* at levels higher than the total fecal coliform count (Table 6). This is the result of standard lab testing procedures. Fecal coliform tests are conducted with an incubation temperature of 45°C while *E. coli* tests are conducted with an incubation temperature of 35°C. The higher incubation temperatures for the fecal test inhibit the growth of some *E. coli,* resulting in the lower counts for total fecal coliform.

Fecal coliform counts were highest at all four sites on April 23, 2001 but did not exceed state standards because they were collected prior to May 1. These samples were collected during the highest discharge sampled during the project. Other samples collected at high flows during the following weeks (sample dates April 26, 2001 and May 10, 2001) were some of the lowest collected during the project, possibly due to a "flushing" effect from the initial spring runoff reducing the amount of fecal matter present in the stream channel and on the landscape.

The elevated counts in the samples collected on July 17 and 26, 2001 were also the result of rain events that resulted in increases in discharge by 40 cfs or greater. The samples collected on June 27, 2001 are the only ones with elevated counts that could not be linked to a rainstorm event.

Table 6. Bacteria Concentrations in Pierre Creek

Date	LHT1 Fecal	LHT1 *E. coli*	LHT2 Fecal	LHT2 *E. coli*	LHT3 Fecal	LHT3 *E. coli*	LHO Fecal	LHO *E. coli*
4/23/01	11000	>2420	11000	>2420	8600	>2420	2500	>2420
4/26/01	90	189	110	579	50	76.8	420	1050
5/10/01	100	83.3	70	121	140	121		
6/27/01	1590	2420	1350	1990	380	365		
7/17/01	860	1120	1600	>2420				
7/26/01	1300	980	1100	1200			500	816
8/27/01	240	231	180	272			20	<2
8/27/01	320	72.8	350	365			<10	2
9/26/01	240	579	240	308				
10/30/01	100	206	1000	326			<10	2
5/30/02	570	2419	640	921				

Site LHT3 does not have a fecal standard. The standard at sites LHT1 and immediately downstream of site LHT2 are 1,000 colonies/ 100 mL average or a single sample limit of over 2,000 colonies/ 100 mL from May 1 through September 30. Two of the samples collected at these two sites exceeded the 2,000 colony limit for fecals and one of the samples exceeded the 2,000 limit for *E. coli*. An additional nine samples exceeded the 1,000 colony limit for either fecal or *E. coli*.

The sample collected at site LHO on July 26, 2001 was also greater than the state standards allowed for Lake Hanson. Since this site is located at the outlet to the lake which has immersion recreation as a beneficial use, it also indicates some impairment from fecal contamination in the watershed. Further evidence of this is discussed in the lake fecal coliform section on page 30 of this report.

Pierre Creek and Lake Hanson may be impaired as a result of bacterial contamination. Mitigation processes in this watershed should include targeting of sources of animal waste that impact the stream and lake. Increased bacterial counts are often found during periods of increased runoff. Since elevated counts were found during periods of runoff and during base flow conditions, it suggests that targeting should include not only animal feeding operations, but also perennial portions of the creek that are grazed.

Alkalinity

Historically, the term alkalinity referred to the buffering capacity of the carbonate system in water. Today, alkalinity is used interchangeably with acid neutralizing capacity (ANC), which refers to the capacity to neutralize strong acids such as HCL, H_2SO_4 and HNO_3. Alkalinity in water is due to any dissolved species (usually weak acid anions) with the ability to accept and neutralize protons (Wetzel, 2000). Due to the abundance of carbon dioxide (CO_2) and carbonates, most freshwater contains bicarbonates as its primary source of alkalinity. Alkalinity is commonly found in concentrations as high as 200 mg/L.

Alkalinity standards for all of Pierre Creek located upstream from Lake Hanson are a maximum of 1,313 mg/L for any single sample and 750 mg/L for a mean. The highest recorded value during the project occurred at site LHT2 on September 26, 2001 at a concentration of 451 mg/L, well within the standards for the tributary indicating full support for this parameter.

Table 7 depicts the alkalinity loadings that occurred at each gauging site in the Pierre Creek watershed. Alkalinity loadings increase as the creek flows downstream with the exception of where it passes through the lake. Some loss of carbonates likely occurs through sedimentation or biological uses.

Table 7. Alkalinity Loading in the Pierre Creek Watershed

Site	Units	LHO	LHT1	LHT2	LHT3
Area	Acres	48,195	33,852	27,970	16,998
WATER	Acre Feet	11,874	7,874	4,889	2,310
Alkalinity	Tons	3297	2833	1142	218
Loading (Kg/acre)		62.06	75.92	37.03	11.61

pH

pH is a measure of free hydrogen ions (H^+) or potential hydrogen. More simply it indicates the balance between acids and bases in water. It is measured on a logarithmic scale between 0 and 14 and is recorded as standard units (su). At neutral (pH of 7) acid ions (H^+) equal the base ions (OH^-). Values less than 7 are considered acidic (more H^+ ions) and greater than 7 are basic (more OH^- ions).

There were only eight pH measurements recorded during the project. They ranged from a low of 7.02 su to a high of 8.09 su. These values are well within the range specified by state standards of 6.0 su to 9.5 su indicating full support of this parameter.

Temperature and Dissolved Oxygen

Only portions of Pierre Creek located downstream of Highway 262 in Hanson County have temperature and DO standards due to their classification as a fishery. Water temperature is of great importance to any aquatic ecosystem. Many organisms and biological processes are temperature sensitive. Water temperature plays an important role in physical conditions. Oxygen dissolves in higher concentrations in cooler water. Higher toxicity of un-ionized ammonia is also related directly to warmer temperatures.

The water temperatures in Pierre Creek remained well below the state standard of 32^o C with a maximum of 18.4^o C reached at site LHT1 in July of 2001. The coordinator experienced some difficulties with the sampling equipment resulting in a limited dataset of only nine samples. The mean temperature of these samples was 13^o C, considering the low temperatures, ground water influence, and that there were samples taken during July when some of the highest temperatures are typically measured in South Dakota; the stream does not appear to be impaired as a result of high temperatures.

There are many factors that influence the concentration of dissolved oxygen (DO) in a waterbody. Temperature is one of the most important of these factors. As the temperature of water increases, its ability to hold oxygen in solution decreases.

Similar difficulties were experienced with DO measurements as were with temperature measurements. Again, all measurements were within state standards with the exception of the sample collected at site LHT2 on May 10, 2001 at 4.21 mg/L. Other samples collected on that date were above the state standard of 5.0 mg/L. This particular sample may be explained as a natural anomaly or an error in calibrating or reading the meter. Since no fish kills were documented during the project, it is not expected that the portions of the stream that are classified as a fishery experience impairment from low DO concentrations.

Solids

Total solids are the sum of all dissolved and suspended as well as all organic and inorganic materials. Dissolved solids are typically found at higher concentrations in ground water, and typically constitute the majority of the total solids concentration.

The total solids loadings most closely depict the dissolved portion of the solids load. Ground water typically has higher concentrations of dissolved solids than surface water. The amount of influence that ground water has on each site is evident when comparing the total solids loadings/ acre, see Table 8. Site LHT3 has very little if any ground water flow. Site LHT2 is influenced by groundwater flow and the lower sites (LHO and LHT1) in the watershed are heavily influenced by groundwater flow.

Table 8. Solids Loadings in the Pierre Creek Watershed

	Units	LHO	LHT1	LHT2	LHT3
Area	Acres	48,195	33,852	27,970	16,998
Water	Acre Feet	11,874	7,874	4,889	2,310
Total Suspended Solids	Tons	394	286	167	87
Volatile Suspended Solids	Tons	205	59	48	0
Total Solids	Tons	26501	18508	7500	863
Total Suspended Solids	Kg/ Acre	7.4	7.7	5.4	4.6
Volatile Suspended Solids	Kg/ Acre	3.9	1.6	1.5	-
Total Solids	Kg/ Acre	498.8	496.0	243.2	46.1

The suspended solids load at the inlet site recorded 286 tons of sediment entering the lake during the project while the outlet site recorded 394 tons of sediment leaving the lake, which makes it appear that the lake is discharging more than it is acquiring. When these loads are corrected for the number of acres that drain through the site, a loading/ acre is generated that indicates it is likely that some sediment is actually being deposited in the lake.

Sediment loading per acre of drainage increases as the stream approaches the lake and becomes perennial in nature. This indicates that mitigation practices targeting the lower portions of the stream may result in the greatest reductions to the sediment load.

Nitrate/Nitrite and Ammonia

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

As a standard testing procedure, nitrates and nitrites are measured and recorded together. This form of nitrogen is inorganic and readily available for plant use. The water quality standards for wildlife propagation, recreation, and stock watering require that nitrate concentrations remain below 50 mg/L mean over any 30 day period of time and 88 mg/L for any single sample. Nitrate levels were low in Pierre Creek throughout the project. The maximum concentration recorded was measured at site LHT3 on April 23, 2001 at .8 mg/L, indicating full support of all beneficial uses for this parameter.

Nitrogen loads for each site as well as discharge coefficients (load measured in kg divided by the number of acres drained at that site) are listed in Table 9. Inorganic nitrogen (nitrates and ammonia) loads are similar at each of the sites indicating similar loadings of this form of nitrogen throughout the watershed. Organic nitrogen loads appear to be slightly higher in the stream reaches nearest the lake and the lake itself, which directly influences the total nitrogen load resulting in similar changes in the discharge coefficients for this parameter.

Table 9. Nitrogen Loads in Pierre Creek

	Units	LHO	LHT1	LHT2	LHT3
Area	Acres	48,195	33,852	27,970	16,998
WATER	Acre Feet	11,874	7,874	4,889	2,310
Total Nitrogen	Kg	20,216	10,368	6,968	5,896
Inorganic Nitrogen	Kg	4,762	3,827	2,529	1,692
Organic Nitrogen	Kg	15,454	6,542	4,438	4,204
Total Nitrogen	Kg/ acre	0.42	0.31	0.25	0.35
Inorganic Nitrogen	Kg/ acre	0.10	0.11	0.09	0.10
Organic Nitrogen	Kg/ acre	0.32	0.19	0.16	0.25

Phosphorus

Phosphorus is one of the macronutrients required for primary production. In comparison to carbon, nitrogen, and oxygen, it is often the least abundant in natural systems (Wetzel, 2000). Phosphorus loading to lakes can be of an internal or external nature. Total phosphorus is the sum of all attached and dissolved phosphorus in the lake.

The phosphorus loads and discharge coefficients for each subwatershed in the Pierre Creek drainage are listed in Table 10. The highest discharge coefficients were calculated for sites LHT2 and LHT3 in the upper portions of the watershed indicating that these areas are the greatest source of this nutrient.

Table 10. Phosphorus Loads in Pierre Creek

	Units	LHO	LHT1	LHT2	LHT3
Area	Acres	48,195	33,852	27,970	16,998
WATER	Acre Feet	11,874	7,874	4,889	2,310
Total Phosphorus	Kg	4,529	2,750	3,269	2,085
Total Dissolved Phosphorus	Kg	1,836	2,082	2,802	1,487
Total Phosphorus	Kg/ Acre	0.094	0.081	0.117	0.123
Total Dissolved Phosphorus	Kg/ Acre	0.038	0.062	0.100	0.087

A significant loss of phosphorus was measured between sites LHT2 and LHT1, approximately 500 kg. Figure 4 depicts the difference in phosphorus loads measured at each site on a daily basis. This graph closely resembles the water loss between these sites depicted in Figure 3 with the exception of the late season ground water or base flow.

While this may be the result of bad data, a more likely explanation of what is occurring would be to assume that as the water infiltrates the alluvial deposits, the phosphorus is essentially filtered out when it binds to the sediments. Considering the other parameters that were measured, there is some support to this hypothesis. Nitrates are water soluble and should be able to pass into and out of the alluvium with the water. When examining the nitrogen loads, no loss was calculated, see Table 9.

Dissolved solids, and ultimately total solids, should increase dramatically downstream as the water passes through the alluvium and dissolves material. Significantly higher loadings were measured at the downstream sites (LHT1 and LHO) versus the upstream sites (LHT2 and LHT3), see Table 8.

Suspended solids should not infiltrate the alluvium at all and should be transported to the lake. Examining the suspended solids loadings in Table 8 this also appears to have happened since no loss of solids was calculated.

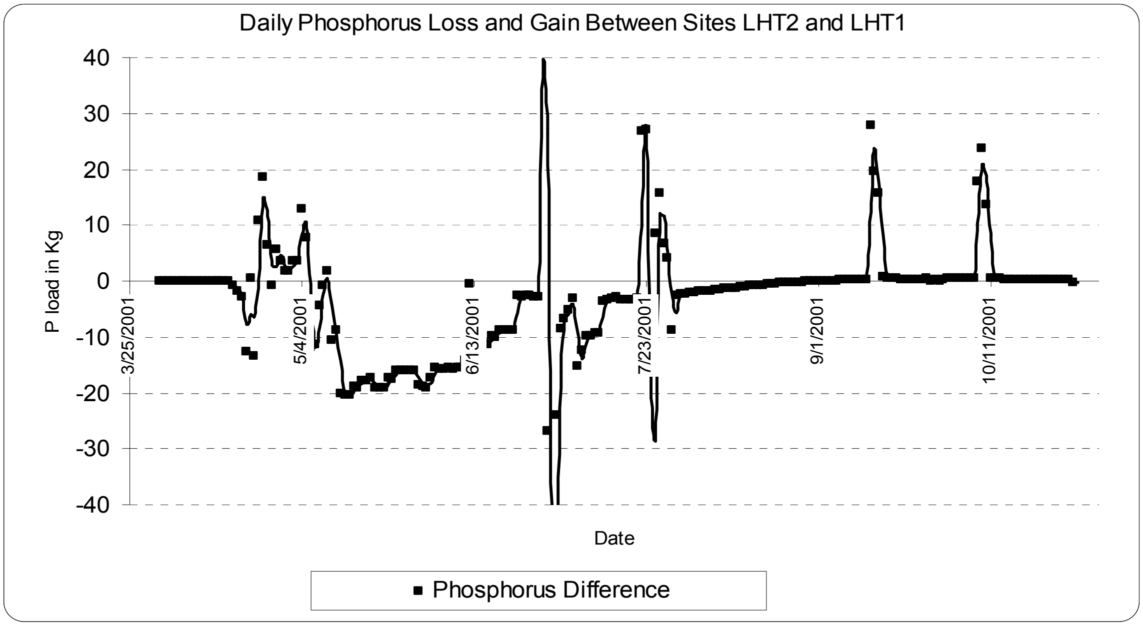


Figure 4. Daily Phosphorus Loss and Gain Between Sites LHT2 and LHT1

Further indication of this can be seen when a comparison is made between phosphorus concentrations and total solids concentrations, Figure 5. Ground water or base flows have higher concentrations of dissolved solids; they also have lower concentrations of phosphorus, presumably due to the filtering effect. During runoff events, phosphorus loads from land sources enter the creek and increase the total phosphorus concentrations. The data in Figure 5 represents all total solids tributary samples collected during the project. There is a noticeable relationship between the increasing influence of ground water and lower phosphorus concentrations.

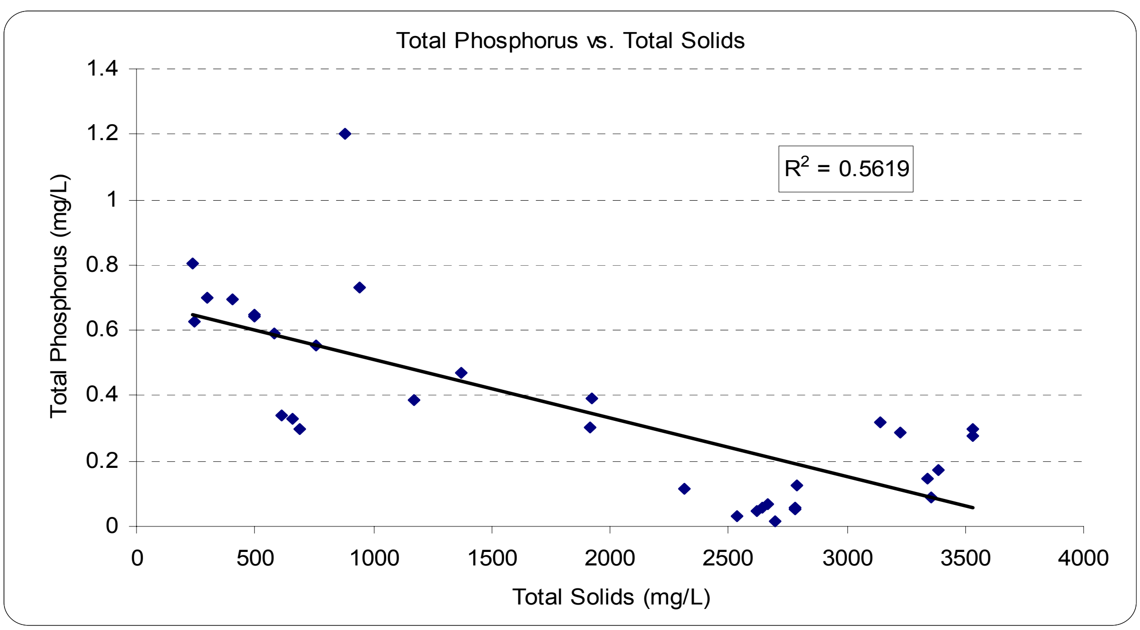


Figure 5. Total Phosphorus to Total Solids Comparison

Tributary Site Summary

When comparing all of the tributary water quality data, it appears that the greatest benefits from mitigation practices may be obtained through application in the areas located downstream of site LHT2, particularly where the creek flows perennially.

The stream is not impaired as a result of high temperature, low DO concentrations, high or low pH values, high alkalinity concentrations, or dissolved solids.

The sediment load in the stream at the inlet site LHT1 is relatively small. If all of the sediment measured at site LHT1 (approximately 280 cubic meters assuming 1 ton of sediment/ cubic meter) were deposited in the lake each year a total accumulation of .04 inches would occur on an annual basis. Taking into consideration the sediment load at the outlet to the lake, the feasibility of lasting improvements from a dredge project can not be confidently predicted from the stream loadings alone. Analysis of the sediment survey and the predicted sediment loads from the watershed modeling should provide clarification as to the feasibility of a dredge project.

Nitrogen loads appear to be the greatest at the lake or in the watershed immediately upstream of the lake. Possible sources for this could be the cabins or livestock around and immediately upstream of the lake as well as city storm sewer discharges.

Bacterial loadings to the lake appear to be a problem that may be addressed by limiting the amount of contact that livestock have with perennial portions of the stream. Reductions in bacterial counts may also be achieved during runoff events through grazing management in the portions of the creek that do not experience perennial flow as well as changes in animal feeding operations. These practices will likely result in reductions of nutrient and sediment loads to the lake that will provide further protection for this water body.

Surface Water Chemistry (Lake Hanson)

Inlake Sampling Schedule

Sampling began in June 2000 and was conducted on a monthly basis until project completion in June 2001. Two sites were selected for sample collection (LH2 located in the shallow east end of the lake and the other in the deeper west end of the lake). Water samples were filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD. Sample data collected at Lake Hanson may be found in Appendix C. The laboratory assessed the following parameters:

Fecal Coliform Counts
Total Solids
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus
Alkalinity
Total Dissolved Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Volatile Total Suspended Solids
Chlorophyll *a*

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

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

Parameters measured in the field by sampling personnel were:

Water Temperature
Secchi Depth
Field pH
Air Temperature
Dissolved Oxygen
Turbidity

South Dakota Water Quality Standards

All public waters within the State of South Dakota have been assigned beneficial uses. All designated waters are assigned the use of fish and wildlife propagation, recreation, and stock watering. Along with each of these uses are sets of water quality standards that must not be exceeded in order to support these uses. Lake Hanson has been assigned the beneficial uses of:

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

The parameters and their associated values listed in Table 11 are those that must be considered when maintaining beneficial uses as well as the concentrations for each. When multiple standards for a parameter exist, the most restrictive standard is used.

Table 11. State Water Quality Standards for Lake Hanson

Parameters	mg/L (except where noted)	Beneficial Use Requiring this Standard
Alkalinity *($CaCO_3$)*	≤ 750 *(mean)* ≤ 1,313 *(single sample)*	Wildlife Propagation and Stock Watering
Coliform, fecal *(per 100 mL)* May 1 to Sept 30	≤ 200 *(mean)* ≤ 400 *(single sample)*	Immersion Recreation
Conductivity *(μmhos / cm @ 25^o C)*	≤ 4,000 *(mean)* ≤ 7,000 *(single sample)*	Wildlife Propagation and Stock Watering
Nitrogen, unionized ammonia as N	≤ 0.04 *(mean)* ≤ 1.75 times the applicable limit *(single sample)*	Warmwater Semi-permanent Fish Propagation
Nitrogen, nitrate as N	≤ 50 mg/L *(mean)* ≤ 88 mg/L *(single sample)*	Wildlife Propagation and Stock Watering
Oxygen, dissolved	≥ 5.0 mg/L	Immersion and Limited Contact Recreation Warmwater Semi-permanent Fish Propagation
pH *(standard units)*	6.5 - 9.0	Warmwater Semi-permanent Fish Propagation
Solids, suspended	≤ 90 mg/L *(mean)* ≤ 158 mg/L *(single sample)*	Warmwater Semi-permanent Fish Propagation
Solids, total dissolved	≤ 2,500 mg/L *(mean)* ≤ 4,375 mg/L *(single sample)*	Wildlife Propagation and Stock Watering
Temperature	≤ 32.22 C	Warmwater Semi-permanent Fish Propagation
Total Petroleum Hydrocarbon Oil and Grease	≤ 10 mg/L ≤ 10 mg/L	Wildlife Propagation and Stock Watering

Inlake Water Quality Parameters

Water Temperature

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

The beneficial uses of Lake Hanson require temperatures to be maintained below 32^{o}C. The maximum recorded temperature for the surface water of Lake Hanson was recorded on July 27, 2000 at site 1 with a value of 27.3^{o}C, which is well within the standards for this body of water. The other site also experienced its highest temperature on this date at 26.4^{o}C. Considering the fact that this lake is spring fed and maintains a constant discharge, it is unlikely that the temperature of Lake Hanson frequently, if ever, exceeds the maximum acceptable temperature of 32.22^{o}C required to maintain the beneficial uses of the lake.

Alkalinity

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

Alkalinity values ranged from 202 mg/L to 344 mg/L during the project period. The maximum alkalinity measured in Lake Hanson during the project was 344 mg/L recorded on August 28, 2001 from the bottom of the lake at site LH1. This value falls well within the state standards of <750 mg/L mean and <1,313 mg/L for a single sample, indicating full support of this parameter.

Dissolved Oxygen

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

Dissolved oxygen concentrations for the surface and bottom of the lake are listed in Table 12. The beneficial use of warm-water, semi-permanent fish propagation requires a minimum DO of 5.0 mg/L. Samples collected on July 19, 2001 did not meet these standards. It is unclear why these samples were below the state standard. Chlorophyll *a* concentrations collected with this sample were low when compared with typical concentrations on this lake and other lakes in its ecoregion. It is unlikely that a large die off of algae occurred prior to the sample as no reports of a bloom were recorded.

Table 12. Lake Hanson DO Concentrations

Date	DO (mg/L)	Sample Depth	Site
5/31/01	10.2	Surface	LH2
7/19/01	4.25	Surface	LH2
5/31/01	10.02	Surface	LH1
7/19/01	4.66	Surface	LH1
9/25/01	11.91	Surface	LH1
5/31/01	10.02	Bottom	LH1
7/19/01	4.66	Bottom	LH1
9/25/01	11.3	Bottom	LH1

No fish kills were reported in Lake Hanson during the project period indicating that oxygen levels were sufficient to support the fish community. Possible explanations for the low readings could be linked to improper calibration of the meter or a short term drop in the DO that did not noticeably affect the fishery.

DO profiles were not collected during the project, but data from previous statewide lake assessments indicate that the lake can experience periods of stratification, particularly in the west (deeper) end of the lake. While the lake data for the project is limited, it does not appear that the lake was stratified while any of the samples were collected.

pH

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

Only six pH values were collected in Lake Hanson during the project period with three collected on both May 31, 2001 and July 19, 2001. Values ranged from 8.02 su to 8.06 su, well within the state standard of 6.5 su to 9.0 su. Data collected from statewide lake assessments in 1989, 1991, and 1992 indicate pH values ranging from 8.13 su to 8.34 su. None of these values exceed the state standards indicating that Lake Hanson does not experience impairment as a result of pH values.

Secchi Depth

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

Secchi disk readings recorded during the project at Lake Hanson ranged from 0.61 meters correlating to a TSI of 67.14 to .91 meters correlating to a TSI of 61.29 (Table 13). These measurements closely reflect historic values for this lake, which ranged from 0.77 meters to 0.87 meters, TSI values of 63.7 to 62.0 respectively. Insufficient data exists to correlate Secchi disk readings with chlorophyll or solids concentrations making it difficult to determine what factors influence the water clarity in Lake Hanson.

Table 13. Secchi Disk Readings for Lake Hanson

Water Body	Date	Secchi (m)	TSI
Lake Hanson	5/31/01	0.64	66.55
Lake Hanson	7/19/01	0.61	67.14
Lake Hanson	8/26/01	0.61	67.14
Lake Hanson	9/25/01	0.73	64.51
Lake Hanson	5/31/01	0.76	63.92
Lake Hanson	7/19/01	0.91	61.29
Lake Hanson	8/28/01	0.61	67.14
Lake Hanson	9/25/01	0.61	67.14
	Max	0.91	67.14
	Min	0.61	61.29
	Average	0.69	65.60

Chlorophyll *a*

Chlorophyll *a* is the primary photosynthetic pigment found in oxygen producing organisms (Wetzel, 1982). Chlorophyll *a* is a good indicator of a lake's productivity as well as its state of eutrophication. The total concentration of chlorophyll *a* is measured in mg/m3 (ppb) and is used in Carlson's Trophic State Index to rank a lake's state of eutrophication.

Chlorophyll *a* data from the project is limited but did not indicate excessive eutrophication. Lake Hanson is located in the Northern Glaciated Plains ecoregion (46). As indicated in "Ecoregion Targeting for Impaired Lakes in South Dakota" Stewart et. al. (2000), reservoirs in ecoregion 46 fully support their beneficial uses at TSI levels of less than 65.

Historically Lake Hanson chlorophyll concentrations (Table 14) only reached TSI levels greater than 65 in a sample and a field duplicate collected on August 7, 2000. Late summer samples are often indicative of the highest chlorophyll concentrations in most lakes located in eastern South Dakota. Other late summer samples from similar time periods (late summer) indicated concentrations of chlorophyll that fully support the beneficial uses of the lake. It is likely that occasional late summer algae blooms will result in TSI levels greater than 65 for short periods of time.

Table 14. Lake Hanson Chlorophyll *a* Data

Waterbody	Sample Date	Sample Time	Type	Total Chlorophyl	TSI
LAKE HANSON	11-Jul-91			9.83	52.99
LAKE HANSON	28-Jul-92			22.78	61.23
LAKE HANSON	26-Aug-92			20.10	60.01
LAKE HANSON	19-Jun-00	15:00		25.41	62.31
LAKE HANSON	07-Aug-00	13:45		36.88	65.96
LAKE HANSON	18-Jul-01	7:15		12.95	55.70
		Max		36.88	65.96
		Min		9.83	52.99
		Mean		21.32	59.70

Solids

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

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

Solids data collected during the project is presented in Table 15. State standards for suspended solids limit the daily maximum to be less than 158 mg/L. This was exceeded in the bottom sample collected on August 28, 2001. This is likely attributable to improper sampling techniques that allowed the Van Dorn sampler to contact the bottom sediments. Water quality data for this date, site, and depth will be omitted for other parameters as they are not representative of the actual water quality of the lake. The remaining samples are well within state standards indicating full support of this parameter. Dissolved solids concentrations also remained well within the state standard of 4,375 mg/L with a maximum concentration of 2,328 mg/L collected on September, 25, 2001 also indicating full support of this parameter.

Table 15. Solids Concentrations for Lake Hanson

Date	Depth	Site		Total	Suspended	Volatile Suspended	Dissolved	Percent Organic
5/31/01	Surface	LH2		1617	5	2	1612	40%
7/19/01	Surface	LH2		1909	9	4	1900	44%
8/26/01	Surface	LH2		1888	14	9	1874	64%
9/25/01	Surface	LH2		2343	15	9	2328	60%
5/31/01	Surface	LH1		1624	6	4	1618	67%
7/19/01	Surface	LH1		1889	43	0.5	1846	1%
8/28/01	Surface	LH1		1851	22	17	1829	77%
9/25/01	Surface	LH1		2295	16	10	2279	63%
5/31/01	Bottom	LH1		1767	11	4	1756	36%
7/19/01	Bottom	LH1		1858	7	4	1851	57%
8/28/01	Bottom	LH1		2199	196	28	2003	14%
9/25/01	Bottom	LH1		2304	16	10	2288	63%
	Max			2343	196	28	2328	
	Min			1617	5	1	1612	
	Average			1962	30	8	1932	

Nitrogen

Nitrogen is analyzed in four forms: nitrate/nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these four forms, total, organic, and inorganic nitrogen may be calculated. Nitrogen compounds are major cellular components of organisms. Because its availability may be less than the biological demand, environmental sources may limit productivity in freshwater ecosystems. Nitrogen is difficult to manage because it is highly soluble and very mobile. In addition, there are bacterial species capable of fixing atmospheric nitrogen for use by algae resulting in a virtually limitless supply of nitrogen.

Nitrogen concentrations as well as their minimum, maximum, and average values collected during the project are listed in Table 16. The state standards that relate to nitrogen concentrations in water are the nitrate standard of 50 mg/L mean or 88 mg/L for a single sample and the unionized ammonia standard of less than .04 mg/L for a 30 day average. As temperatures and pH values increase, the percent of unionized ammonia also increases.

Nitrate levels in Lake Hanson were below the detection limit in all samples indicating full support of this parameter. Ammonia levels were frequently found above the detection limit, however these concentrations remained sufficiently low to meet state standards and support the fish life.

Datasets collected in ’89, ’91, and ’92 had total nitrogen concentrations ranging from 1.18 mg/L to 1.64 mg/L. The current data indicate that there has been some reduction in the amount of nitrogen in the lake, possible reasons for this could include a reduction in the number of animal feeding operations in the watershed and improved conservation on cropland.

Table 16. Nitrogen Concentrations in Lake Hanson

Water Body	Date	Depth	Ammonia	Nitrate/Nitrite	TKN	Total	Organic	Inorganic
Lake Hanson	5/31/01	Surface	0.01	≤ 0.05	0.78	0.83	0.77	0.06
Lake Hanson	7/19/01	Surface	0.08	≤ 0.05	0.56	0.61	0.48	0.13
Lake Hanson	8/26/01	Surface	0.13	≤ 0.05	0.66	0.71	0.53	0.18
Lake Hanson	9/25/01	Surface	0.02	≤ 0.05	0.81	0.86	0.79	0.07
Lake Hanson	5/31/01	Surface	0.04	≤ 0.05	0.88	0.93	0.84	0.09
Lake Hanson	7/19/01	Surface	0.25	≤ 0.05	0.97	1.02	0.72	0.3
Lake Hanson	8/28/01	Surface	0.1	≤ 0.05	0.97	1.02	0.87	0.15
Lake Hanson	9/25/01	Surface	0.01	≤ 0.05	0.87	0.92	0.86	0.06
Lake Hanson	5/31/01	Bottom	0.04	≤ 0.05	0.76	0.81	0.72	0.09
Lake Hanson	7/19/01	Bottom	0.06	≤ 0.05	0.74	0.79	0.68	0.11
Lake Hanson	8/28/01	Bottom		≤ 0.05				
Lake Hanson	9/25/01	Bottom	0.03	≤ 0.05	0.95	1	0.92	0.08
		Max	0.25	≤ 0.05	1.21	1.26	0.92	0.37
		Min	0.01	≤ 0.05	0.56	0.61	0.48	0.06
		Average	0.09	≤ 0.05	0.85	0.90	0.76	0.14

Some difference was observed between site LH2 (East end by the inlet) to site LH1 (West end by the outlet). The ammonia and TKN concentrations at the inlet were 0.06 mg/L and 0.7 mg/L respectively. BATHTUB calculated a short nitrogen residence time of 13 days for the lake (due to continuous stream flow). As a result of this, it would be expected that both sites would have similar concentrations, however site LH1 was 67% higher at .1 mg/L for ammonia and 31% higher at 0.923 mg/L for TKN. Bottom samples were nearly the same as surface samples indicating that internal loading was very minimal. The most likely sources for this would either be the cabins on the lake or livestock use at the lake.

Phosphorus

Phosphorus is one of the macronutrients required for primary production. When compared with carbon, nitrogen, and oxygen, it is often the least abundant (Wetzel, 2000). Phosphorus loading to lakes can be of an internal or external nature. External loading refers to surface runoff, dust, and precipitation. Internal loading refers to the release of phosphorus from the bottom sediments to the water column of the lake. Total phosphorus is the sum of all attached and dissolved phosphorus in the lake.

Total dissolved phosphorus is the unattached portion of the total phosphorus load. It is found in solution, but readily binds to soil particles when they are present. Total dissolved phosphorus, including soluble reactive phosphorus, is more readily available to plant life than attached phosphorus. Table 17 lists the total and dissolved phosphorus data collected during the project.

There are no state standards relating to the concentration of phosphorus in water bodies. Phosphorus is an important measurement of a lakes productivity and is directly linked to its trophic state. Historic phosphorus concentrations for Lake Hanson range from 0.078 mg/L to 0.141 mg/L. Current concentrations of phosphorus indicate similar reductions to those observed for nitrogen (page 27). It is likely that the reasons for these reductions are similar; reduced numbers of animal feeding operations and improved conservation practices on cropland.

Table 17. Total and Dissolved Phosphorus Concentrations in Lake Hanson

Water Body	Date	Depth	Site	Total P	Total Dissolved P	TSI Phos
Lake Hanson	5/31/01	Surface	LH2	0.101	0.086	70.73
Lake Hanson	7/19/01	Surface	LH2	0.143	0.093	75.75
Lake Hanson	8/28/01	Surface	LH2	0.063	0.011	63.92
Lake Hanson	9/25/01	Surface	LH2	0.088	0.011	68.74
Lake Hanson	5/31/01	Surface	LH1	0.132	0.068	74.59
Lake Hanson	7/19/01	Surface	LH1	0.321	0.155	87.41
Lake Hanson	8/28/01	Surface	LH1	0.154	0.016	76.82
Lake Hanson	9/25/01	Surface	LH1	0.106	0.012	71.43
Lake Hanson	5/31/01	Bottom	LH1	0.121	0.070	
Lake Hanson	7/19/01	Bottom	LH1	0.146	0.102	
Lake Hanson	8/28/01	Bottom				
Lake Hanson	9/25/01	Bottom	LH1	0.117	0.012	
			Max	0.321	0.190	87.41
			Min	0.063	0.011	63.92
			Average	0.157	0.069	73.68

There were similar differences to those observed for nitrogen between site LH2 (east end by the inlet) and site LH1 (West end by the outlet). The mean total phosphorus concentration at the inlet was .098 mg/L, very similar to what the stream load was. Bathtub calculated a short phosphorus residence time of 9 days for the lake (due to continuous stream flow). As a result of this, it would be expected that both sites would have similar concentrations, however site LH1 was nearly double with a concentration of .178 mg/L.

Bottom samples were nearly the same as surface samples indicating that internal loading was minimal during the project. It is possible with the limited number of samples collected that the releases from the bottom sediments were not detected. Another possible explanation could be linked to mixing from continuous flow, although this would not seem likely as continuous mixing should have provided sufficient oxygenation of the bottom layers to prevent a release of phosphorus.

More likely explanations of what happened include mistakes in sampling techniques used for collection of bottom samples. If the anoxic zone were fairly thin, less than 3 feet, and the bottom samples were mistakenly collected at 4 to 5 feet from the bottom, they would likely have similar concentrations to surface samples. Finally, the increased concentrations could be the result of discharges from individual waste water systems and livestock located at the lake.

Fecal Coliform Bacteria

Fecal coliform are bacteria that are found in the waste of warm-blooded animals. Some common types of bacteria are *E. coli*, Salmonella, and Streptococcus, which are associated with livestock, wildlife, and human waste. (Novotny, 1994).

The state standard for fecal coliform between May 1 and September 30 is less than 400 colonies/ 100mL in any one sample. The geometric mean must remain less than 200 colonies/ 100mL based on samples collected during a minimum of five separate 24 hour periods for any 30-day period, and they may not exceed this value in more than 20 % of the samples examined in this same 30-day period.

All of the fecal coliform samples collected from Lake Hanson during the project are represented in Table 18. While none of the samples collected during the project from the lake indicated the presence of fecal contamination, examination of the 52 microbial samples collected from the swimming beach from 1993 through 2002 indicate that the lake does periodically experience unsafe levels of bacteria. In one instance (June of 1999) a beach closure was advised. Eight of the beach samples exceeded 400 colonies/ 100mL indicating that impairment of the lake occurs approximately 15% of the time that the beach is open for public use. It is possible that the source is beach use by people and pets, however, data from the tributary sites suggests that these impairments likely occur during or immediately following runoff events.

The source of the bacteria is unclear. Some contamination does occur from the watershed. The presence of permanent homes and cabins on the lake as well as livestock are also potential candidates for sources of impairment. Mitigation activities in the watershed should include further examination of sources at the lake or elimination of all potential through reducing or eliminating livestock contact with the lake and full containment of all wastewater generated by residents around the lake in addition to mitigation efforts described in the tributary site summary of this report.

Table 18. Bacteria Concentrations in Lake Hanson

Water Body	Date	Depth	Site	Fecal	*e. coli*
Lake Hanson	5/31/01	Surface	LH2	<10	20.3
Lake Hanson	7/19/01	Surface	LH2	10	23.3
Lake Hanson	8/26/01	Surface	LH2	10	3
Lake Hanson	9/25/01	Surface	LH2	29.2	30
Lake Hanson	5/31/01	Surface	LH1	20	8.4
Lake Hanson	7/19/01	Surface	LH1	<10	3.1
Lake Hanson	8/28/01	Surface	LH1	<10	5.2
Lake Hanson	9/25/01	Surface	LH1	<10	5
			Max	29	30.0
			Min	5	3.0
			Average	11	12.3

Limiting Nutrients

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

Figure 6 indicates the N:P ratios that were recorded during the project. The mean ratio of nitrogen to phosphorus for the project was 7.4:1, indicating that the lake is nitrogen limited. This is further reinforced when nitrate/nitrite (the most readily plant available form of nitrogen) are taken into consideration. Concentrations were consistently below the detection limit of 0.1 mg/L.

When recent samples are compared with historic samples collected in 1989, 1991, and 1992, some change is observed. The 1989 samples had a mean ratio of 9.0:1, indicating that it was nitrogen limited. The samples collected in 1991 and 1992 had ratios of 15.1:1 and 14.0:1 respectively. The later set of samples also had nitrate/nitrite concentrations above the detection limit, 0.6 mg/L and 0.45 mg/L for '91 and '92 respectively. Taking into consideration the nitrogen and phosphorus discussions (previous sections in this report) Lake Hanson has experienced reduced loading of both nitrogen and phosphorus. Reductions of the nitrogen load to the lake were greater than the phosphorus reductions, possibly resulting in a shift from phosphorus limitation in the early '90s to the current nitrogen limited state.

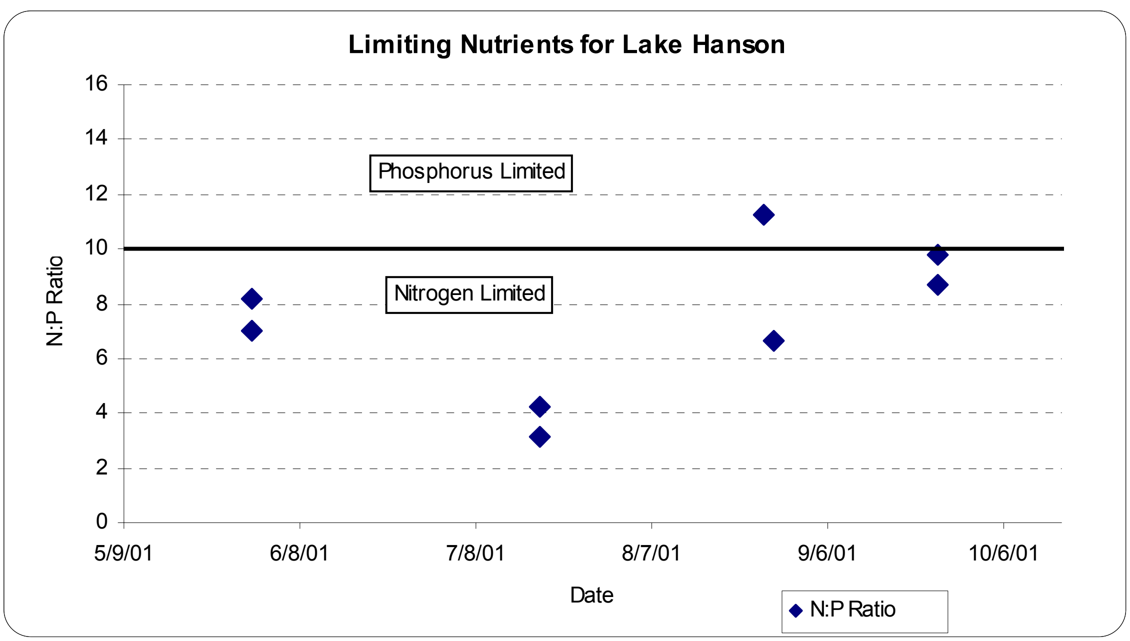


Figure 6. Limiting Nutrients for Lake Hanson

Trophic State

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

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

Table 19. Carlson's Trophic State Index

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

Individual measured TSI values as well as an average between dates are represented in Figure 7. TSI values for Lake Hanson ranged from 55.7 (chlorophyll sample collected on 7/19/01) to 87.4 (phosphorus sample collected on 7/19/01). Mean TSI values are typically only calculated on dates where data for Secchi, phosphorus, and chlorophyll are all available. Due to the fact that there is only one chlorophyll sample during the assessment, values were calculated for dates in which only Secchi and phosphorus data existed as well as the sample on 7/19/01 with all three parameters. Mean values ranged from 65.5 to 72.0 during the assessment.

TSI chlorophyll values in eastern South Dakota Lakes are typically less than TSI phosphorus or TSI Secchi values. Had TSI chlorophyll data been available, it is likely that TSI values would have been lower. If the mean TSI for the sample on 7/19/02 is calculated without the chlorophyll value, it changes from 68.1 to 74.3, a 6 point increase. With a conservative assumption that chlorophyll data would reduce each mean TSI by 4 points for each sample date that does not have it, the mean TSI for the assessment would change from 68.8 to 65.3. A TSI of 65.3 should be used as the starting point for reductions because it reflects the current state of Lake Hanson better than 68.8.

Lake Hanson requires a TSI of 65 to fully support its beneficial uses. Taking into consideration margins of error, it is likely that the lake is fully supporting its beneficial uses and that all mitigation activities should be completed as a margin of safety to ensure full support is maintained.

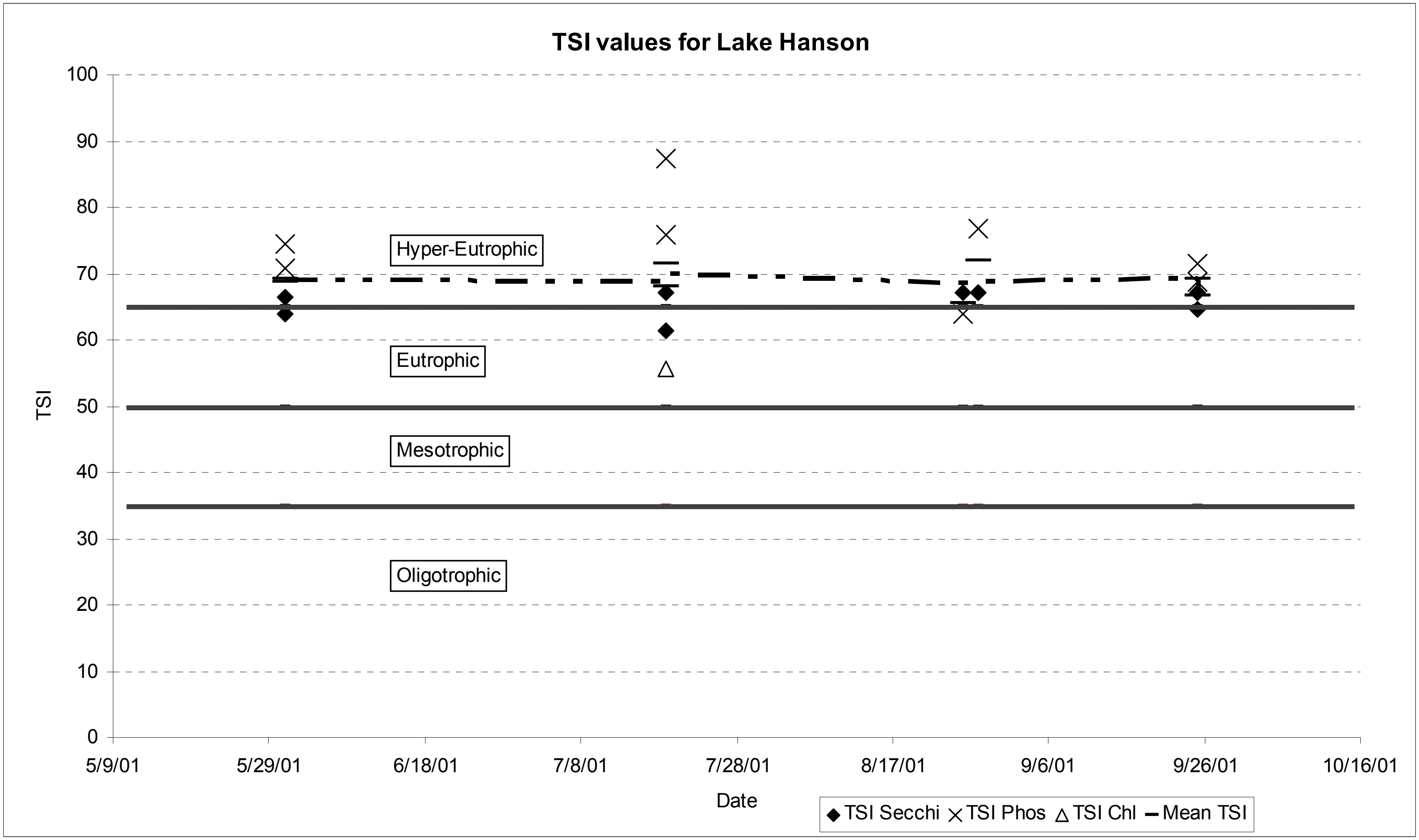


Figure 7. Measured Trophic State by Date for Lake Hanson

Reduction Response Modeling

Inlake reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model (Walker, 1999). System responses were calculated using reductions in the loading of phosphorus to the lake from Pierre Creek. Loading data for Pierre Creek was taken directly from the results obtained from the FLUX modeling data calculated for the inlet to the lake. Atmospheric loads were provided by SDDENR. A summary of the data is listed in Figure 8.

BATHTUB provides numerous models for the calculation of inlake concentrations of phosphorus, nitrogen, chlorophyll *a*, and Secchi depth. Models are selected that most closely predict current inlake conditions from the loading data provided. As reductions in the phosphorus load are predicted in the loading data, the selected models will closely mimic the response of the lake to these reductions. Due to differences in calculation methods, the TSI values in the BATHTUB model outputs will be slightly different from those calculated in the report

BATHTUB not only predicts the inlake concentrations of nutrients; it also produces a number of diagnostic variables that help to explain the lake responses. Table 20 shows the response to reductions in the phosphorus load. The observed and predicted water quality for Lake Hanson had less than .1% difference between them indicating that model responses should closely represent actual changes in the lakes condition.

The variables (N-150)/P and INORGANIC N/P are both indicators of phosphorus and nitrogen limitation. The first, (N-150)/P, is a ratio of total nitrogen to total phosphorus. Values less than 10 are indicators of a nitrogen-limited system. The second variable, INORGANIC N/P, is an inorganic nitrogen to ortho-phosphorus ratio. Values less than 7 are nitrogen-limited. The current state of Lake Hanson is nitrogen-limited. Phosphorus limitation is not possible with 50% or less reductions in the phosphorus load from Pierre Creek.

The variables FREQ (CHL-a)% represent the predicted algal nuisance frequencies or bloom frequencies. Blooms are often associated with concentrations of 30 to 40 ppb of total phosphorus. These frequencies are the percentage of days during the growing season that algal concentrations may be expected to exceed the respective values. The model predicts small yet consistent reductions in bloom frequency to reductions in phosphorus loads from Pierre Creek. It is unclear why the model predicts increased chlorophyll concentrations with increased depth, a possible explanation is the assumption that there will be less macrophyte growth to consume excess nutrients.

The model does predict some reduction in TSI as a result of dredging. Due to the data used to develop the model, it automatically assumes a certain amount of internal loading. As a result of this, the predicted reductions as a result of dredging may actually be less than what will be observed through water quality measurements.

Table 20. BATHTUB Calculations for Lake Hanson

	Phosphorus load reductions without dredging						Phosphorus loads with dredging					
Mean Depth	2.4	2.4	2.4	2.4	2.4	2.4	3.4	3.4	3.4	3.4	3.4	3.4
% Reduction	0%	10%	20%	30%	40%	50%	0%	10%	20%	30%	40%	50%
VARIABLE	Current	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
TOTAL P MG/M3	138.82	129.22	119.59	109.22	98.75	87.78	126.15	117.78	109.37	100.27	91.05	81.33
TOTAL N MG/M3	864.54	864.54	864.54	864.54	864.54	864.54	851.32	851.32	851.32	851.32	851.32	851.32
C.NUTRIENT MG/M3	54.72	54.08	53.3	52.28	50.99	49.28	53.03	52.35	51.55	50.49	49.18	47.46
CHL-A MG/M3	27.11	26.46	25.71	24.8	23.72	22.41	29.61	28.79	27.88	26.76	25.48	23.93
SECCHI M	0.69	0.69	0.7	0.71	0.73	0.75	0.7	0.71	0.72	0.73	0.75	0.77
ORGANIC N MG/M3	834.48	819.53	802.56	781.65	757.21	727.2	891.39	872.78	851.9	826.51	797.27	761.96
ANTILOG PC-1	858.39	831.88	801.53	763.85	719.53	664.93	895.54	864.44	829.31	786.35	736.63	676.52
ANTILOG PC-2	9.86	9.75	9.63	9.49	9.33	9.14	10.84	10.69	10.54	10.35	10.15	9.9
(N - 150) / P	5.15	5.53	5.97	6.54	7.24	8.14	5.56	5.95	6.41	6.99	7.7	8.62
INORGANIC N / P	0.4	0.67	1.05	1.64	2.56	4.12	0.02	0.02	0.02	0.65	1.74	3.7
FREQ(CHL-a>10) %	90.3	89.61	88.75	87.59	86.07	83.93	92.52	91.86	91.05	89.94	88.47	86.38
FREQ(CHL-a>20) %	57.18	55.63	53.8	51.47	48.61	44.95	62.66	60.95	58.93	56.36	53.22	49.17
FREQ(CHL-a>30) %	31.8	30.4	28.81	26.85	24.55	21.75	37.02	35.33	33.41	31.06	28.32	25
FREQ(CHL-a>40) %	17.43	16.43	15.32	13.98	12.45	10.66	21.32	20.04	18.61	16.9	14.98	12.74
FREQ(CHL-a>50) %	9.73	9.07	8.34	7.47	6.52	5.43	12.4	11.5	10.52	9.37	8.11	6.7
FREQ(CHL-a>60) %	5.58	5.15	4.68	4.13	3.54	2.88	7.36	6.75	6.1	5.35	4.54	3.65
CARLSON TSI-P	75.29	74.25	73.14	71.83	70.38	68.68	73.91	72.92	71.85	70.6	69.2	67.58
CARLSON TSI-CHLA	62.97	62.73	62.45	62.1	61.66	61.1	63.84	63.56	63.25	62.85	62.36	61.75
CARLSON TSI-SEC	65.43	65.29	65.13	64.91	64.63	64.24	65.07	64.93	64.75	64.51	64.21	63.81
Mean TSI	67.9	67.4	66.9	66.3	65.6	64.7	67.6	67.1	66.6	66.0	65.3	64.4

Table 21. BATHTUB Calculations Legend

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

Biological Monitoring

Fishery

South Dakota Game Fish and Parks conducts statewide fishery surveys of public fishing waters in South Dakota. The data in this section is taken directly from the most recently published survey which was completed on June 6 of 2000. The species collected during this survey may be found in Table 20, all species were collected by electrofishing. Lake Hanson currently has no fishery management plan.

Table 22. Fish Species Present in Lake Hanson

Primary Game Species	Secondary and Other Species
Largemouth Bass	Walleye
Bluegill	Saugeye
White Crappie	Common Carp
Black Crappie	Channel Catfish
	Black Bullhead
	Green Sunfish

A total of 1.3 hours of electrofishing was conducted on the survey date. The catch consisted of Bluegill (30.3%), white crappie (20.0%), walleye (17.0%), and black crappie (16.4%) making up the majority. Other species sampled included common carp, saugeye, largemouth bass, black bullhead, channel catfish, and green sunfish.

Only 8 largemouth bass were sampled during the survey that year and all were at least 4 years old indicating that natural reproduction has been poor. The largemouth bass are growing slower than average for South Dakota waters. Lake Hanson may not be able to support populations of walleye, saugeye, and largemouth bass.

The majority of the bluegill population sampled that year ranged in length from 5.5 to 7.0 inches and growth was above average for South Dakota waters.

White crappies sampled ranged in length from 6.7 to 9.4 inches. Black crappies consisted of two year classes, one ranging from 4.3 to 5.1 inches in length and the other from 7 to 9 inches.

Walleye and saugeye were introduced into Lake Hanson in 1996 as part of an SDSU study designed to research their performance in small impoundments. Most of the fish are still less than 14 inches in length.

At least two more years of electrofishing data will be needed before any recommendations concerning the fish populations can be made. Lake Hanson contains excellent populations of panfish that should provide excellent angling opportunity. Continued all-species electrofishing every other year to monitor the fishery was planned.

Aquatic Macrophyte Survey

DENR staff conducted an aquatic macrophyte survey during late August, 2001. Thirteen transects were located at approximately 300 meter intervals along the shoreline of the lake. No aquatic emergent or submerged vegetation were encountered at any of the transects. Secchi readings were also recorded at each site along with a habitat assessment.

The primary focus of the survey was to document the existence of invasive species, such as Eurasian water milfoil, in the lake. At no point during the survey were any of these invaders encountered. While no vegetation was recorded during this survey, aquatic macrophytes have created a nuisance in Lake Hanson during previous years through excessive growth.

Table 23 identifies the bank stability and riparian zone condition at each of the transects as well as the primary land use at each site and a habitat assessment score. Habitat scores are based on a narrative description with associated values ranging from 0 to 10 for each of the parameters.

There appears to be very little overall difference between the areas with cabins and those that are grazed. The shoreline along the cabins had better bank stability, which is due to the use of riprap and cement. Some shoreline erosion may be reduced on the grazed portions of the lake if a permanent riparian zone is established and stabilization of the bank is completed either through hard (rip rap) or soft (vegetation) practices.

Table 23. Aquatic Macrophyte Survey

Transect #	1	2	3	4	5	6	7
Bank Stability	9	10	8	1	1	4	8
Vegetative Protection	1	2	8	2	1	4	9
Riparan Veg Zone	0	0	3	2	2	3	5
Total Score	10	12	19	5	4	11	22
Land use	Cabins	Dam	Graze	Graze	Graze	Graze	Graze
Secchi (meters)	0.5	0.3	0.5	0.7	0.5	0.35	0.9

Transect #	8	9	10	11	12	13
Bank Stability	5	7	8	9	10	8
Vegetative Protection	5	6	8	0	2	10
Riparan Veg Zone	2	3	4	1	1	9
Total Score	12	16	20	10	13	27
Land use	Graze	Graze	Native	Cabins	Cabins	Cabins
Secchi (meters)	0.4	0.2	0.4	0.7	0.75	0.5

Threatened and Endangered Species

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

Bald eagles typically prefer large trees for perching and roosting. As there are no confirmed documentation of bald eagles within the Pierre Creek watershed, little impact to the species should occur. Any mitigation processes that take place should avoid the destruction of large trees that may be used as eagle perches, particularly if an eagle is observed using the tree as a perch or roost.

The Topeka Shiner is an endangered species that occurs in the small prairie streams in pools containing clear, clean water. These streams generally have clean gravel, rock or sand bottoms. However, these fish have been found in streams where silt covered these substrata. South Dakota State University (SDSU) is currently involved with the Topeka Shiner Study. The Topeka Shiner was once abundant and widely distributed throughout the Central Plains and western tall grass region. Present estimate are that the species now inhabits less than 10 percent of its original geographical range. However, recent findings from the SDSU study suggest that the Topeka Shiner may inhabit significantly more than 10 percent of its original range in South Dakota. The actions most likely to impact the species are sedimentation and eutrophication resulting from intensive agricultural development. Feedlot operations on or near streams are also known to impact prairie fishes because of the organic input that causes eutrophication. Intensive land use practices, maintenance of altered waterways, de-watering of streams, tributary impoundments, and channelization are the greatest threats to the Topeka Shiner. Over grazing of riparian zones along streams and the removal of riparian vegetation to increase tillable acreage greatly diminishes a watershed’s ability to filter sediments, organic wastes, and other impurities from the stream system.

Four specimens of the Northern Cricket Frog (*Acris Crepitans)* were collected from Pierre Creek near Lake Hanson on May 27, 1959 and are stored at the University of South Dakota. This species is listed by the State of South Dakota as rare. Northern Cricket Frogs are olympic jumpers using their strong hind legs to propel themselves distances of three feet in a single jump. They hang around the water's edge and stay still to blend in with the muddy bank or hop into the water to escape danger. They do not like deep water, however, and instead of diving and remaining submerged like other frogs, they swim quickly in a semi circle to another location on the shore. Cricket Frogs breed late; June through July and sometimes later. The males make a "glicking" call that sounds like two pebbles being struck together. They start out slow and then increase the rapidity until the individual "glicks" cannot be singled out. Females lay several clutches of eggs numbering up to 200 eggs per clutch. These are attached to vegetation underwater. The tadpoles are about an inch long when they hatch and they morph into froglets in about 7 weeks. The young frogs stay active later in the year than adults. (LeClere, 2002)

Other Monitoring

Annualized Agricultural Non-Point Source Model (AnnAGNPS)

AnnAGNPS is a data intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into cells of varying sizes based on topography. Each cell is then assigned a primary land use and soil type. Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells and reductions are calculated at the outlet to the watershed.

The input data set for AnnAGNPS Pollutant Loading Model consists of 33 sections of data, which can be supplied by the user in a number of ways. This model execution utilized; digital elevation maps (DEM's) to determine cell and reach geometry, SSURGO soil layers to determine primary soil types and the associated NASIS data tables for each soils properties, and primary land use based on a 40 acre grid pattern, collected initially with the intention of executing the AGNPS version 3.65 model. Impoundment data was obtained from analysis of the National Wetlands Inventory (NWI). Weather data was generated using a synthetic weather generator based on climate information from the two closest stations, Huron and Sioux Falls. Mean annual precipitation for this watershed is about 21 inches.

It is important to note that these model results are based on 10 simulated years of data with precipitation ranging from 14 to 28 inches per year. None of these represent 2001, which experienced over 29 inches of precipitation.

Part of the modeling process includes the assessment of animal feeding operations (AFOs) located in the watershed. This assessment was completed with the assistance of the conservation district which provided estimates on the number of animal units and duration of use. Execution of the stand alone feedlot assessment model as well as analysis using the annualized version of the model indicated that nutrient production in the assessed lots (located in Figure 10) did not have a major impact accounting for less than 2% of total phosphorus loadings to the lake.

Bacterial loading problems addressed earlier in the assessment for the lower reaches of Pierre Creek could not be addressed using the AnnAGNPS model. To determine the potential impact that the various animal feeding operation could have on Lake Hanson, fecal decay rates were calculated for the animal feeding operations in the watershed. Only two of them have significant potential for bacterial contamination of the lake, lots number 559 and 999.

Through the use of the fecal decay rate equation, it was found that lots 559 and 999 have the potential to deliver 70% to 90% of the fecal bacteria washing from the lots to the lake.

Fecal Decay Rate Equation:

$$\text{Percent Delivered} = 100 * e^{-.51\,(\text{Distance in Miles/ Velocity in Miles per Day})}$$

An additional thirteen AFOs were assessed and found to have little or no impact based on a variety of reasons, insufficient animal numbers, lack of defined drainage to the creek, or the lot was no longer in use.

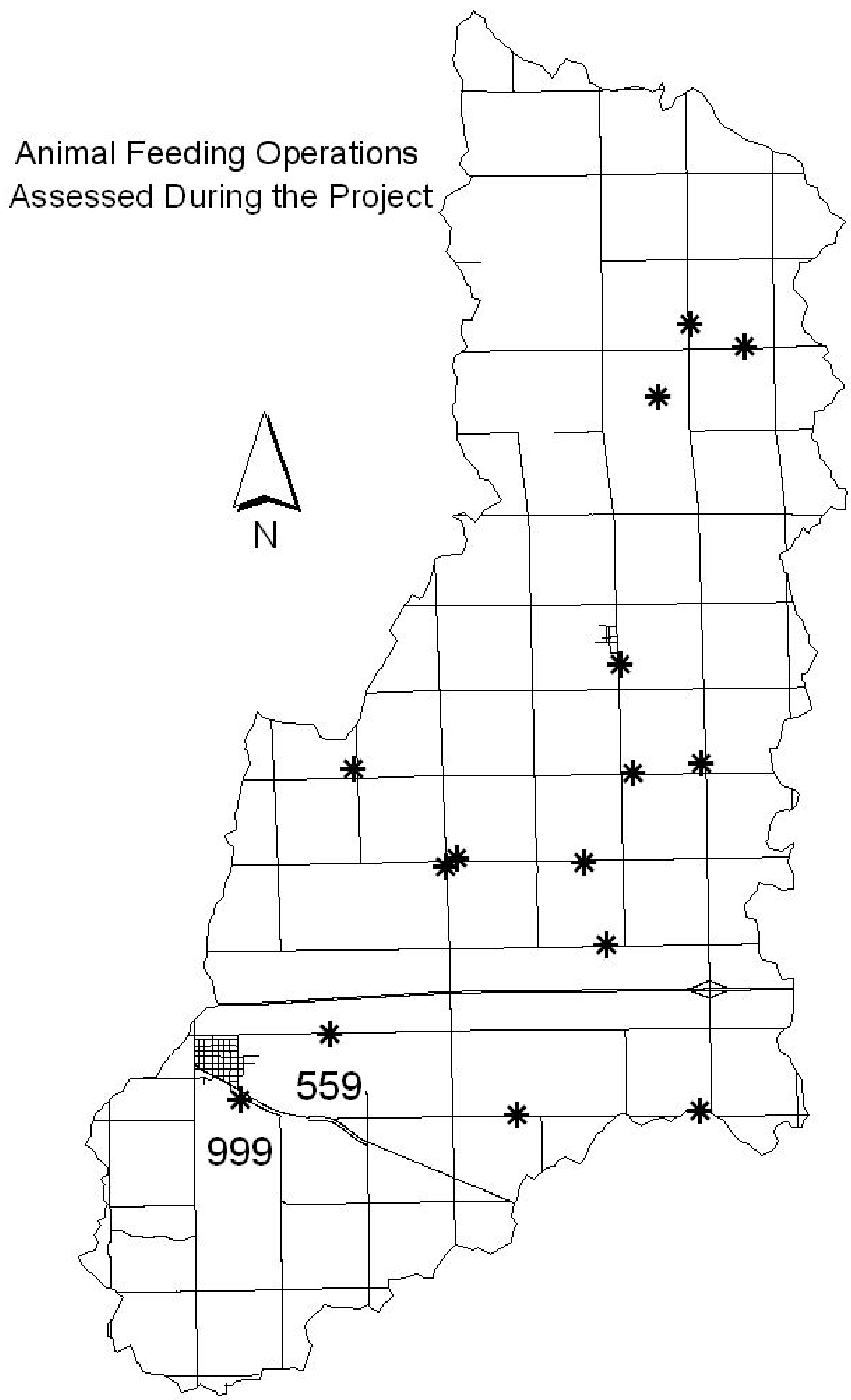


Figure 8. Lake Hanson Animal Feeding Operations

Determination of the most critical cells for nutrient loadings to Lake Hanson was completed using the model. Figure 11 depicts these cells in addition to areas in the watershed that were identified during the land use survey as using conventional tillage practices, defined as breaking the soil both in the fall and in the spring.

The AnnAGNPS model identified approximately 5,500 acres of critical acres within the Lake Hanson watershed. Of these, over 3,200 acres were associated with conventional tillage practices. The economic and social benefits to conservation tillage have become increasingly recognized and accepted throughout the state of South Dakota over recent years. It is likely that the trend to more conservation tillage will result in continued benefits and additional protection to this water body as well as many others throughout the state. Informational and educational programs in this watershed may help to expedite this process.

Sediment delivery rates predicted by the AnnAGNPS model were completed for the watershed under its current condition and also simulating 80% of the fields with conventional tillage practices, as would have been expected 20 to 30 years ago. Sediment accumulations in the lake have been reduced by 57% with the use of conservation tillage. Conventional tillage practices resulted in an annual accumulation of 243 tons of sediment each year. The model predicts that current practices are resulting in 105 tons on an average annual basis.

With the simulated conversion of all tillage practices in the watershed to no till systems, a predicted sediment accumulation of 25 tons per year is estimated. Similarly, if the entire watershed were converted to grass in a condition similar to what would be found in CRP, the sediment accumulation in the lake is reduced to nearly nothing at less than 1 ton per year. This reinforces the need to promote conservation tillage in the watershed in an effort to lengthen the useable life of the reservoir.

The combination of increased implementation of conservation tillage, grazing management and reduction of runoff from the identified animal feeding operations will result in reductions in sediment and phosphorus. Conservative estimates of at least 5% to 10% can be expected.

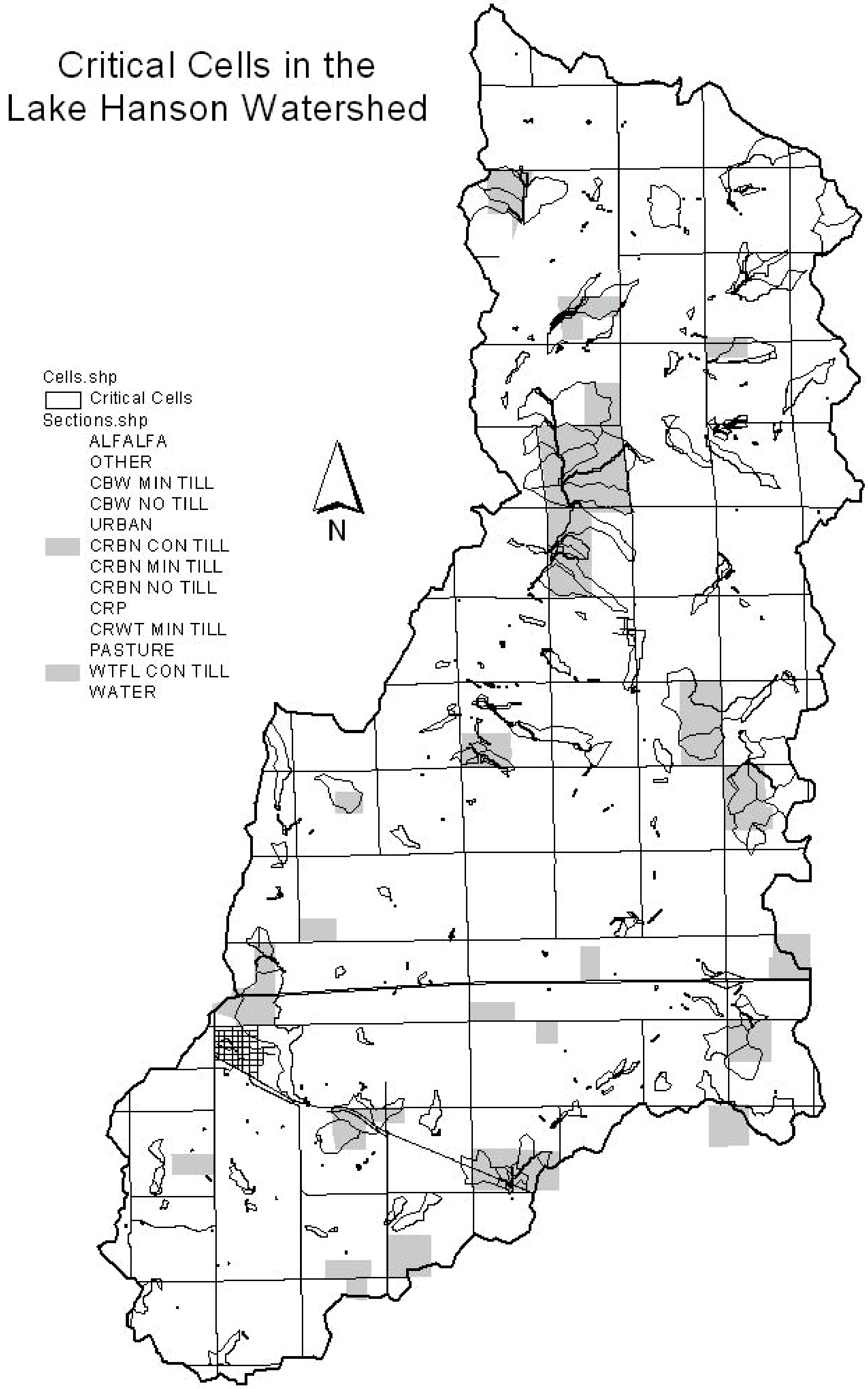


Figure 9. Critical Nutrient Cells in the Lake Hanson Watershed

Sediment Survey

Elutriate samples were collected with a Petite Ponar and shipped to the State Health Lab for analysis. In addition to sediment, a volume of 3 gallons of water were collected at each of the testing sites and were analyzed for the same chemicals as the sediment. Table 24 indicates the various parameters that were tested for in the elutriate sample.

Results from the elutriate and receiving water tests yielded many concentrations below the detection limit. Those metals and chemicals that were detected were not at concentrations high enough to generate any concern.

Table 24. Elutriate and Receiving Water Test Results

Parameter	Elutriate	Receiving Water	Units	Parameter		Elutriate	Receiving Water	Units
COD	28.4	14	mg/L	Alachlor		<0.100	<0.100	ug/L
Total Phosphorus	0.107	0.019	mg/L	Chlordane		<0.500	<0.500	ug/L
TKN	4.26	0.39	mg/L	Endrin		<0.500	<0.500	ug/L
Ammonia	3.96	0.03	mg/L	Heptachlor		<0.400	<0.400	ug/L
Hardness	1460	1440	mg/L	Heptachlor Epoxide		<0.500	<0.500	ug/L
Nitrate	<0.1	0.1	mg/L	Methoxychlor		<0.500	<0.500	ug/L
Aluminum	0.6	<0.3	ug/L	Toxaphene		NonDetect	NonDetect	
Zinc	7.6	<2.0	ug/L	Aldrin		<0.500	<0.500	ug/L
Silver	<0.2	<0.2	ug/L	Dieldrin		<0.500	<0.500	ug/L
Selenium	1.7	<0.5	ug/L	PCB Screen	Aroclor 1016	<0.100	<0.100	ug/L
Nickel	10	10.7	ug/L		Aroclor 1221	<0.100	<0.100	ug/L
Total Mercury	<0.1	<0.1	ug/L		Aroclor 1232	<0.100	<0.100	ug/L
Lead	<0.1	<0.1	ug/L		Aroclor 1242	<0.100	<0.100	ug/L
Copper	1	1	ug/L		Aroclor 1248	<0.100	<0.100	ug/L
Cadmium	<0.2	<0.2	ug/L		Aroclor 1254	<0.100	<0.100	ug/L
Arsenic	0.006	<.001	mg/L		Aroclor 1260	<0.100	<0.100	ug/L
Nitrite	<0.02	<0.02	mg/L	Diazinon		<0.500	<0.500	ug/L
Endosulfan II	<0.500	<0.500	ug/L	DDD		<0.500	<0.500	ug/L
Atrazine	<0.100	<0.100	ug/L	DDT		<0.500	<0.500	ug/L
				DDE		<0.800	<0.800	ug/L
				Beta BHC		<0.500	<0.500	ug/L
				Gamma BHC		<0.500	<0.500	ug/L
				Alpha BHC		<0.500	<0.500	ug/L

A sediment survey was performed on Lake Hanson May 29, 2002. The survey was performed from a boat using a ½-inch diameter spud bar to sound the sediment depth and a global positioning unit to locate the sampling points. Both water and sediment depths were measured at each sampling location. Soundings were taken at 83 locations. The figure above shows the sampling locations and the distribution of sediment throughout the lake. The maximum water depth was 15-feet, and the average water depth was 7.6-feet. The volume of the reservoir was approximately 240 acre-feet. The maximum sediment depth recorded was 7.5-feet, and the average sediment depth was 2.9-feet. The sediment volume was estimated at 200,000-cubic yards.

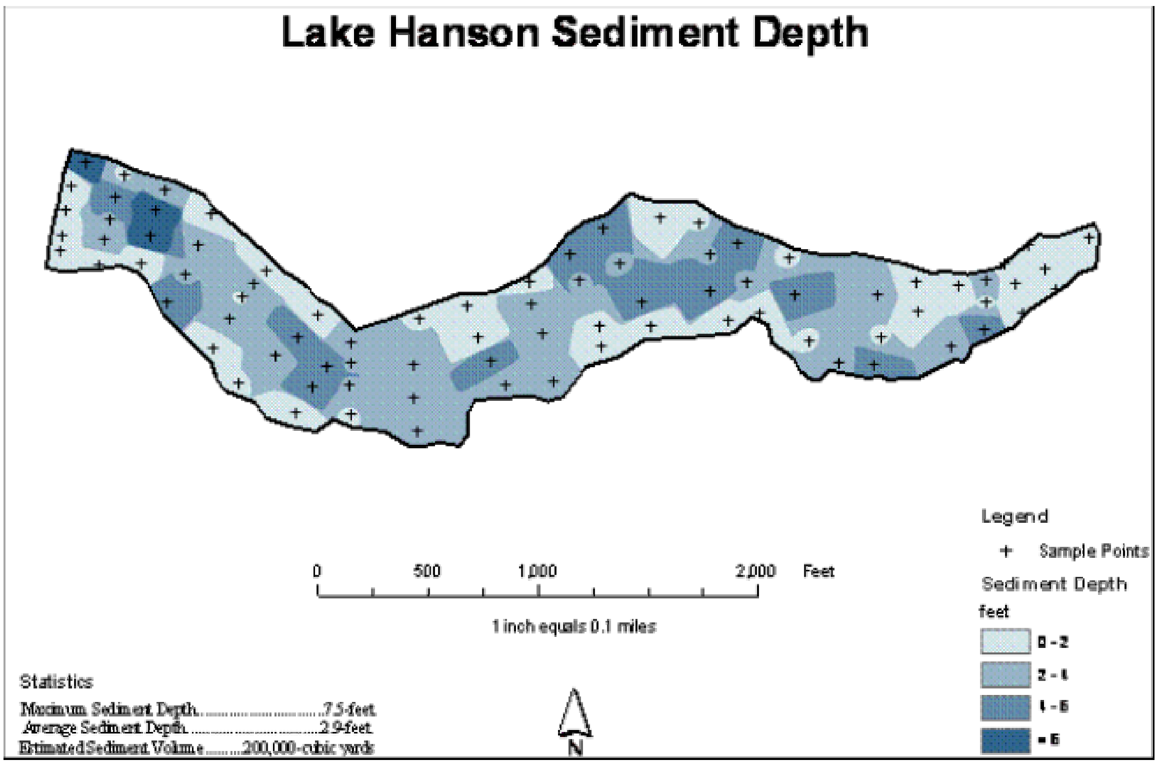


Figure 10. Lake Hanson Sediment Map

Quality Assurance Reporting (QA/QC)

Quality assurance and quality control or QA/QC samples were supposed to be collected for 10% of the inlake and tributary samples taken. A total of 33 tributary samples and 8 lake samples were collected along with three replicate samples representing analysis of 7% of the data collected. All QA/QC samples may be found in Table 25. No blank samples were collected during the project.

Replicate samples for alkalinity, total solids, nitrates, TKN, and dissolved phosphorus were all under 10% mean percent difference for the three replicate samples indicating good precision for these parameters. Total phosphorus and suspended solids had mean percent differences of 12% and 17% respectively indicating fair precision for these parameters.

Table 25. Quality Assurance/ Quality Control Data

Date	Site	Talka	Tsol	Tssol	Vtss	Ammo	Nit	TKN	TP	TDP	Fecal	*E. coli*
8/27/01	LHT1	395	2780	12	2	0.03	0.1	0.18	0.055	0.025	240	231
8/27/01	LHT1	394	2779	14	3	0.07	0.1	0.18	0.053	0.027	320	72.8
Percent Difference		0%	0%	15%	40%	80%	0%	0%	4%	8%	29%	104%
8/27/01	LHO	223	1913	33	26	0.11	0.05	1.58	0.304	0.016	20	1
8/27/01	LHO	223	1921	35	30	0.28	0.05	1.87	0.394	0.016	5	2
Percent Difference		0%	0%	6%	14%	87%	0%	17%	26%	0%	120%	67%
8/27/01	LHT2	447	3532	6	1	0.12	0.1	0.18	0.297	0.208	180	272
8/27/01	LHT2	447	3536	8	2	0.01	0.1	0.18	0.276	0.208	350	365
Percent Difference		0%	0%	29%	67%	169%	0%	0%	7%	0%	64%	29%
Avg % Difference		0%	0%	17%	40%	112%	0%	6%	12%	3%	71%	67%

Fecal coliform and *E. coli* samples had significant variance between replicates. This may most easily be explained as the natural variation of bacterial samples collected from the environment as these are frequently not as close as the other parameters.

Volatile suspended solids had a large percent difference mostly due to the low concentrations. Although the difference was large, acceptable accuracy can still be expected in the loadings and concentrations for this parameter.

During the project ammonia samples exhibited unusually high variation. It is unclear why these samples varied so much. Had blank samples been collected, this may have provided some indication as to whether the samples were being contaminated or if the bottles had not been properly rinsed prior to sample collection.

Public Involvement and Coordination

State Agencies

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

South Dakota Department of Game, Fish and Parks also aided in the completion of the assessment by providing historical information on use of the recreation area and a complete report on the condition of the fishery in Lake Hanson.

Federal Agencies

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

Natural Resource Conservation Service (NRCS) provided technical assistance, particularly in the collection of soils data for the AnnAGNPS portion of the report.

The Farm Service Agency provided a great deal of information that was utilized in the completion of the AnnAGNPS modeling portion of the assessment.

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

The Hanson County Conservation District provided work space, financial assistance, and aided in the completion of the AnnAGNPS portion of the report. The district also provided personnel for the collection of the field data.

Public involvement consisted of some individual meetings with landowners that provided a great deal of historic perspective on the watershed. Additionally, landowners were contacted through mailings to which most responded with information needed to complete the AGNPS model.

Aspects of the Project that did Not Work Well

All of the objectives proposed for the project were met in an acceptable fashion and in a reasonable time frame (see the milestone table on page 6). The number of tributary samples collected during the project was less than proposed, but adequate for the completion of the report.

There was fewer lake samples collected than were proposed. This was due in part to poor ice conditions that persisted on the lake for an extended period of time preventing travel by foot or boat. Summer sampling was not completed as frequently as planned, this is likely due to the fact that the coordinator was also involved with other job functions for the district. The best solution for preventing this from occurring in future projects is to hire a coordinator who will be solely involved in the project and not have other job obligations for the sponsor that will impede the collection of data.

The quality assurance/ quality control dataset was not complete and efforts should be made on future projects to ensure that an adequate number of duplicate and blank samples are collected.

Future Activities Recommendations

There are a number of concerns that need to be addressed in the Pierre Creek and Lake Hanson watershed. Mitigation processes in this watershed should take into consideration the following items:

1. Animal feeding operations do not have a major impact on the nutrient load to Lake Hanson accounting for less than 2% of the total annual load of phosphorus. There does appear to be some risk of bacterial contamination as a result of the two lots identified in the AnnAGNPS section of this report.

2. Grazing management along the stream corridor from I-90 to the lake will prove beneficial in reducing fecal loads and will likely reduce sediment and nutrient loading. The most beneficial practices include the establishment of permanent riparian zones and alternative water sources for livestock.

3. Contact with the district indicated that a sediment trap may have been located upstream of the lake at one point in time. Reconditioning of this trap may help reduce sediment accumulations in Lake Hanson in the future.

4. Promotion of conservation tillage practices in the watershed will provide further protection for the lake from both nutrients and sediments.

5. Bank stabilization along the south shore of the lake with either hard (rip-rap) or soft (vegetation) practices will help reduce sedimentation as well as nutrient and bacterial loads associated with livestock located in adjacent pastures. The establishment of a permanent riparian zone and the provision of an alternative watering source should result in the greatest benefits.

6. Full containment of all waste water produced by residents along the lake, or those with failing or insufficient systems will reduce nutrient and possibly bacterial loadings to the lake.

7. Dredging the excess sediment from the lake will increase the number of boatable acres in the lake, reduce the potential for excessive plant growth, and remove nutrient rich sediments that could potentially increase nutrient concentrations in the lake during periods of stratification. Dredging may also help to indicate those residences along the lake with inadequate waste water management systems.

In addition to "on the ground" management practices, the use of informational meetings and materials will also aid in local understanding and involvement in a project. Continued monitoring as well as a post-implementation assessment should be completed to determine the effectiveness of best management practices completed.

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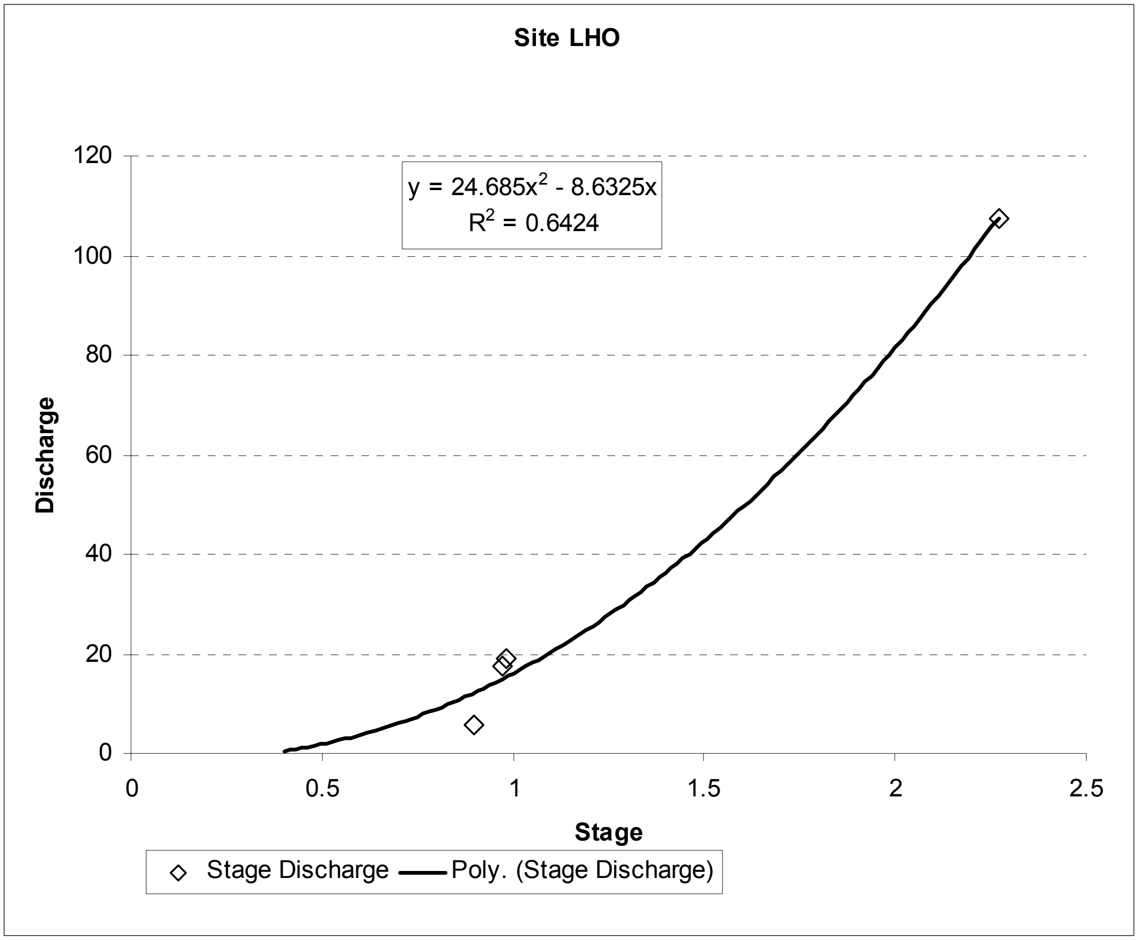
List of Tables

List of Figures

List of Appendices

Appendix A. Stage to Discharge Tables



Lake discharges will be based on the data collected at Site LHT1 and Site LHO from July 5 to August 29 at a rate of Lake Discharge is 5.5 CFS greater than inlet volume. This date range appears to be the best and will provide the best estimate of discharges for dates with no data and those dates from 5/23 to 6/28 and 9/26 through 10-30 during which the gauging equipment did not operate correctly.

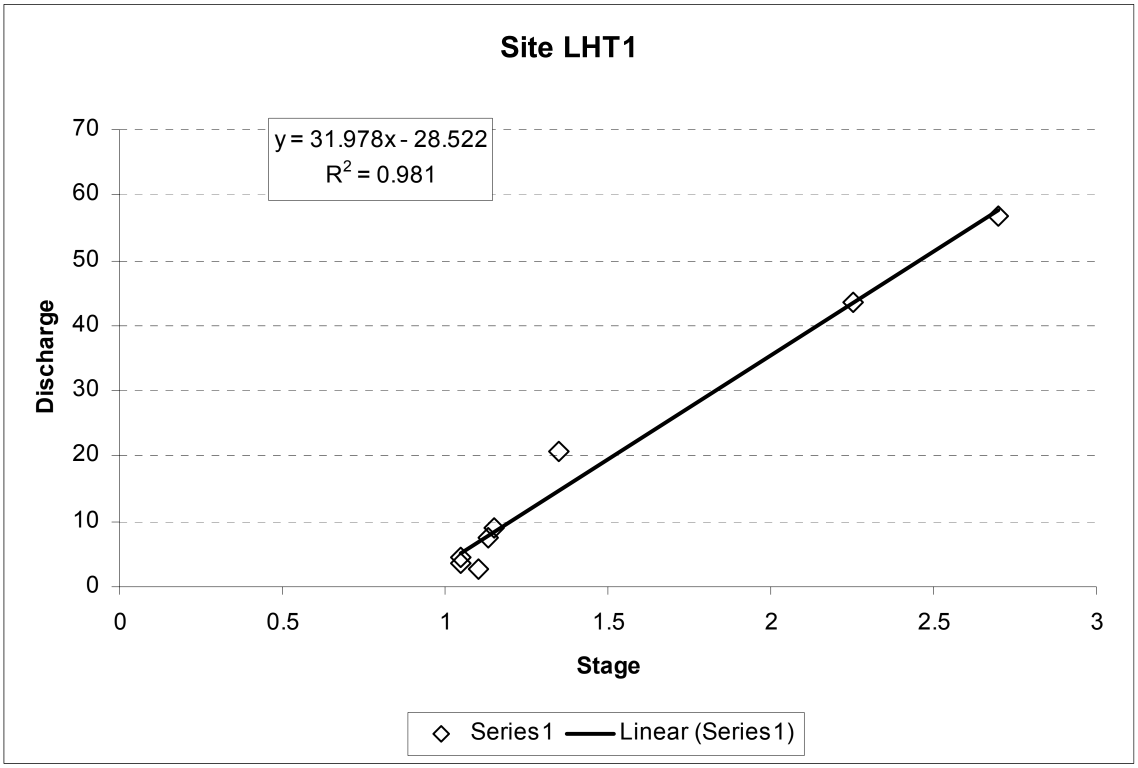
Discharge HLT 1	date	HLO Stage from data sheets	HLO Discharge	Field Notes
0.00	4/1/2001		0.00	
0.00	4/2/2001		0.00	
0.00	4/3/2001		0.00	
0.00	4/4/2001		0.00	
0.00	4/5/2001		0.00	
0.00	4/6/2001		0.00	
0.00	4/7/2001		0.00	
0.00	4/8/2001		0.00	
0.00	4/9/2001		0.00	
0.00	4/10/2001		0.00	
0.00	4/11/2001		0.00	
0.00	4/12/2001		0.00	
0.00	4/13/2001		0.00	
0.00	4/14/2001		0.00	

Chart Data		
Date	Stage	Discharge
4/20/2001		12.14
4/26/2001		49.34
7/26/2001	2.27	107.45
8/27/2001	0.9	5.66
9/26/2001	0.97	17.53
10/30/2001	0.98	18.98

Discharge HLT 1	date	HLO Stage from data sheets	HLO Discharge	Field Notes	Discharge HLT 1	date	HLO Stage from data sheets	HLO Discharge	Field Notes
0.00	4/15/2001		0.00		7.29	6/1/2001	1.23	12.79	
0.00	4/16/2001		0.00		6.65	6/2/2001	1.26	12.15	
0.00	4/17/2001		0.00		6.65	6/3/2001	1.27	12.15	
0.26	4/18/2001		5.76		8.25	6/4/2001	1.33	13.75	
3.46	4/19/2001		8.96		7.61	6/5/2001	1.37	13.11	
8.25	4/20/2001		13.75		7.61	6/6/2001	1.45	13.11	
8.89	4/21/2001		14.39		7.93	6/7/2001	1.44	13.43	
16.25	4/22/2001		21.75		7.29	6/8/2001	1.50	12.79	
67.41	4/23/2001		72.91	12 feet below cement	9.85	6/9/2001	1.60	15.35	
86.60	4/24/2001		92.10		8.25	6/10/2001	1.78	13.75	
57.82	4/25/2001		63.32		7.93	6/11/2001	1.81	13.43	
40.23	4/26/2001		45.73		14.01	6/12/2001	1.88	19.51	
29.04	4/27/2001		34.54		9.85	6/13/2001	2.03	15.35	
29.04	4/28/2001		34.54		9.21	6/14/2001	2.20	14.71	
22.64	4/29/2001		28.14		8.57	6/15/2001	2.36	14.07	
22.64	4/30/2001		28.14		8.25	6/16/2001	2.60	13.75	
22.64	5/1/2001		28.14		8.57	6/17/2001	2.80	14.07	
24.24	5/2/2001		29.74		8.25	6/18/2001	2.97	13.75	
24.24	5/3/2001		29.74		8.25	6/19/2001	2.93	13.75	
25.84	5/4/2001		31.34		8.25	6/20/2001	3.28	13.75	
27.44	5/5/2001		32.94		8.57	6/21/2001	3.51	14.07	
25.84	5/6/2001		31.34		8.57	6/22/2001	3.87	14.07	Plugging may have occurred
24.24	5/7/2001		29.74	1 foot deep	8.57	6/23/2001	4.19	14.07	
21.04	5/8/2001		26.54		8.25	6/24/2001	4.48	13.75	
17.85	5/9/2001		23.35		8.57	6/25/2001	8.27	14.07	
14.65	5/10/2001		20.15		9.21	6/26/2001	15.14	14.71	
13.05	5/11/2001		18.55		7.61	6/27/2001	15.13	13.11	
11.45	5/12/2001		16.95		7.61	6/28/2001	9.55	13.11	
10.49	5/13/2001		15.99		67.41	6/29/2001	0.72	6.58	
8.89	5/14/2001		14.39		65.81	6/30/2001	0.76	7.70	
7.93	5/15/2001		13.43	4 inches deep	35.43	7/1/2001	1.38	35.10	
8.25	5/16/2001		13.75		24.24	7/2/2001	1.88	71.02	
6.65	5/17/2001		12.15		17.85	7/3/2001	1.55	45.93	
5.05	5/18/2001		10.55		14.65	7/4/2001	1.29	29.94	
5.05	5/19/2001		10.55		13.05	7/5/2001	1.11	20.83	
6.65	5/20/2001		12.15		12.09	7/6/2001	1.02	16.88	
6.65	5/21/2001		12.15		10.81	7/7/2001	0.95	14.08	
6.65	5/22/2001		12.15		9.85	7/8/2001	0.92	12.95	
6.65	5/23/2001	1.14	12.15		9.85	7/9/2001	0.91	12.59	
6.65	5/24/2001	1.21	12.15		9.53	7/10/2001	0.89	11.87	
5.69	5/25/2001	1.18	11.19		8.89	7/11/2001	0.88	11.52	
5.37	5/26/2001	1.17	10.87		4.74	7/12/2001	0.87	11.17	
5.05	5/27/2001	1.27	10.55		4.42	7/13/2001	0.89	11.87	
4.74	5/28/2001	1.28	10.24		4.42	7/14/2001	0.91	12.59	
5.05	5/29/2001	1.24	10.55		4.10	7/15/2001	0.88	11.52	
5.05	5/30/2001	1.22	10.55		4.42	7/16/2001	0.88	11.52	
9.85	5/31/2001	1.21	15.35		4.74	7/17/2001	0.87	11.17	

Discharge HLT 1	date	HLO Stage from data sheets	HLO Discharge	Field Notes	Discharge HLT 1	date	HLO Stage from data sheets	HLO Discharge	Field Notes
4.74	7/18/2001	0.88	11.52	Switched to a Stevens	6.01	9/3/2001		11.51	
4.42	7/19/2001	0.88	11.52		6.33	9/4/2001		11.83	
4.42	7/20/2001	0.85	10.50		6.33	9/5/2001		11.83	
6.65	7/21/2001	0.85	10.50		8.25	9/6/2001		13.75	
24.24	7/22/2001	0.95	14.08		8.25	9/7/2001		13.75	
38.31	7/23/2001	1.20	25.19		8.25	9/8/2001		13.75	
131.37	7/24/2001	2.82	171.96		7.93	9/9/2001		13.43	
73.81	7/25/2001	2.62	146.83		7.61	9/10/2001		13.11	
40.23	7/26/2001	1.85	68.51		7.29	9/11/2001		12.79	
21.04	7/27/2001	1.45	39.38		7.29	9/12/2001		12.79	
14.01	7/28/2001	1.23	26.73		22.64	9/13/2001		28.14	
10.17	7/29/2001	1.10	20.37		16.25	9/14/2001		21.75	
8.25	7/30/2001	1.02	16.88		13.05	9/15/2001		18.55	
6.33	7/31/2001	0.95	14.08		10.81	9/16/2001		16.31	
5.69	8/1/2001	0.93	13.32		9.21	9/17/2001		14.71	
5.37	8/2/2001	0.90	12.23		8.57	9/18/2001		14.07	
5.05	8/3/2001	0.89	11.87		8.57	9/19/2001		14.07	
4.74	8/4/2001	0.87	11.17		8.25	9/20/2001		13.75	
4.74	8/5/2001	0.86	10.83		8.25	9/21/2001		13.75	
4.42	8/6/2001	0.86	10.83		8.25	9/22/2001		13.75	
4.42	8/7/2001	0.85	10.50		7.93	9/23/2001		13.43	
4.42	8/8/2001	0.86	10.83		7.93	9/24/2001		13.43	
4.42	8/9/2001	0.86	10.83		7.61	9/25/2001		13.11	
4.42	8/10/2001	0.86	10.83		6.65	9/26/2001	0.97	12.15	1 foot deep
4.42	8/11/2001	0.86	10.83		6.65	9/27/2001	0.97	12.15	
4.42	8/12/2001	0.86	10.83		8.25	9/28/2001	0.97	13.75	
4.42	8/13/2001	0.86	10.83		6.65	9/29/2001	0.97	12.15	
5.05	8/14/2001	0.86	10.83		8.25	9/30/2001	0.97	13.75	
5.05	8/15/2001	0.89	11.87		9.85	10/1/2001	0.98	15.35	
5.05	8/16/2001	0.89	11.87		9.85	10/2/2001	0.98	15.35	
5.05	8/17/2001	0.89	11.87		9.85	10/3/2001	0.98	15.35	
5.05	8/18/2001	0.89	11.87		9.85	10/4/2001	0.98	15.35	
5.05	8/19/2001	0.89	11.87		9.85	10/5/2001	0.98	15.35	
5.05	8/20/2001	0.89	11.87		9.85	10/6/2001	0.98	15.35	
5.05	8/21/2001	0.89	11.87		9.85	10/7/2001	0.99	15.35	
5.69	8/22/2001	0.91	12.59		14.65	10/8/2001	0.99	20.15	
5.69	8/23/2001	0.91	12.59		19.45	10/9/2001	0.99	24.95	
5.69	8/24/2001	0.90	12.23		11.45	10/10/2001	0.99	16.95	
5.69	8/25/2001	0.90	12.23		9.85	10/11/2001	0.99	15.35	
5.69	8/26/2001	0.90	12.23		9.85	10/12/2001	1.00	15.35	
5.05	8/27/2001	0.90	12.23		9.85	10/13/2001	1.00	15.35	
5.05	8/28/2001	0.90	12.23		8.25	10/14/2001	1.00	13.75	
5.69	8/29/2001	0.90	12.23		8.25	10/15/2001	1.00	13.75	
5.37	8/30/2001		10.87		8.25	10/16/2001	1.00	13.75	
5.37	8/31/2001		10.87		8.25	10/17/2001	1.00	13.75	
5.69	9/1/2001		11.19		8.25	10/18/2001	1.00	13.75	
5.69	9/2/2001		11.19		8.25	10/19/2001	1.00	13.75	

Discharge HLT 1	date	HLO Stage from data sheets	HLO Discharge	Field Notes	Discharge HLT 1	date	HLO Stage from data sheets	HLO Discharge	Field Notes
8.25	10/20/2001	1.00	13.75		8.25	4/12/2002		13.75	
8.25	10/21/2001	1.00	13.75		8.25	4/13/2002		13.75	
8.25	10/22/2001	1.02	13.75		8.25	4/14/2002		13.75	
8.25	10/23/2001	1.02	13.75		8.25	4/15/2002		13.75	
8.25	10/24/2001	1.02	13.75		6.65	4/16/2002		12.15	
8.25	10/25/2001	1.02	13.75		6.65	4/17/2002		12.15	
8.25	10/26/2001	1.02	13.75		6.65	4/18/2002		12.15	
8.25	10/27/2001	1.02	13.75		5.05	4/19/2002		10.55	
8.25	10/28/2001	1.02	13.75		11.45	4/20/2002		16.95	
8.25	10/29/2001	1.02	13.75		8.25	4/21/2002		13.75	
8.25	10/30/2001	0.98	13.75	1 foot deep	6.65	4/22/2002		12.15	
8.25	10/31/2001	1.00	13.75		6.65	4/23/2002		12.15	
8.25	11/1/2001	No data	13.75		6.65	4/24/2002		12.15	
8.25	11/2/2001	baterry	13.75		6.65	4/25/2002		12.15	
8.25	11/3/2001	was in	13.75		13.05	4/26/2002		18.55	
8.25	11/4/2001	backwards	13.75		13.05	4/27/2002		18.55	
8.25	11/5/2001		13.75		9.85	4/28/2002		15.35	
8.25	11/6/2001		13.75		8.25	4/29/2002		13.75	
8.25	11/7/2001		13.75		9.85	4/30/2002		15.35	
8.25	11/8/2001		13.75		9.85	5/1/2002		15.35	
8.25	11/9/2001		13.75		8.25	5/2/2002		13.75	
8.25	11/10/2001		13.75		8.25	5/3/2002		13.75	
9.85	11/11/2001		15.35		8.25	5/4/2002		13.75	
9.85	11/12/2001		15.35		8.44	5/5/2002		13.94	
9.85	11/13/2001		15.35		8.25	5/6/2002		13.75	
9.85	11/14/2001		15.35		14.65	5/7/2002		20.15	
9.85	11/15/2001		15.35		11.45	5/8/2002		16.95	
9.85	11/16/2001		15.35		9.85	5/9/2002		15.35	
9.85	11/17/2001		15.35		11.45	5/10/2002		16.95	
9.85	11/18/2001		15.35		9.85	5/11/2002		15.35	
9.85	11/19/2001		15.35		9.85	5/12/2002		15.35	
					9.85	5/13/2002		15.35	



Date	Stage	Discharge	Field Notes
1-Apr	0.89	0.00	True 0 stage is @ .892 stage recorder stage
2-Apr	0.89	0.00	
3-Apr	0.89	0.00	
4-Apr	0.89	0.00	
5-Apr	0.89	0.00	
6-Apr	0.89	0.00	
7-Apr	0.89	0.00	
8-Apr	0.89	0.00	
9-Apr	0.89	0.00	
10-Apr	0.89	0.00	
11-Apr	0.89	0.00	
12-Apr	0.89	0.00	
13-Apr	0.89	0.00	
14-Apr	0.89	0.00	
15-Apr	0.89	0.00	
16-Apr	0.89	0.00	
17-Apr	0.89	0.00	
18-Apr	0.90	0.26	
19-Apr	1.00	3.46	
20-Apr	1.15	8.25	11 inches from the bottom of the board 12 feet wide

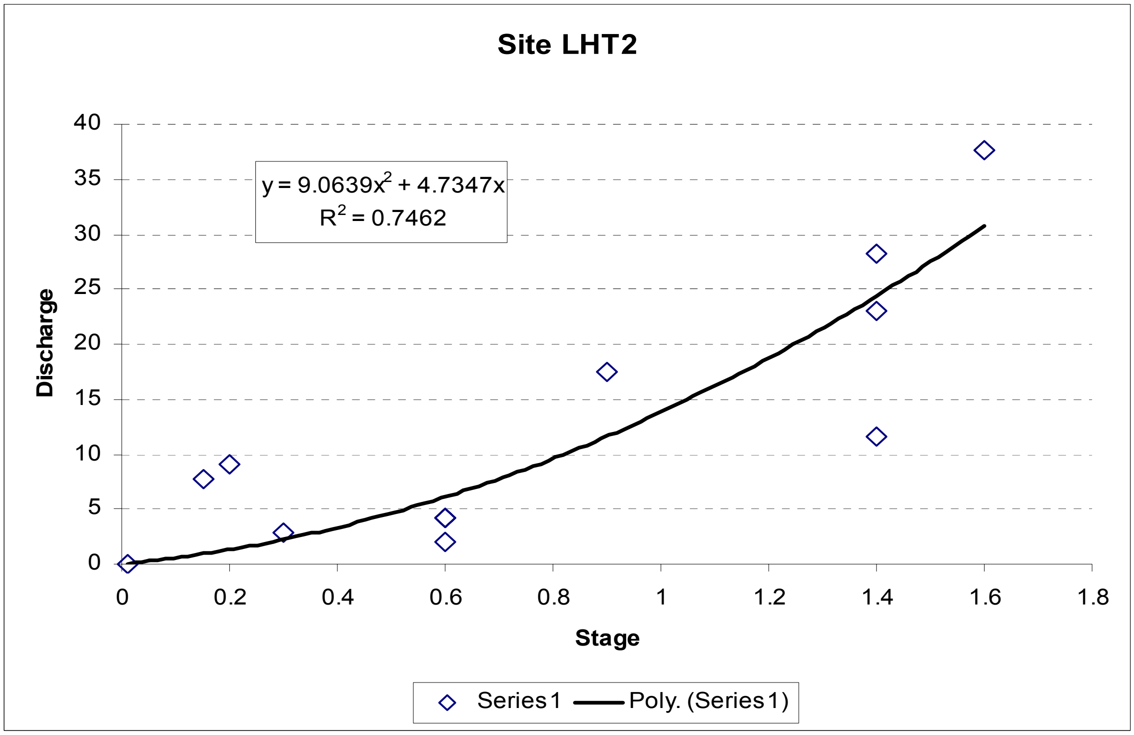
Chart Data

Date	Discharge	Stage
4/20	7.37	
4/26	43.56	2.25
5/10	20.78	1.35
6/27	7.57	1.13
7/17	3.62	1.05
7/26	56.69	2.7
8/27	4.62	1.05
9/26	2.8	1.1
10/30	8.89	1.15

Date	Stage	Discharge	Field Notes	Date	Stage	Discharge	Field Notes
21-Apr	1.17	8.89		11-Jun	1.14	7.93	
22-Apr	1.40	16.25		12-Jun	1.33	14.01	
23-Apr	3.00	67.41	6 feet deep 31 feet wide	13-Jun	1.20	9.85	
24-Apr	3.60	86.60		14-Jun	1.18	9.21	1.58 feet deep
25-Apr	2.70	57.82		15-Jun	1.16	8.57	
26-Apr	2.15	40.23		16-Jun	1.15	8.25	
27-Apr	1.80	29.04		17-Jun	1.16	8.57	
28-Apr	1.80	29.04		18-Jun	1.15	8.25	
29-Apr	1.60	22.64		19-Jun	1.15	8.25	
30-Apr	1.60	22.64		20-Jun	1.15	8.25	
1-May	1.60	22.64		21-Jun	1.16	8.57	1.4 feet deep
2-May	1.65	24.24		22-Jun	1.16	8.57	
3-May	1.65	24.24		23-Jun	1.16	8.57	
4-May	1.70	25.84		24-Jun	1.15	8.25	
5-May	1.75	27.44		25-Jun	1.16	8.57	
6-May	1.70	25.84		26-Jun	1.18	9.21	
7-May	1.65	24.24	2.33 feet deep	27-Jun	1.13	7.61	1.25 feet deep
8-May	1.55	21.04		28-Jun	1.13	7.61	
9-May	1.45	17.85		29-Jun	3.00	67.41	
10-May	1.35	14.65	1.8 feet deep and 1.5 feet from bbottom of board, 7 feet wide	30-Jun	2.95	65.81	
11-May	1.30	13.05		1-Jul	2.00	35.43	
12-May	1.25	11.45		2-Jul	1.65	24.24	
13-May	1.22	10.49		3-Jul	1.45	17.85	
14-May	1.17	8.89		4-Jul	1.35	14.65	
15-May	1.14	7.93	1.8 feet deep	5-Jul	1.30	13.05	
16-May	1.15	8.25		6-Jul	1.27	12.09	
17-May	1.10	6.65		7-Jul	1.23	10.81	
18-May	1.05	5.05		8-Jul	1.20	9.85	
19-May	1.05	5.05		9-Jul	1.20	9.85	1.55 feet deep
20-May	1.10	6.65		10-Jul	1.19	9.53	
21-May	1.10	6.65		11-Jul	1.17	8.89	
22-May	1.10	6.65		12-Jul	1.04	4.74	
23-May	1.10	6.65		13-Jul	1.03	4.42	
24-May	1.10	6.65		14-Jul	1.03	4.42	
25-May	1.07	5.69		15-Jul	1.02	4.10	
26-May	1.06	5.37		16-Jul	1.03	4.42	
27-May	1.05	5.05		17-Jul	1.04	4.74	1.25 feet deep
28-May	1.04	4.74		18-Jul	1.04	4.74	
29-May	1.05	5.05		19-Jul	1.03	4.42	
30-May	1.05	5.05	1.85 feet deep	20-Jul	1.03	4.42	
31-May	1.20	9.85		21-Jul	1.10	6.65	
1-Jun	1.12	7.29		22-Jul	1.65	24.24	
2-Jun	1.10	6.65		23-Jul	2.09	38.31	
3-Jun	1.10	6.65		24-Jul	5.00	131.37	
4-Jun	1.15	8.25		25-Jul	3.20	73.81	4 feet deep
5-Jun	1.13	7.61		26-Jul	2.15	40.23	
6-Jun	1.13	7.61		27-Jul	1.55	21.04	
7-Jun	1.14	7.93	1.75 feet deep	28-Jul	1.33	14.01	
8-Jun	1.12	7.29		29-Jul	1.21	10.17	
9-Jun	1.20	9.85		30-Jul	1.15	8.25	
10-Jun	1.15	8.25		31-Jul	1.09	6.33	

Date	Stage	Discharge	Field Notes
1-Aug	1.07	5.69	
2-Aug	1.06	5.37	
3-Aug	1.05	5.05	
4-Aug	1.04	4.74	
5-Aug	1.04	4.74	
6-Aug	1.03	4.42	
7-Aug	1.03	4.42	
8-Aug	1.03	4.42	1 foot deep
9-Aug	1.03	4.42	
10-Aug	1.03	4.42	
11-Aug	1.03	4.42	
12-Aug	1.03	4.42	
13-Aug	1.03	4.42	
14-Aug	1.05	5.05	
15-Aug	1.05	5.05	
16-Aug	1.05	5.05	
17-Aug	1.05	5.05	
18-Aug	1.05	5.05	
19-Aug	1.05	5.05	
20-Aug	1.05	5.05	
21-Aug	1.05	5.05	
22-Aug	1.07	5.69	
23-Aug	1.07	5.69	
24-Aug	1.07	5.69	
25-Aug	1.07	5.69	
26-Aug	1.07	5.69	
27-Aug	1.05	5.05	.66 feet deep, 0 stage set @ .35 less than stage of 1 on recorder sheets.
28-Aug	1.05	5.05	
29-Aug	1.07	5.69	
30-Aug	1.06	5.37	
31-Aug	1.06	5.37	
1-Sep	1.07	5.69	
2-Sep	1.07	5.69	
3-Sep	1.08	6.01	
4-Sep	1.09	6.33	
5-Sep	1.09	6.33	
6-Sep	1.15	8.25	
7-Sep	1.15	8.25	
8-Sep	1.15	8.25	
9-Sep	1.14	7.93	
10-Sep	1.13	7.61	
11-Sep	1.12	7.29	
12-Sep	1.12	7.29	
13-Sep	1.60	22.64	
14-Sep	1.40	16.25	
15-Sep	1.30	13.05	
16-Sep	1.23	10.81	
17-Sep	1.18	9.21	
18-Sep	1.16	8.57	
19-Sep	1.16	8.57	
20-Sep	1.15	8.25	
21-Sep	1.15	8.25	
22-Sep	1.15	8.25	
23-Sep	1.14	7.93	
24-Sep	1.14	7.93	
25-Sep	1.13	7.61	
26-Sep	1.10	6.65	.75 feet deep, 6 feet wide
27-Sep	1.10	6.65	
28-Sep	1.15	8.25	
29-Sep	1.10	6.65	
30-Sep	1.15	8.25	
1-Oct	1.20	9.85	
2-Oct	1.20	9.85	
3-Oct	1.20	9.85	
4-Oct	1.20	9.85	
5-Oct	1.20	9.85	
6-Oct	1.20	9.85	
7-Oct	1.20	9.85	
8-Oct	1.35	14.65	
9-Oct	1.50	19.45	
10-Oct	1.25	11.45	
11-Oct	1.20	9.85	
12-Oct	1.20	9.85	
13-Oct	1.20	9.85	
14-Oct	1.15	8.25	
15-Oct	1.15	8.25	
16-Oct	1.15	8.25	
17-Oct	1.15	8.25	
18-Oct	1.15	8.25	
19-Oct	1.15	8.25	
20-Oct	1.15	8.25	
21-Oct	1.15	8.25	
22-Oct	1.15	8.25	
23-Oct	1.15	8.25	
24-Oct	1.15	8.25	
25-Oct	1.15	8.25	
26-Oct	1.15	8.25	
27-Oct	1.15	8.25	
28-Oct	1.15	8.25	
29-Oct	1.15	8.25	

Date	Stage	Discharge	Field Notes	Date	Stage	Discharge	Field Notes
30-Oct	1.15	8.25	1 foot deep	12-Apr	1.15	8.25	
31-Oct	1.15	8.25		13-Apr	1.15	8.25	
1-Nov	1.15	8.25		14-Apr	1.15	8.25	
2-Nov	1.15	8.25		15-Apr	1.15	8.25	
3-Nov	1.15	8.25		16-Apr	1.10	6.65	
4-Nov	1.15	8.25		17-Apr	1.10	6.65	
5-Nov	1.15	8.25		18-Apr	1.10	6.65	
6-Nov	1.15	8.25		19-Apr	1.05	5.05	
7-Nov	1.15	8.25		20-Apr	1.25	11.45	
8-Nov	1.15	8.25		21-Apr	1.15	8.25	
9-Nov	1.15	8.25		22-Apr	1.10	6.65	
10-Nov	1.15	8.25		23-Apr	1.10	6.65	
11-Nov	1.20	9.85		24-Apr	1.10	6.65	
12-Nov	1.20	9.85		25-Apr	1.10	6.65	
13-Nov	1.20	9.85		26-Apr	1.30	13.05	
14-Nov	1.20	9.85		27-Apr	1.30	13.05	
15-Nov	1.20	9.85		28-Apr	1.20	9.85	
16-Nov	1.20	9.85		29-Apr	1.15	8.25	
17-Nov	1.20	9.85		30-Apr	1.20	9.85	
18-Nov	1.20	9.85		1-May	1.20	9.85	
19-Nov	1.20	9.85		2-May	1.15	8.25	
1-Apr	****			3-May	1.15	8.25	
2-Apr	****			4-May	1.15	8.25	
3-Apr	****			5-May	1.16	8.44	
4-Apr	****			6-May	1.15	8.25	
5-Apr	****			7-May	1.35	14.65	
6-Apr	****			8-May	1.25	11.45	
7-Apr	****			9-May	1.20	9.85	
8-Apr	****			10-May	1.25	11.45	
9-Apr	****			11-May	1.20	9.85	
10-Apr	1.15			12-May	1.20	9.85	
11-Apr	****			13-May	1.20	9.85	



date	stage	Discharge	Field Notes
04/01/01		0.00	
04/02/01		0.00	
04/03/01		0.00	
04/04/01		0.00	
04/05/01		0.00	
04/06/01		0.00	
04/07/01		0.00	
04/08/01		0.00	
04/09/01		0.00	
04/10/01		0.00	
04/11/01		0.00	
04/12/01		0.00	
04/13/01		0.00	
04/14/01		0.00	
04/15/01		0.00	
04/16/01		0.00	
04/17/01		0.00	
04/18/01	0.2	1.31	
04/19/01	0.4	3.34	
04/20/01	0.6	6.10	1.8 to bottom of 1st board 1.2 deep
04/21/01	0.8	9.59	
04/22/01	1	13.80	
04/23/01	2.5	68.49	54 feet wide 3.8 feet deep
04/24/01	2.5	68.49	
04/25/01	1.8	37.89	
04/26/01	1.6	30.78	
04/27/01	1.45	25.92	
04/28/01	1.3	21.47	
04/29/01	1.15	17.43	
04/30/01	1.2	18.73	

Chart Data

Date	disch	Stage
4/20	4.2	0.6
4/26	37.61	1.6
5/10	17.5	0.9
6/27	4.12	0.6
7/17	2.02	0.6
7/26	11.62	1.4
7/26	23.1	1.4
7/26	28.3	1.4
8/27	9.08	0.2
9/26	7.75	0.15
10/30	2.88	0.3
	0.01	0.01

date	stage	Discharge	Field Notes
05/01/01	1.2	18.73	
05/02/01	1.2	18.73	
05/03/01	1.2	18.73	
05/04/01	1	13.80	
05/05/01	1.2	18.73	
05/06/01	1.6	30.78	
05/07/01	1.55	29.11	2.15 feet deep
05/08/01	1.3	21.47	
05/09/01	1.1	16.18	
05/10/01	0.9	11.60	1.5 feet from bottom of board
05/11/01	1.2	18.73	
05/12/01	1.1	16.18	
05/13/01	1.05	14.96	
05/14/01	1.05	14.96	
05/15/01	1.05	14.96	1.7 feet deep
05/16/01	1	13.80	
05/17/01	1	13.80	
05/18/01	0.95	12.68	
05/19/01	0.95	12.68	
05/20/01	0.95	12.68	
05/21/01	1	13.80	
05/22/01	1	13.80	
05/23/01	1	13.80	
05/24/01	0.95	12.68	
05/25/01	0.95	12.68	
05/26/01	0.9	11.60	
05/27/01	0.9	11.60	
05/28/01	0.9	11.60	
05/29/01	0.9	11.60	
05/30/01	0.9	11.60	1.5 feet deep
05/31/01	1	13.80	
06/01/01	1	13.80	
06/02/01	1	13.80	
06/03/01	0.95	12.68	
06/04/01	0.9	11.60	
06/05/01	0.9	11.60	
06/06/01	0.9	11.60	
06/07/01	0.9	11.60	1.5 feet deep
06/08/01	0.9	11.60	
06/09/01	0.9	11.60	
06/10/01	0.9	11.60	
06/11/01	0.85	10.57	
06/12/01	0.95	12.68	
06/13/01	0.9	11.60	
06/14/01	0.8	9.59	1.4 feet deep
06/15/01	0.75	8.65	
06/16/01	0.75	8.65	

date	stage	Discharge
06/17/01	0.7	7.76
06/18/01	0.7	7.76
06/19/01	0.65	6.91
06/20/01	0.65	6.91
06/21/01	0.65	6.91
06/22/01	0.65	6.91
06/23/01	0.6	6.10
06/24/01	0.6	6.10
06/25/01	0.6	6.10
06/26/01	0.6	6.10
06/27/01	0.6	6.10
06/28/01	0.6	6.10
06/29/01	0.6	6.10
06/30/01	2.65	76.20
07/01/01	2.65	76.20
07/02/01	1.8	37.89
07/03/01	1.3	21.47
07/04/01	1.15	17.43
07/05/01	1.05	14.96
07/06/01	0.95	12.68
07/07/01	0.9	11.60
07/08/01	0.8	9.59
07/09/01	0.7	7.76
07/10/01	0.7	7.76
07/11/01	0.68	7.41
07/12/01	0.65	6.91
07/13/01	0.63	6.58
07/14/01	0.6	6.10
07/15/01	0.58	5.80
07/16/01	0.55	5.35
07/17/01	0.6	6.10
07/18/01	0.6	6.10
07/19/01	0.6	6.10
07/20/01	0.6	6.10
07/21/01	0.6	6.10
07/22/01	0.6	6.10
07/23/01	1.05	14.96
07/24/01	3.95	160.12
07/25/01	2.3	58.84
07/26/01	1.4	24.39
07/27/01	1	13.80
07/28/01	0.79	9.40
07/29/01	0.66	7.07
07/30/01	0.57	5.64
07/31/01	0.52	4.91
08/01/01	0.5	4.63
08/02/01	0.48	4.36

date	stage	Discharge	Field Notes
08/03/01	0.47	4.23	

date	stage	Discharge	Field Notes
09/20/01	0.2	1.31	

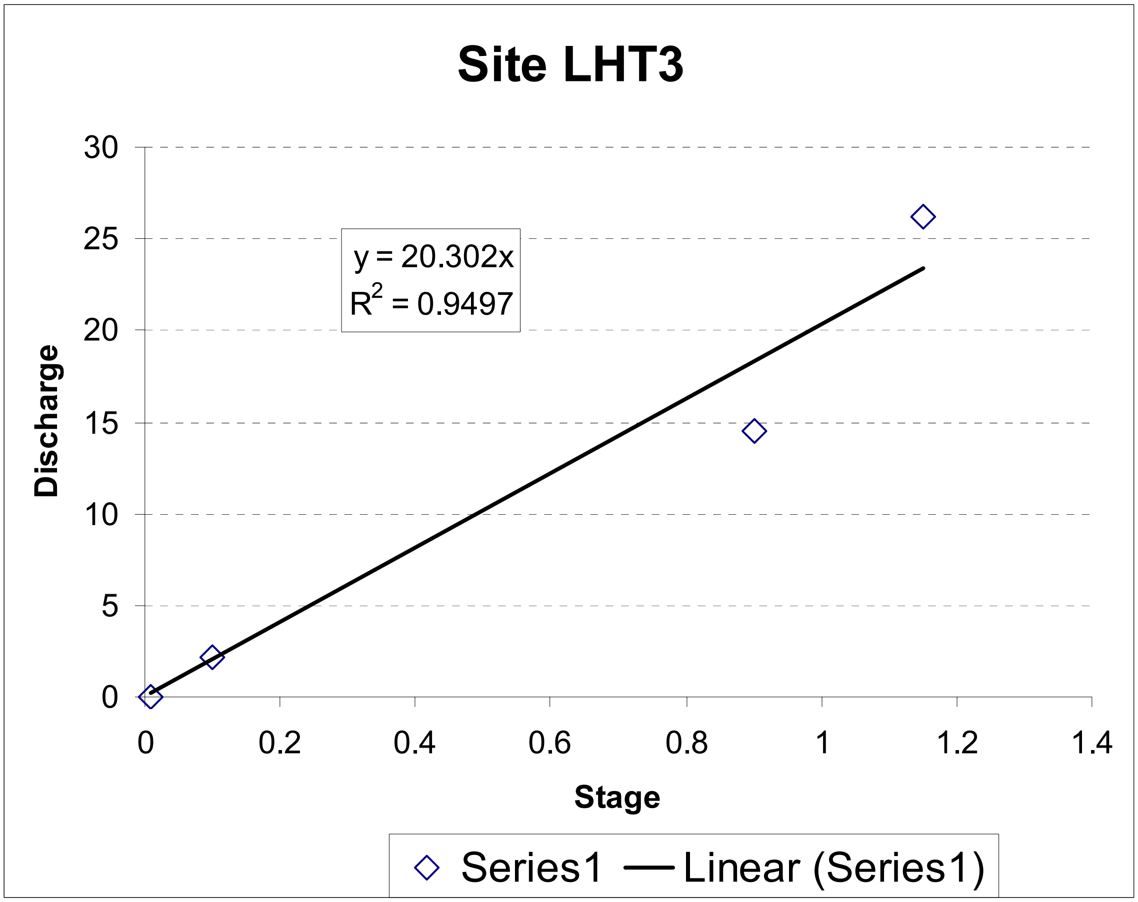
08/04/01	0.45	3.97	
08/05/01	0.45	3.97	
08/06/01	0.43	3.71	
08/07/01	0.42	3.59	
08/08/01	0.4	3.34	1 foot deep
08/09/01	0.39	3.23	
08/10/01	0.38	3.11	
08/11/01	0.37	2.99	
08/12/01	0.36	2.88	
08/13/01	0.35	2.77	
08/14/01	0.34	2.66	
08/15/01	0.33	2.55	
08/16/01	0.32	2.44	
08/17/01	0.31	2.34	
08/18/01	0.3	2.24	
08/19/01	0.29	2.14	
08/20/01	0.28	2.04	
08/21/01	0.27	1.94	
08/22/01	0.26	1.84	
08/23/01	0.25	1.75	
08/24/01	0.24	1.66	
08/25/01	0.23	1.57	
08/26/01	0.22	1.48	
08/27/01	0.2	1.31	.8 feet deep
08/28/01	0.2	1.31	
08/29/01	0.2	1.31	
08/30/01	0.2	1.31	
08/31/01	0.2	1.31	
09/01/01	0.2	1.31	
09/02/01	0.2	1.31	
09/03/01	0.2	1.31	
09/04/01	0.2	1.31	
09/05/01	0.2	1.31	
09/06/01	0.2	1.31	
09/07/01	0.2	1.31	
09/08/01	0.2	1.31	
09/09/01	0.2	1.31	
09/10/01	0.2	1.31	
09/11/01	0.2	1.31	
09/12/01	0.2	1.31	
09/13/01	0.2	1.31	
09/14/01	0.2	1.31	
09/15/01	0.2	1.31	
09/16/01	0.2	1.31	
09/17/01	0.2	1.31	
09/18/01	0.2	1.31	
09/19/01	0.2	1.31	

09/21/01	0.2	1.31	
09/22/01	0.2	1.31	
09/23/01	0.2	1.31	
09/24/01	0.2	1.31	
09/25/01	0.2	1.31	
09/26/01	0.15	0.91	Pole is .75 feet deep 3 feet wide
09/27/01	0.2	1.31	
09/28/01	0.2	1.31	
09/29/01	0.2	1.31	
09/30/01	0.2	1.31	
10/01/01	0.2	1.31	
10/02/01	0.2	1.31	
10/03/01	0.2	1.31	
10/04/01	0.2	1.31	
10/05/01	0.2	1.31	
10/06/01	0.2	1.31	
10/07/01	0.2	1.31	
10/08/01	0.2	1.31	
10/09/01	0.2	1.31	
10/10/01	0.2	1.31	
10/11/01	0.2	1.31	
10/12/01	0.2	1.31	
10/13/01	0.2	1.31	
10/14/01	0.2	1.31	
10/15/01	0.2	1.31	
10/16/01	0.2	1.31	
10/17/01	0.2	1.31	
10/18/01	0.2	1.31	
10/19/01	0.2	1.31	
10/20/01	0.2	1.31	
10/21/01	0.2	1.31	
10/22/01	0.2	1.31	
10/23/01	0.2	1.31	
10/24/01	0.2	1.31	
10/25/01	0.2	1.31	
10/26/01	0.2	1.31	
10/27/01	0.2	1.31	
10/28/01	0.2	1.31	
10/29/01	0.2	1.31	
10/30/01	0.3	2.24	.9 feet deep 8.5 feet wide
10/31/01		0.00	
11/01/01		0.00	
11/02/01		0.00	
11/03/01		0.00	
11/04/01		0.00	
11/05/01		0.00	
11/06/01		0.00	

date	stage	Discharge	Field Notes
11/07/01		0.00	

date	stage	Discharge	Field Notes
04/10/02	0.1	0.56	

11/08/01		0.00
11/09/01		0.00
11/10/01		0.00
11/11/01		0.00
11/12/01		0.00
11/13/01		0.00
11/14/01		0.00
11/15/01		0.00
11/16/01		0.00
11/17/01		0.00
11/18/01		0.00
11/19/01		0.00
11/20/01	0	0.00
11/21/01	0	0.00
11/22/01	0	0.00
11/23/01	0	0.00
11/24/01	0	0.00
11/25/01	0	0.00
11/26/01	0	0.00
11/27/01	0	0.00
11/28/01	0	0.00
11/29/01	0	0.00
11/30/01	0	0.00
04/01/02	0	0.00
04/02/02	0	0.00
04/03/02	0	0.00
04/04/02	0	0.00
04/05/02	0	0.00
04/06/02	0	0.00
04/07/02	0	0.00
04/08/02	0	0.00
04/09/02	0.05	0.26
04/11/02	0.2	1.31
04/12/02	0.3	2.24
04/13/02	0.3	2.24
04/14/02	0.25	1.75
04/15/02	0.25	1.75
04/16/02	0.2	1.31
04/17/02	0.2	1.31
04/18/02	0.2	1.31
04/19/02	0.15	0.91
04/20/02	0.2	1.31
04/21/02	0.15	0.91
04/22/02	0.15	0.91
04/23/02	0.1	0.56
04/24/02	0.1	0.56
04/25/02	0.25	1.75
04/26/02	0.35	2.77
04/27/02	0.25	1.75
04/28/02	0.15	0.91
04/29/02	0.15	0.91
04/30/02	0.15	0.91
05/01/02	0.15	0.91
05/02/02	0.1	0.56
05/03/02	0.1	0.56
05/04/02	0.1	0.56
05/05/02	0.1	0.56
05/06/02	0.25	1.75
05/07/02	0.25	1.75
05/08/02	0.15	0.91
05/09/02	0.15	0.91
05/10/02	0.15	0.91
05/11/02	0.15	0.91
05/12/02	0.15	0.91



Date	stage	Dpth @ Culvrt	Dischrg
04/01/01	0.00		0.00
04/02/01	0.00		0.00
04/03/01	0.00		0.00
04/04/01	0.00		0.00
04/05/01	0.00		0.00
04/06/01	0.00		0.00
04/07/01	0.00		0.00
04/08/01	0.00		0.00
04/09/01	0.00		0.00
04/10/01	0.00		0.00
04/11/01	0.00		0.00
04/12/01	0.00		0.00
04/13/01	0.00		0.00
04/14/01	0.00		0.00
04/15/01	0.00		0.00
04/16/01	0.00		0.00
04/17/01	0.20		4.06
04/18/01	0.40		8.12
04/19/01	0.60		12.18
04/20/01	0.80	1.2	16.24

Highlighted stages are estimated, no data between sheets or bad data

Date	Dis	Stg	
4/20	1.39	1	<--This point is an outlier
4/26	26.25	1.15	
5/10	14.55	0.9	
6/27	2.16	0.1	
	0.01	0.01	

Date	stage	Dpth @ Culvrt	Dischrg
04/21/01	1.00		20.30
04/22/01	1.20		24.36
04/23/01	1.40	1.8	28.42
04/24/01	1.30		26.39
04/25/01	1.20		24.36
04/26/01	1.15		23.35
04/27/01	1.10		22.33
04/28/01	0.95		19.29
04/29/01	0.95		19.29
04/30/01	1.00		20.30
05/01/01	1.05		21.32
05/02/01	1.05		21.32
05/03/01	1.00		20.30
05/04/01	1.10		22.33
05/05/01	1.20		24.36
05/06/01	1.10		22.33
05/07/01	1.00	1.5	20.30
05/08/01	0.95		19.29
05/09/01	0.95		19.29
05/10/01	0.90	1.2	18.27
05/11/01	0.90		18.27
05/12/01	0.85		17.26
05/13/01	0.75		15.23
05/14/01	0.70		14.21
05/15/01	0.70	1.2	14.21
05/16/01	0.75		15.23
05/17/01	0.70		14.21
05/18/01	0.60		12.18
05/19/01	0.65		13.20
05/20/01	0.80		16.24
05/21/01	0.75		15.23
05/22/01	0.75		15.23
05/23/01	0.70		14.21
05/24/01	0.60		12.18
05/25/01	0.55		11.17
05/26/01	0.50		10.15
05/27/01	0.45		9.14
05/28/01	0.40		8.12
05/29/01	0.40		8.12
05/30/01	0.40	0.8	8.12
05/31/01	0.45		9.14
06/01/01	0.50		10.15
06/02/01	0.40		8.12
06/03/01	0.30		6.09
06/04/01	0.25		5.08
06/05/01	0.25		5.08
06/06/01	0.25		5.08
06/07/01	0.20	0.6	4.06
06/08/01	0.15		3.05
06/09/01	0.20		4.06
06/10/01	0.20		4.06
06/11/01	0.20		4.06
06/12/01	0.25		5.08
06/13/01	0.25		5.08

Date	stage	Dpth @ Culvrt	Dischrg
06/14/01	0.25	0.6	5.08
06/15/01	0.25		5.08
06/16/01	0.20		4.06
06/17/01	0.20		4.06
06/18/01	0.30		6.09
06/19/01	0.20		4.06
06/20/01	0.15		3.05
06/21/01	0.15	0.3	3.05
06/22/01	0.15		3.05
06/23/01	0.10		2.03
06/24/01	0.10		2.03
06/25/01	0.05		1.02
06/26/01	0.05		1.02
06/27/01	0.10		2.03
06/28/01	0.05		1.02
06/29/01	0.50		10.15
06/30/01	0.40		8.12
07/01/01	0.40		8.12
07/02/01	0.50		10.15
07/03/01	0.45		9.14
07/04/01	0.40		8.12
07/05/01	0.35		7.11
07/06/01	0.30		6.09
07/07/01	0.25		5.08
07/08/01	0.20		4.06
07/09/01	0.15	0.3	3.05
07/10/01	0.15		3.05
07/11/01	0.15		3.05
07/12/01	0.15		3.05
07/13/01	0.15		3.05
07/14/01	0.15		3.05
07/15/01	0.15		3.05
07/16/01	0.15		3.05
07/17/01	0.11		2.13
07/18/01	0.07		1.49
07/19/01	0.05		1.04
07/20/01	0.04		0.73
07/21/01	0.03		0.51
07/22/01	0.02		0.36
07/23/01	0.01		0.25
07/24/01	0.01		0.18
07/25/01	0.01	0.3	0.12
07/26/01	0.00		0.00
07/27/01	0.00		0.00
07/28/01	0.00		0.00
07/29/01	0.00		0.00
07/30/01	0.00		0.00
07/31/01	0.00		0.00
08/01/01	0.00		0.00
08/02/01	0.00		0.00
08/03/01	0.00		0.00

No Flow occurred After this point in the Project

Appendix B. Tributary Data

spec #	Discharge	date	time	DO	pH	sample depth		wat temp	alk-M	tot	susp	vtss	ammon	nitrate	TKN	TP	TDP	fecal	e coli
E01EC002453	67.41	4/23/01	1000			Surface	LHT1		82	498	52	10	0.39	0.8	1.67	0.64	0.534	11000	>2420
E01EC002751	43.56	4/26/01	1345			Surface	LHT1		147	758	27	10	0.03	0.2	1.13	0.554	0.456	90	189
E01EC003240	20.78	5/10/01	1200	6.57	7.51	Surface	LHT1	16.06	239	1373	28	1	0.01	0.2	0.83	0.472	0.304	100	83.3
E01EC004934	7.57	6/27/01	1200			Surface	LHT1		391	2642	10	3	0.01	0.2	0.62	0.058	0.032	1590	2420
E01EC005625	3.62	7/17/01	900			Surface	LHT1	18.4	394	2668	17	2	0.01	0.2	0.53	0.07	0.032	860	1120
E01EC005859	73.81	7/25/01	1000			Surface	LHT1				27								
E01EC005861	56.69	7/26/01	1015			Surface	LHT1		127	688	26	2	0.01	0.1	0.78	0.3	0.2	1300	980
E01EC006764	4.62	8/27/01	1130			Surface	LHT1		395	2780	12	2	0.03	0.1	0.18	0.055	0.025	240	231
E01EC006765	4.62	8/27/01	1130			Surface	LHT1		394	2779	14	3	0.07	0.1	0.18	0.053	0.027	320	72.8
E01EC007560	2.8	9/26/01	1030	10.6	7.62	Surface	LHT1	10.12	411	2789	72	14	0.03	0.2	0.18	0.126	0.024	240	579
E01EC008481	8.89	10/30/01	1130	15		Surface	LHT1		406	2697	3	0.5	0.03	0.2	0.18	0.017	0.03	100	206
E02EC002861	4	5/30/02					LHT1		387	2623	6	1	0.01	0.2	0.46	0.047		570	2419
E01EC002452		4/23/01	1030			Surface	LHO		183	1171	40	8	0.18	0.4	1.3	0.385	0.23	2500	>2420
E01EC002750		4/26/01	1445			Surface	LHO		109	581	37	12	0.17	0.7	1.49	0.592	0.41	420	1050
E01EC005860		7/25/01	1020			Surface	LHO				23								
E01EC005863		7/26/01	830			Surface	LHO		99	615	8	1	0.01	0.3	0.81	0.341	0.27	500	816
E01EC006763		8/27/01	1230			Surface	LHO		223	1913	33	26	0.11	0.05	1.58	0.304	0.016	20	1
E01EC006762		8/27/01	1230			Surface	LHO		223	1921	35	30	0.28	0.05	1.87	0.394	0.016	5	2
E01EC007558		9/26/01	1115	14.14	8.09	Surface	LHO		251	2318	22	13	0.06	0.05	0.79	0.117	0.012	5	1
E01EC008483		10/30/01	1230	16.26	8.07	Surface	LHO	6.86	299	2536	7	1	0.01	0.1	0.53	0.033	0.023	5	2
E01EC002454	28.42	4/23/01	900			Surface	LHT3		47	240	46	12	0.54	0.8	2.29	0.805	0.46	8600	>2420
E01EC002753	26.25	4/26/01	1040			Surface	LHT3		60	248	10	6	0.03	0.1	1.37	0.628	0.516	50	76.8
E01EC003241	14.55	5/10/01	1000	5.25	6.46	Surface	LHT3	15.4	96	296	4	<1	0.01	0.05	1.15	0.699	0.647	140	121
E01EC004936	2.16	6/27/01	800			Surface	LHT3		247	879	188	52	0.25	0.05	2.47	1.2	0.336	380	365
E01EC002455	68.49	4/23/01	930			Surface	LHT2		66	403	56	12	0.34	0.5	0.92	0.696	0.552	11000	>2420
E01EC002752	37.61	4/26/01	1215			Surface	LHT2		113	501	18	8	0.02	0.1	1.14	0.648	0.571	110	579
E01EC003242	17.5	5/10/01	1100	4.21	7.28	Surface	LHT2	16.21	187	943	13	3	0.01	0.1	1.13	0.731	0.655	70	121
E01EC004935	4.12	6/27/01	1100			Surface	LHT2		446	3225	18	2	0.01	0.1	0.77	0.288	0.169	1350	1990
E01EC005626	2.02	7/17/01	800			Surface	LHT2	17.68	430	3138	5	1	0.01	0.1	0.65	0.32	0.25	1600	>2420
E01EC005858	58.84	7/25/01	900			Surface	LHT2				12								
E01EC005862	21.07	7/26/01	1100			Surface	LHT2		117	656	15	3	0.01	0.2	0.73	0.331	0.28	1100	1200
E01EC006766	9.08	8/27/01	1000			Surface	LHT2		447	3532	6	1	0.12	0.1	0.18	0.297	0.208	180	272
E01EC006767	9.08	8/27/01	1000			Surface	LHT2		447	3536	8	2	0.01	0.1	0.18	0.276	0.208	350	365
E01EC007559	7.75	9/26/01	930	7.85	7.02	Surface	LHT2	9.07	451	3390	9	2	0.03	0.1	0.18	0.174	0.108	240	308
E01EC008482	2.88	10/30/01	1000	9.9	7.03	Surface	LHT2	7.6	435	3360	7	0.5	0.03	0.1	0.48	0.089	0.076	1000	326
E02EC002862	9.08	5/30/02					LHT2		429	3340	8	2	0.01	0.1	0.65	0.145		640	921
		Max		16.26	8.09			18.4	451	3536	188	52	0.54	0.8	2.47	1.2	0.655	11000	2420
		Min		4.21	6.46			6.86	47	240	3	0.5	0.01	0.05	0.18	0.017	0.012	5	1
		Average		9.98	7.39			13.04	266.00	1849.61	25.61	7.69	0.09	0.20	0.89	0.36	0.25	1414.39	600.60

Appendix C. Lake Data

spec #	date	time	DO	pH	Secchi M	sample depth		Tot Wat Dpth	wat temp	alk-M	tot	susp	vtss	ammon	nitrate	TKN	TP	TDP	fecal	e coli
E01EC003996	5/31/01	1000	10.02	8.02		Bottom	LH1	12'		292	1767	11	4	0.04	0.05	0.76	0.121	0.07	40	42.2
E01EC005716	7/19/01	800	4.66	8.06		Bottom	LH1	9'	27.32	246	1858	7	4	0.06	0.05	0.74	0.146	0.102		
E01EC006807	8/28/01	800				Bottom	LH1	12'		344	2199	196	28	0.32	0.05	1.21	0.396	0.19	120	24.7
E01EC007549	9/25/01	1130	11.3			Bottom	LH1	11.3	16	246	2304	16	10	0.03	0.05	0.95	0.117	0.012		
E01EC003998	5/31/01	900	10.2	8.02	0.635	Surface	LH2	2'-1'	7	273	1617	5	2	0.01	0.05	0.78	0.101	0.086	5	20.3
E01EC005715	7/19/01	715	4.25	8.02	0.6096	Surface	LH2	4.5'	26.37	258	1909	9	4	0.08	0.05	0.56	0.143	0.093	10	23.3
E01EC006808	8/26/01	730			0.6096	Surface	LH2	5'-2'		212	1888	14	9	0.13	0.05	0.66	0.063	0.011	10	3
E01EC007550	9/25/01	1015			0.73152	Surface	LH2	3.5'	13.69	149	2343	15	9	0.02	0.05	0.81	0.088	0.011	29.2	30
E01EC003997	5/31/01	1000	10.02	8.02	0.762	Surface	LH1	12'		273	1624	6	4	0.04	0.05	0.88	0.132	0.068	20	8.4
E01EC005714	7/19/01	800	4.66	8.06	0.9144	Surface	LH1	9'	27.32	256	1889	43	0.5	0.25	0.05	0.97	0.321	0.155	5	3.1
E01EC006806	8/28/01	800			0.6096	Surface	LH1	12'		202	1851	22	17	0.1	0.05	0.97	0.154	0.016	5	5.2
E01EC007548	9/25/01	1100	11.91		0.6096	Surface	LH1	11.3	16.09	248	2295	16	10	0.01	0.05	0.87	0.106	0.012	5	5

Appendix D. Total Maximum Daily Load

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

LAKE HANSON

PIERRE CREEK WATERSHED

(HUC 10160009)

HANSON COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

MARCH, 2003

LakeHanson Total Maximum Daily Load

Waterbody Type:	**Lake (Impounded)**
303(d) Listing Parameter:	**TSI**
Designated Uses:	**Recreation, Warmwater semipermanent aquatic life**
Size of Waterbody:	**60 acres**
Size of Watershed :	**48,000 acres**
Water Quality Standards:	**Narrative and Numeric**
Indicators:	**Trophic State Index (TSI)**
Analytical Approach:	**AnnAGNPS, BATHTUB, FLUX**
Location:	**HUC Code: 10160009**
Goal:	**Complete restoration activities (dredging + 5% phosphorus reduction) to restore recreational use to the lake and create a margin of safety for the TSI**
Target:	**TSI less than 65 increase in boatable acres**

Objective:

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

Introduction

Lake Hanson is a 60-acre man-made impoundment located in Hanson County, South Dakota. The 1998 South Dakota 303(d) Waterbody List (page 22) identified Lake Hanson for TMDL development for trophic state index (TSI).

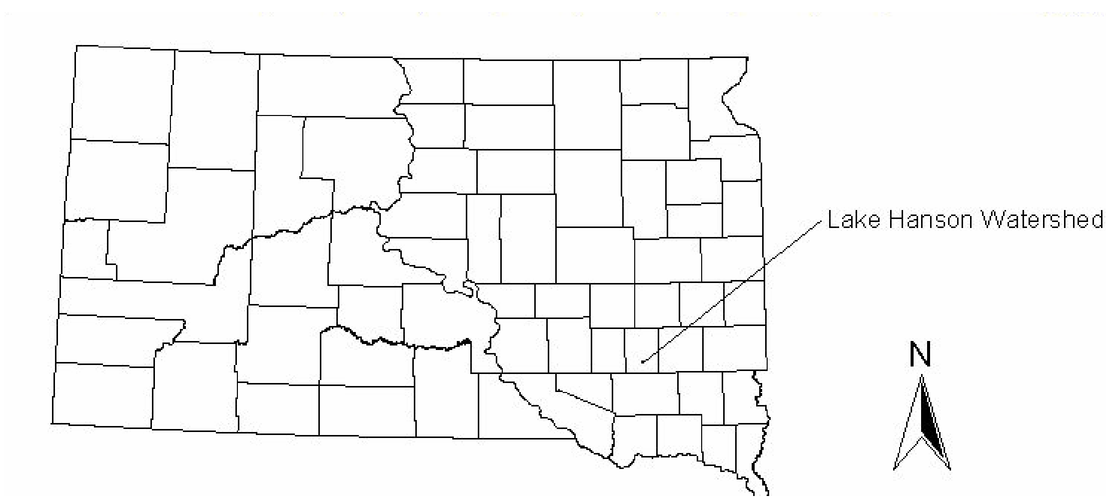


Figure 11. Location of Lake Hanson Watershed in South Dakota

The damming of Pierre Creek 2 miles south of Alexandria created the lake, which has an average depth of 7.6 feet (2.3 meters) and over 2.2 miles (3.5 km) of shoreline. The lake currently has a maximum depth of 12 feet (3.6 m), holds 418.5 acre-feet of water, and is subject to periods of stratification during the summer. The outlet for the lake empties into Pierre Creek, which eventually reaches the James River south of Mitchell.

Problem Identification

Pierre Creek is the primary tributary to Lake Hanson and drains a mixture of grazing lands with cropland acres. Winter feeding areas for livestock are present in the watershed. The stream carries nutrient loads, which degrade water quality in the lake and cause increased eutrophication. Additional impairments are a result of cabins and grazing along the lake.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

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

Warmwater semipermanent fish life propagation; Immersion recreation; Limited contact recreation; and fish and wildlife propagation, recreation and stock watering.
Individual parameters, including the lake's Trophic State Index (TSI) (Carlson, 1977) value, determine the support of beneficial uses and compliance with standards. A gradual increase in fertility of the water due to nutrients washing into the lake from external sources is a sign of the eutrophication process.

Lake Hanson is identified in both the 1998 South Dakota Waterbody List and "Ecoregion Targeting for Impaired Lakes in South Dakota" as partially supporting its aquatic life beneficial use. This support was determined through comparison of its trophic state to other lakes in its ecoregion.

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

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

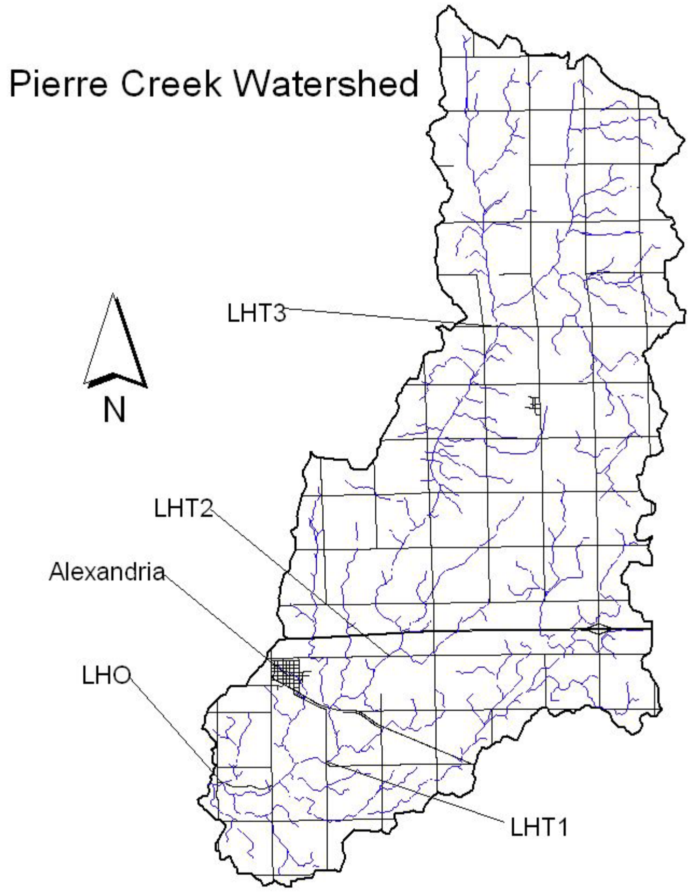


Figure 13. Lake Hanson and Pierre Creek Watershed

Lake Hanson currently has a mean TSI of 65.3, which is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of the high productivity is phosphorus loads from the watershed and at the lake itself most likely from livestock and wastewater from cabins (page 32).

The numeric target, established to improve the trophic state of Hanson Lake, is a growing season average TSI of less than 65. The current state of the lake is close enough to remove the lake from the impaired list, however there is a desire in the watershed to improve the lake in addition to a number of mitigation practices that will result in improved water quality to Lake Hanson and ultimately the James River. Practices that will prove beneficial include livestock grazing management, elimination of septic wastes from cabins along the lake, and dredging excess sediments from the lake.

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

Lake Hanson receives a load of 2,750 kg of phosphorus on an annual basis. As a result of the lakes nearly full support of its beneficial uses, any restoration efforts completed should result in attainment of full support. Attainment of full support will be accomplished through phosphorus load reductions of 5% in addition to dredging of 125,000 cubic yards of sediment from the lake. Phosphorus reductions from the watershed of 10% or more would result in a TSI shift sufficient to reach full support of beneficial uses, however it would not restore the number of boatable acres in the lake to improve that beneficial use.

Linkage Analysis

Water quality data was collected from five monitoring sites within the Lake Hanson and Pierre Creek watershed. Samples collected at each site were taken according to South Dakota's Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were supposed to be collected on 10% of the samples according to South Dakota's EPA approved Clean Lakes Quality Assurance/Quality Control Plan. Replicate samples were collected but blank samples were not. Details concerning water sampling techniques, analysis, and quality control are addressed on pages 9-48 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The Annualized Agriculture Nonpoint Pollution Source (AnnAGNPS) model was used to provide comparative values for each of the land uses and animal feeding operations located in the watershed. See the AnnAGNPS section of the final report, pages 39-42.

The impacts of phosphorus reductions on the condition of Lake Hanson were calculated using BATHTUB, an Army Corps of Engineers model. The model predicted that to achieve a 0.3 point reduction in the TSI, dredging efforts removing 1 meter (240,000 cubic yards) of sediment from the lake or a 10% reduction in watershed loading. It is recommended that completion of dredging (increasing depth by 0.5 meters) in addition to managed grazing in the watershed, runoff control for two animal feeding operations, and elimination of cabin waste water (5% phosphorus reduction for all combined) will shift the TSI to full support in addition to restoring the number of boatable acres in Lake Hanson.

TMDL and Allocations

TMDL for Phosphorus

	0 kg/yr	**(WLA)**
+	**2,612 kg/yr**	**(LA)**
+	**,0 kg/yr**	**(Background)**
	Implicit (MOS)	
	2,612 kg/yr	**(TMDL)**

Wasteload Allocations (WLAs)

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

Load Allocations (LAs)

A 5% reduction in the phosphorus load to Lake Hanson may be obtained through the improvement of grazing management and the critical crop cells identified in the AnnAGNPS section of the final report reducing the annual load from 2,750 kg/yr to 2,612 kg/yr of phosphorus. Further reductions in ambient phosphorus concentrations in Lake Hanson will be achieved through dredging 125,000 cubic yards of sediment.

Combined with elimination of the discharges from the waste waters produced by the cabins and the two animal feeding operations, this meets or exceeds the reductions needed to meet the lakes water quality goal.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and agricultural practices. To determine seasonal differences, Lake Hanson samples were separated into spring (March-May), summer (June-August), fall (September-November), and winter (December-February) collection periods. Seasonalized data is discussed in detail on page 11-19.

Margin of Safety

Implementation of best management practices on the Lake Hanson watershed will result in an implicit margin of safety for the loading reductions.

Critical Conditions

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

Follow-Up Monitoring

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.

Lake Hanson will also be monitored continually as a part of the South Dakota Statewide Lakes Assessment program to ensure that the lake continues to support its beneficial uses.

Public Participation

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

1. **Hanson County Conservation District Board Meetings**
2. **Individual contact with residents in the watershed.**

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

Implementation Plan

The South Dakota DENR is working with the Hanson County Conservation District and the Lower James RC&D to initiate an implementation project beginning in the Summer of 2003. It is expected that a local sponsor will request project assistance during the winter 2003 EPA Section 319 funding round.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
999 18TH STREET - SUITE 300
DENVER, CO 80202-2466
http://www.epa.gov/region08

June 3, 2004

Ref: 8EPR-EP

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

Re: TMDL Approvals
Lake Alice
Byre Lake
Lake Hanson

Dear Mr. Pirner:

We have completed our review, and have received Endangered Species Act Section 7 concurrence from the U.S. Fish and Wildlife Service, on the total maximum daily loads (TMDLs) as submitted by your office for the waterbodies listed in the enclosure to this letter. In accordance with the Clean Water Act (33 U.S.C. 1251 *et. seq.*), we approve all aspects of the TMDLs as developed for the water quality limited waterbodies as described in Section 303(d)(1).

Based on our review, we feel the separate TMDL elements listed in the enclosed review table adequately address the pollutants of concern, taking into consideration seasonal variation and a margin of safety. Please find enclosed a detailed review of these TMDLs.

For years, the State has sponsored an extensive clean lakes program. Through the lakes assessment and monitoring efforts associated with this program, priority waterbodies have been identified for cleanup. It is reasonable that these same priority waters have been a focus of the Section 319 nonpoint source projects as well as one of the priorities under the State's Section 303(d) TMDL efforts.

In the course of developing TMDLs for impaired waters, EPA has recognized that not all impairments are linked to water chemistry alone. Rather, EPA recognizes that *"Section 303(d) requires the States to identify all impaired waters regardless of whether the impairment is due to toxic pollutants, other chemical, heat, habitat, or other problems."* (see 57 Fed. Reg. 33040 for July 24, 1992). Further, EPA states that "*...in some situations water quality standards – particulary designated uses and biocriteria – can only be attained if nonchemical factors such as hydrology, channel morphology, and habitat are also addressed. EPA recognizes that it is appropriate to use the TMDL process to establish control measures for quantifiable non-*

chemical parameters that are preventing the attainment of water quality standards." (see Guidance for Water Quality-based Decisions: The TMDL Process; USEPA; EPA 440/4-91-001, April 1991; pg. 4). We feel the State has developed TMDLs that are consistent with this guidance, taking a comprehensive view of the sources and causes of water quality impairment within each of the watersheds. For example, in several of the TMDLs, the State considered nonchemical factors such as trophic state index (TSI) and its relationship to the impaired uses. Further, we feel it is reasonable to use factors such as TSI as surrogates to express the final endpoint of the TMDL.

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

Sincerely,

/s/ by Max H. Dodson

Max H. Dodson
Assistant Regional Administrator
Office of Ecosystems Protection and
Remediation

Enclosure

Enclosure

APPROVED TMDLS

Waterbody Name*	TMDL Parameter/ Pollutant	Water Quality Goal/Endpoint	TMDL	Section 303(d)1 or 303(d)3 TMDL	Supporting Documentation (not an exhaustive list of supporting documents)
Lake Alice*	phosphorus	TSI mean < 65	216 kg/yr total phosphorous load to the lake	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Lake Alice, Deuel County, South Dakota (SD DENR, July 2002)
Byre Lake	phosphorus	TSI mean ≤ 65	7,550 kg/yr total phosphorous load to the lake (19.6% reduction in average annual total phosphorus load)	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report and TMDL, Byre Lake / Grouse Creek, Lyman County, South Dakota (SD DENR, April 2003)
Lake Hanson*	phosphorus	TSI mean < 65 Increase boatable acres in the lake (add 8 acres)	2,612 kg/yr total phosphorous load to the lake (5% reduction of in average annual total phosphorus load)	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Lake Hanson / Pierre Creek, Hanson County, South Dakota (SD DENR, December 2002)

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

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Lake Alice, Deuel County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: May 17, 2004 Date Review completed: May 25, 2004 VEB

Review Criteria (All criteria must be met for approval)	**Approved** (check if yes)	**Comments**
■ **TMDLs result in maintaining and attaining water quality standards**	X	The waterbody classification uses which are addressed by this TMDL are warmwater semipermanent fish life propagation, immersion recreation, limited contact recreation, and criteria for fish and wildlife propagation, recreation and stock watering.
■ **Water Quality Standards Target**	X	Water quality target was established based on the targets in the document "Ecoregion Targeting for Impaired Lakes in South Dakota." These targets meet the fully support beneficial uses of identified lakes. This is a reasonable approach because the trophic status of the waterbody relates to the uses of concern.
■ **TMDL**	X	The TMDL is expressed in terms of annual phosphorus load to the lake. This is a reasonable way to express the TMDL for this lake because it provides an effective surrogate that reflects both aquatic life and recreational needs, and reflects the long response time of lakes of this type to pollutant controls within the watershed.
■ **Significant Sources Identified**	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified.
■ **Technical Analysis**	X	Monitoring, empirical relationships, BATHTUB and FLUX modeling, and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ **Margin of Safety and Seasonality**	X	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.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to range and cropland management practices, and internal loading.
■ **Public Review**	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ **EPA approved Water Quality Standards**	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota Waterbody Name: Byre Lake, Lyman County Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both) Date Received: May 17, 2004 Date Review completed: May 25, 2004 VEB	
A. Water Quality Standards - **Approved**	The State's submittal provides a good description of the geographic scope of the TMDL as well as information on the watershed and land use characteristics of Byre Lake. The South Dakota Department of Environment and Natural Resources (SD DENR) has identified Byre Lake as a water that is intended to support a range of designated uses including: domestic water supply, warmwater permanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation, stock watering, and irrigation. 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)
B. Water Quality Standards Targets - **Approved**	Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In May 2000, SD DENR published *Ecoregion Targeting for Impaired Lakes in South Dakota*. This document proposed ecoregion-specific targeted Trophic State Index (TSI) values based on beneficial uses. EPA approved the use of these ecoregion-specific targets to evaluate lakes using beneficial use categories. In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met. The overall mean TSI for Byre Lake during the period of the assessment (April 2000 through May 2001) was 66.2. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 80% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use TSI target of 55 or less. However, Byre Lake does not appear to fit the ecoregion-based beneficial use criteria due to legacy phosphorous loading to the lake and the technical and financial inability to fully treat new loading to the lake. Therefore, an alternative watershed specific TSI target has been established, which will fully support the beneficial uses for Byre Lake. The target used in this TMDL is: ■ TSI mean $\leq$ 65 (growing season average)

State/Tribe: South Dakota Waterbody Name: Byre Lake, Lyman County Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both) Date Received: May 17, 2004 Date Review completed: May 25, 2004 VEB	
C. Significant Sources - **Approved**	The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed and internal loading from bottom sediments within the lake. In particular, a loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors.
D. Technical Analysis - **Approved**	The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 19.6% reduction in average annual total phosphorous loads to Byre Lake. Based on the loads measured during the period of the assessment the total phosphorous load should be 7,550 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 Annualized Agricultural Non-Point Source Model (AnnAGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The nutrient loading source analysis, that was used to identify necessary controls in the watershed, was based on the identification of targeted or "critical" cells. Cell priority was assigned based on average nutrient and sediment loads produced that ultimately reach the outlet of the watershed. Cells that produce nitrogen, sediment *and* phosphorous loads greater than one standard deviation over the mean for the watershed were given a priority ranking of 1. Cells that produce loads for 2 out of the 3 pollutants greater than one standard deviation over the mean were given a priority ranking of 2. Cells that produce loads for 1 out of the 3 pollutants greater than one standard deviation over the mean were given a priority ranking of 3. The initial load reductions under this TMDL will be achieved through controls on the priority 1 and 2 cells within the watershed combined with modification of grazing practices.
E. Margin of Safety & Seasonality - **Approved**	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, BMPs were specified that go beyond what is necessary to achieve the target, and ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.
F. TMDL - **Approved**	The TMDL established for Byre Lake is a 7,550 kg/yr total phosphorus load to the lake (19.6% reduction in annual total phosphorus load). Since the annual loading varies from year-to-year, this TMDL is considered a long term average percent reduction in phosphorous loading.
G. Allocation - **Approved**	This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Byre Lake. The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. The allocation for phosphorous was attributed to such sources as runoff from cropland, rangeland and pastureland. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorous reductions can be achieved through modifications to priority cells within the watershed combined with modification of grazing practices. Additional phosphorous load reductions are possible from streambank stabilization, conversion highly erodible cropland to rangeland, riparian management, and shoreline stabilization. Reduction percentages were not calculated for these additional BMPs.

State/Tribe: South Dakota Waterbody Name: Byre Lake, Lyman County Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both) Date Received: May 17, 2004 Date Review completed: May 25, 2004 VEB	
H. Public Participation - **Approved**	The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, articles in local newspapers, individual contact with the residents in the watershed, and widespread solicitation of comments on the draft TMDL. The State also employed the Internet to post the draft TMDL and to solicit comments. The level of public participation is found to be adequate.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Lake Hanson, Hanson County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: May 17, 2004 Date Review completed: May 25, 2004 VEB

Review Criteria (All criteria must be met for approval)	**Approved** (check if yes)	**Comments**
■ **TMDLs result in maintaining and attaining water quality standards**	X	The waterbody classification uses which are addressed by this TMDL are warmwater semipermanent fish life propagation, immersion recreation, limited contact recreation and fish and wildlife propagation, recreation and stock watering.
■ **Water Quality Standards Target**	X	Water quality target was established based on the targets in the document "Ecoregion Targeting for Impaired Lakes in South Dakota." These targets meet the fully support beneficial uses of identified lakes. This is a reasonable approach because the trophic status of the waterbody relates to the uses of concern.
■ **TMDL**	X	The TMDL is expressed in terms of total phosphorus load to the lake, and the corresponding average annual percent reduction in phosphorous load. This is a reasonable way to express the TMDL for this lake because it provides an effective surrogate that reflects both aquatic life and recreational needs.
■ **Significant Sources Identified**	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified as grazing lands, animal feeding operations and septic systems near the lake.
■ **Technical Analysis**	X	Monitoring, empirical relationships, AnnAGNPS, FLUX and BATHTUB modeling , and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ **Margin of Safety and Seasonality**	X	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, BMPs were specified that go beyond what is necessary to achieve the target, and ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to range and cropland management practices, and internal loading.
■ **Public Review**	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ **EPA approved Water Quality Standards**	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

Fifty copies of this document were printed by the Department of Environment and Natural Resources at a cost of $?.?? per copy.