WATERSHED ASSESSMENT/TMDL
FINAL REPORT

WHITE LAKE
MARSHALL 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

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

WHITE LAKE ASSESSMENT FINAL REPORT

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Marshall Conservation District

6/1/05

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

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ACKNOWLEDGEMENTS

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

City of Britton, SD
James River Water Development District
Marshall Conservation District
South Dakota Department of Environment and Natural Resources
US Natural Resource Conservation Service
US Environmental Protection Agency
Wild Rice River Water Development District
Prairie Agricultural Research, Inc.

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ABBREVIATIONS

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

EXECUTIVE SUMMARY

PROJECT TITLE: White Lake Assessment

PROJECT START DATE: 1/1/01 PROJECT COMPLETION DATE: 8/31/04

FUNDING: TOTAL BUDGET: $111,210.00

TOTAL EPA GRANT:	$66,786.00
TOTAL EXPENDITURE OF EPA FUNDS:	$58,536.15
NONFEDERAL MATCH	
South Dakota Dept. Env. Nat. Res.	$29,374.00
James River Water Dev. District	$10,000.00
Wild Rice River Dev. District	$1,000.00
Marshall Con. District	$1,002.77
BUDGET REVISIONS:	None
TOTAL EXPENDITURES:	$99,912.92

SUMMARY ACCOMPLISHMENTS

The White Lake Assessment Project was conducted as a result of White Lake being placed on the 303(d) list for an increasing trophic state index (TSI) trend, and nonpoint source pollution. The primary goal for the project was to determine sources of impairment to White Lake, and provide sufficient background data to drive a Section 319 Implementation Project.

An EPA section 319 grant provided a majority of the funding for this project. The James River Water Development District, Wild Rice River Water Development District, and Marshall County Conservation District provided local matching funds for the project. Prairie Agricultural Research, Inc. was contracted to do the field sampling and data collection.

Water quality monitoring indicated a lake having relatively typical water quality for a lake in northeast South Dakota. The lake did not thermally stratify but dissolved oxygen concentrations were sometimes dangerously low at the bottom of the lake. The water quality standard for dissolved oxygen was exceeded a number of times in the bottom samples but a viable crappie fishery indicated low dissolved oxygen levels did not destroy the fishery. Lake aeration was recommended to alleviate low dissolved oxygen conditions. The standards for nitrate, unionized ammonia, conductivity, and fecal coliform bacteria were not exceeded. Seasonality was indicated by typical temperature changes throughout the year and by seasonal changes in some parameter concentrations. Aquatic macrophyte, algae, and sediment surveys were completed for the lake. Aquatic macrophytes were not deemed a problem. Sediment amounts in the lake were not considered excessive or unusual for a South Dakotan reservoir.

Using the FLUX and BATHTUB computer models, seasonality was also indicated with the greatest sediment and nutrient loadings occurring during the spring run-off period. The results from these models were also used to establish a TMDL for total phosphorus.

The Annualized Agricultural Non-point Source computer model (ANNAGNPS) was used to judge the effect of implementing various agricultural BMPs on nutrient and sediment loading to the lake. Feedlots were not deemed problematic but the model runs indicated that no-till on small grains and row crops and developing "good" conditioned pastures could reduce nutrient and sediment loading to the lake. However, the model runs also indicated an unlikelihood of achieving the needed total phosphorus reductions and so the ecoregion based TSI target was not deemed realistic for White Lake.

It was recommended the TSI target reflect the social and economic limitations of the watershed while still supporting the beneficial uses of the lake. It was also recommended the total phosphorus TSI be used and that a total phosphorus TSI value of 71 or less be used to indicate full support of beneficial uses. Using this new target, a 30% reduction in total phosphorus loading is needed to fully support the lakes beneficial uses and reach the new TMDL of 2,355 kg/year. Achieving this target will also likely meet the TMDL for dissolved oxygen.

This reduction was considered reasonable and achievable given the social and economic constraints in the watershed. Approximately half of the small grains and row crops need to use no-till residue management and half of the pastures put in good condition to reach a 27% reduction in total phosphorus loading. The remaining 3% could come from converting some cropland to CRP or from secondary activities. Secondary restoration activities were recommended and included animal waste management system activities, lake aeration, and alum treatment.

INTRODUCTION

Purpose

The purpose of this assessment is to determine the sources of impairment to White Lake in Marshall County, South Dakota and the tributaries in its watershed. These tributaries carry sediment and nutrients that enter the Wild Rice River and reach White Lake. The lake's outlet drains to the Red River of the North drainage basin.

Wild Rice River is the primary tributary to White Lake and drains predominantly grazing lands with some cropland acres. There are three additional but smaller tributaries to White Lake that also drain predominantly grazing lands, with some cropland acres. Winter feeding areas for livestock are present in the watershed. The streams carry sediment loads and nutrient loads, which degrade water quality in the lake and cause increased eutrophication.

General Lake Description

White Lake is a 186.8-acre man-made impoundment located in north central Marshall County, South Dakota (Figure 1). White Lake was constructed as a WPA project in the 1930's. The dam impounds water on the upper watershed of the Wild Rice River, which is a tributary of the Red River. The lake offers some flood protection for downstream benefits and is used for recreation. The average depth of the lake is eight feet and it has a maximum depth of twenty feet. The outlet for the lake empties into the Wild Rice River.

Lake Identification and Location

Lake Name: White Lake
County: Marshall
Range: 57W
Nearest Municipality: Britton
Longitude: -97.618710
Primary Tributary: Wild Rice River
HUC Code: 09020105

State: South Dakota
Township: 128N
Sections: 25 and 36
Latitude: 45.861735
EPA Region: VIII
Receiving Body of Water: Wild Rice River
HUC Name: Red River Basin

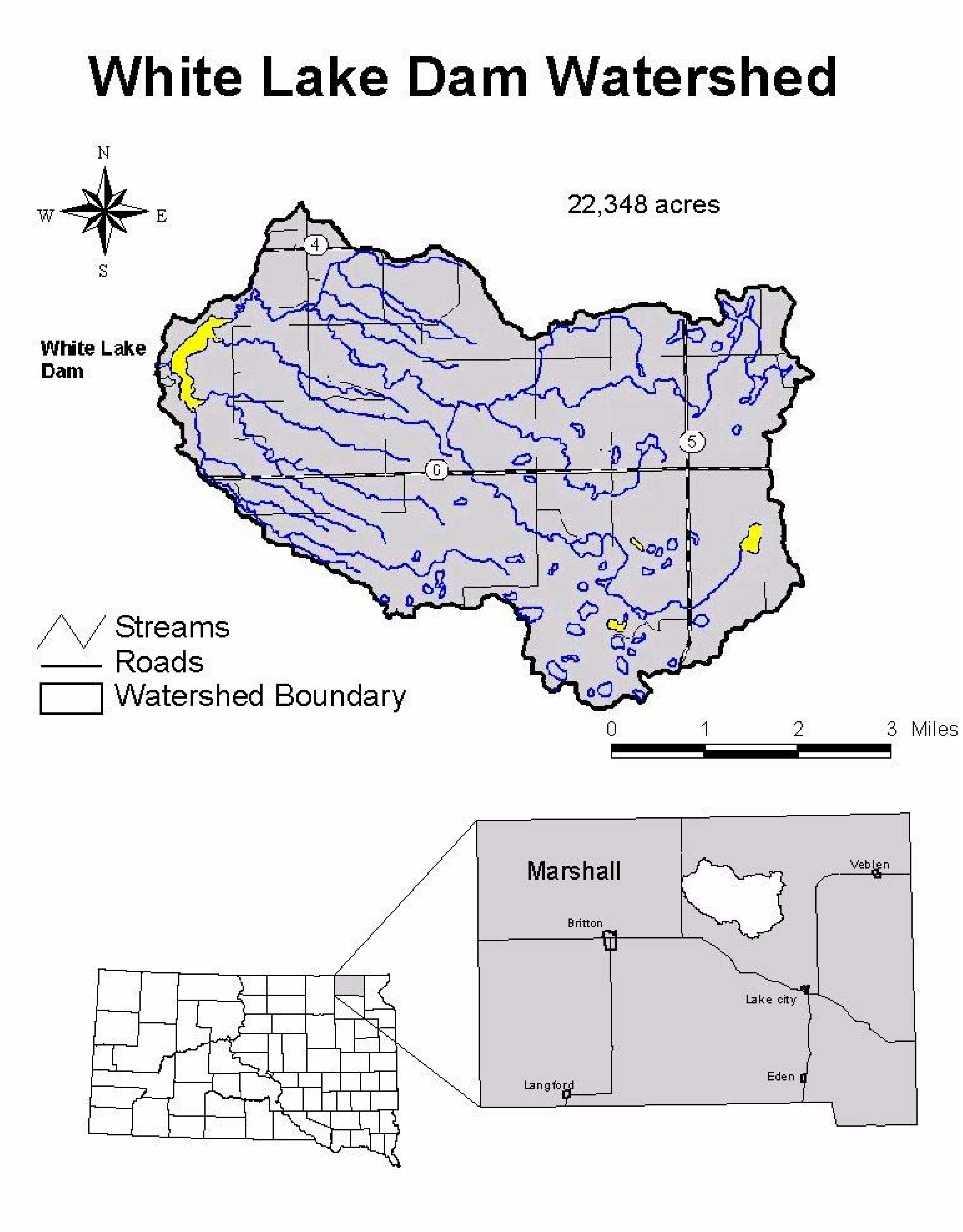

Figure 1. White Lake and its watershed, Marshall County, South Dakota.

Trophic Status Comparison

Developed by Carlson (1977), the Trophic State Index, or TSI, is a numerical value from 0 to 100 that 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 White Lake to other lakes in the area (Table 1) shows that a high rate of productivity is common for the region. The values provided in Table 1 were generated from a statewide lake assessment final report (Stueven and Stewart, 1996).

Table 1. TSI comparison of White Lake and other area lakes.

Lake	Nearest Municipality	TSI	Mean Trophic State
Elm Lake	Aberdeen	75.17	Hypereutrophic
Nine Mile Lake	Lake City	63.35	Eutrophic
Richmond Lake	Aberdeen	66.51	Hypereutrophic
South Buffalo Lake	Lake City	62.83	Eutrophic
White Lake	**Britton**	**70.13**	**Hypereutrophic**
TSI Target		**58.4**	

Beneficial Uses and Water Quality Standards

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

(1) Domestic water supply waters
(4) Warm water permanent fish life propagation
(7) Immersion recreation
(8) Limited contact recreation
(9) Fish and wildlife propagation, recreation and stock watering

With each of these uses are sets of water quality standards that must not be exceeded in order to maintain these uses. The following tables list those parameters measured during this study that must be considered when maintaining the beneficial uses as well as the concentrations for each parameter. When multiple standards for a parameter exist, the most restrictive standard is used. Additional "narrative" standards that may apply can be found in the Administrative Rules of South Dakota Articles 74:51:01:05; 06; 08; and 09. These contain language that generally prohibits the existence of materials causing pollutants to form, visible pollutants, and nuisance aquatic life. Carlson's (1977) Trophic State Indices are used during this study as a measure of beneficial use support. The indices are based on total phosphorus, Secchi disc transparency and chlorophyll a.

The critical values for beneficial use status were derived from a SDDENR study of South Dakota lake attributes (Lorenzen, 2005).

Table 2. State beneficial use standards for White Lake, Marshall County, South Dakota. Other parameters may apply but are not listed because there were no data for them.

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, Total (per 100ml)	≤5,000 *(mean)*, ≤20,000 *(single sample)*	Domestic Water Supply
Coliform, fecal *(per 100 ml)* May 1 to Sept 30	<200 *(mean),* <400 *(single sample)*	Immersion Recreation
Conductivity *(µmhos/cm @ 25 °C)*	<4,000 *(mean,)* <7,000 *(single sample)*	Wildlife Propagation and Stock Watering
Nitrogen, Unionized ammonia as N	<.04 *(mean),* <1.75 times the applicable limit *(single sample)*	Warmwater Permanent Fish Propagation
Nitrogen, nitrates as N	≤10 *(mean)*	Domestic Water Supply
Oxygen, dissolved	>5.0	Immersion and Limited Contact Recreation
pH (standard units)	6.5 - 9.0	Warmwater Permanent Fish Propagation
Solids, suspended	<90 *(mean),* <158 *(single sample)*	Warmwater Permanent Fish Propagation
Temperature	<26.67 C	Warmwater Permanent Fish Propagation

Individual parameters as well as the lake's TSI value determine the support of these beneficial uses. White Lake is listed in the state 2004 303(d) list and was identified as not supporting its beneficial uses due to nonpoint source pollution.

Wild Rice River upstream of White Lake has the beneficial uses of:

(9) Fish and wildlife propagation, recreation, and stock watering, and
(10) Irrigation

In order for the River to maintain these uses, there are five standards that must be maintained, these standards, along with their numeric criteria, are listed in Table 3.

Table 3. State water quality standards for Wild Rice River and the other unnamed tributaries of White Lake.

Parameters	Criterion, mg/l (except where noted)
Nitrate	<50 (mean) <88 (single sample)
Alkalinity	<750 (mean) <1,313 (single sample)
pH	> 6.5 and <9.5
Conductivity	<4,000 (mean) <7,000 (single sample)

Recreational Uses

The South Dakota Department of Game, Fish, and Parks provide a list of public facilities that are maintained at area lakes (Table 4). In contrast to other regional lakes, White Lake only has one boat ramp and a primitive toilet. Camping, picnicking, fishing, and swimming are possible recreational uses.

Table 4. Comparison of recreational uses on lakes in northeast South Dakota.

Lake	Parks	Ramps	Boating	Camping	Fishing	Picnicking	Swimming	Nearest Municipality
Elm Lake	1	1	X	X	X	X	X	Aberdeen
Nine Mile Lake	1	3	X	X	X	X	X	Lake City
Richmond Lake	1	2	X	X	X	X	X	Aberdeen
South Buffalo Lake		2	X		X		X	Lake City
White Lake	**1**	**1**	**X**	**X**	**X**	**X**	**X**	**Britton**

Geology

The watershed of White Lake is located at the base of the Coteau des Prairie Hills, 6 miles east and 4.5 miles north of the city of Britton in northwestern Marshall County, South Dakota. It is an accumulation of glacial sediments. The landscape in the watershed is characterized by prairie land with some low hill and stream channels. Major soil associations found in the watershed include Foremam-Poinsett and Forman-Aastad-Buse.

Land use in the watersheds is primarily agricultural composed of approximately 70% pasture, 20% cropland and 10% woodland. Small grains and hay are the main crops on cultivated lands. Some animal feeding areas are located in the watershed. Publicly owned wildlife land makes up 1100 acres in the watershed.

The average annual precipitation in the watershed is 20 inches, of which 80% usually falls in April through September. Tornadoes and severe thunderstorms strike occasionally. These storms are local and of short duration and occasionally produce heavy rain fall events. The average seasonal snowfall is 40 inches per year.

The James Aquifer underlies the lower portion of the watershed. A well located at White Lake pumps water out of the aquifer from a depth of about 220 feet and was used as a water source by the City of Britton for domestic water. A rural water system also uses this aquifer for domestic water. White Lake is primarily used during early summer to fall and provides a popular recreational area for hunting and fishing.

History

White Lake was constructed in the 1930's as a WPA project. In the early 1960's, 3 additional flood control structures were constructed in the watershed above the White Lake using PL-166 funding. These dams are functioning today as intended. According to the 1996 South Dakota Report to Congress, 305(b) water quality assessment by SD DENR, the water quality of White Lake is being impacted by non-point source agricultural pollution. Recreational users of White Lake report algae blooms and odors associated with decaying vegetation.

Additionally, the manager of the city water treatment plant stated that solids, silt and very fine sand, has been a problem for the pumps and that there has been significant increases in the cost of treating the water. Residents of the city of Britton made negative comments on water odor, color and taste when White Lake is the water source, rather than well water. The City of Britton no longer uses the lake as a drinking water source (they switched to the Brown-Day-Marshall Rural Water System about 2.5 years ago). The lake water is only used to water the local golf course.

The condition of the lake prompted the Marshall Conservation District to request Section 319 funding for a Watershed Assessment Project. After receiving 319 funds, the District contracted with Prairie Agricultural Research, Inc. to perform the water sampling and field work.

PROJECT GOALS, OBJECTIVES, AND ACTIVITIES

Planned and Actual Milestones, Products, and Completion Dates

Objective 1. Lake Sampling and Sediment Survey

The tributary water sampling and lake water sampling commenced in March, 2001. Sampling of nutrient and solids parameters continued at the three scheduled sites through October 2001 as planned. Sufficient ice cover for foot travel lasted through January and February, 2001 during which samples were collected through the ice. Spring samples were collected during March, April and May of 2001. Additional samples were taken during, the months of June, July, August, September, and October to obtain monthly readings. The sediment survey was conducted during the months of January and February, 2001, a period of safe ice cover.

Objective 2. Tributary Sampling

Immediately after the start of the project, the local coordinator began sampling the tributaries. Detailed level and flow data were entered into a database that was used to assess the nutrient and sediment loads to the lake. Measurable water flow was present from April through mid-summer, 2001 and these data were used in this report.

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

Duplicate and blank samples were collected during the course of the project to provide defendable proof that sample data were collected in a scientific and reproducible manner. QA/ QC data collection began in April of 2001 and was completed on schedule in September of 2001.

Objective 4. ANNAGNPS Modeling

On October 19, 2000, the project officer, coordinator, technician, and several range and soils specialists toured the watershed and made initial determinations for the ANNAGNPS model. The NRCS office located in Britton provided much information. This objective was completed during October and November of 2000, sooner than the proposed start and finish date.

Objective 5. Public Participation

Many of the landowners were contacted individually to assess the condition of animal feeding operations located within the project area. Further information was provided at the Marshall County Conservation District meetings. Press releases were also provided to local papers at various points throughout the project.

Objectives 6 and 7. Restoration Alternatives and Final Report

The completion of the restoration alternatives and final report for White Lake in Marshall County was delayed due to the original contractor taking a full-time job and because the DENR project officer had conflicting workloads.

Evaluation of Goal Achievements

The goal of the watershed assessment project for White Lake was to determine and document sources of impairment to the lake and to develop feasible alternatives for restoration. This was accomplished through the collection of tributary and lake data and aided by the completion of the ANNAGNPS watershed modeling. Through data analysis and modeling, identification of impairment sources was possible. The identification of these impairment sources will aid the state's non-point source (NPS) program by allowing strategic targeting of funds to portions of the watershed that will provide the greatest benefit per expenditure. A comparison of the planned and actual objective completion dates is given in Table 5.

Table 5. Proposed and actual objective completion dates for the White Lake Assessment Project.

	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Jun-05
Objective 1				▨	▨	▨	▨	▨	▨	▨						
Lake Sampling			■	■	■	■	■	■	■	■						
Objective 2			▨	▨	▨	▨	▨	▨	▨	▨						
Tributary Sampling			■	■	■	■	■	■	■							
Objective 3				▨	▨	▨	▨	▨	▨	▨	▨	▨				
QA/QC				■	■	■	■		■	■						
Objective 4				▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
Modeling						■	■									
Objective 5			▨					▨			▨			▨		
Public Participation	■	■	■	■	■	■	■	■	■	■	■	■	■			
Objective 6 & 7												▨	▨	▨	▨	
Restoration Alternatives And Final Report												■	■	■	■	■
Proposed Completion Date															▨	
Actual Completion Date															■	■

MONITORING METHODS AND RESULTS

OBJECTIVE 1 – Lake Sampling and Sediment Survey

In-lake Sampling Schedule, Methods, and Materials

Sampling began in March 1, 2001, and was conducted on a monthly basis at the three pre-selected lake sites (see Figure 2) until the project completion in October 16, 2001. Water samples were collected with a Van Dorn sampler. The samples were filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD according to the Standard Operating Procedures for Field Samplers (Stueven, et al., 2000). The laboratory analyzed the samples for the following parameters:

Fecal coliform bacteria
Total solids
Total volatile suspended solids
Nitrate/nitrite
Total phosphorus
Alkalinity
Total suspended solids
Ammonia
Total Kjeldahl nitrogen (TKN)
Total dissolved phosphorus

Personnel conducting the sampling at each of the sites recorded the following observations.

Precipitation
Odor
Dead fish
Width
Ice cover
Wind
Septic
Film
Water depth
Water color

Parameters measured in the field by sampling personnel were:

Water temperature
Conductivity
Field pH
Air temperature
Dissolved oxygen
Secchi depth

Original data may be found in Appendix A.

In-lake Water Quality Results

Water Temperature

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

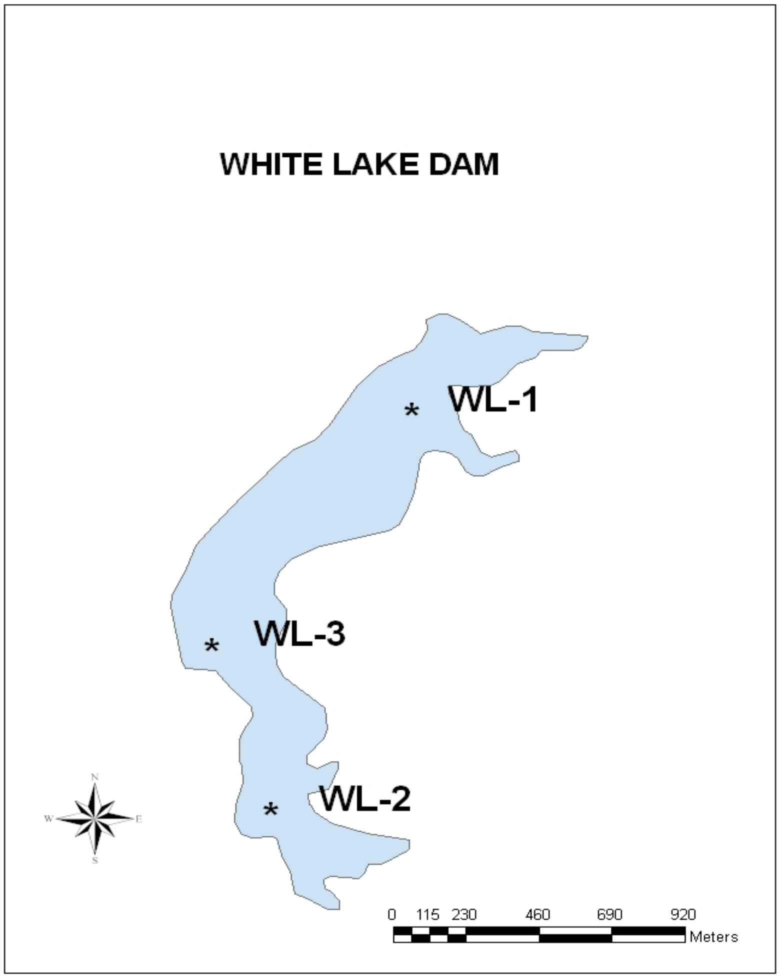

Figure 2. Sampling sites in White Lake, Marshall County, South Dakota.

The water temperature in White Lake exhibited little variation between the sites, WL1, WL2 & WL3. Temperatures showed seasonal variations that are consistent with its geographic location, steadily increasing in the spring and summer and consistently decreasing in the fall and winter (Figure 3). It can be reasonably expected that during most years the in-lake temperatures would be within a few degrees of the project data at their respective dates.

The lowest water temperatures were recorded at the two sampling times in March, 2001; these were the only samples that were taken while the lake was completely covered in ice. The peak annual temperatures were at 25.3 ºC, in July, 2001, which is well below the state standards that require it to maintain a maximum temperature under 32.2^{o} C.

White Lake did not show strong thermal stratification as evidenced by the similarity between surface and bottom temperatures. The greatest difference between surface and bottom temperatures was 2.4 ºC and occurred on May 30, 2001. Most surface and bottom temperatures were within a 1.5 ºC of each other.

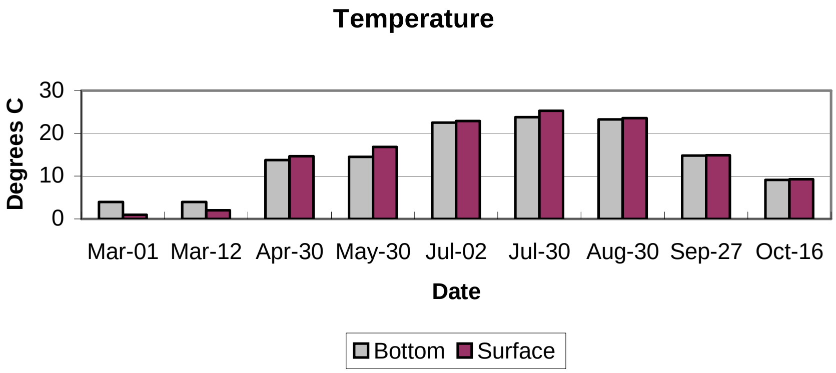

Figure 3. Average water temperatures for White Lake, Marshall County, South Dakota, 2001.

Dissolved Oxygen

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

Oxygen levels in White Lake were usually sufficient to maintain the minimum requirement for the local managed fishery (Figure 4). However, seventeen percent of the samples (17 out of 102 samples) had dissolved oxygen levels below 5.0 mg/l, the dissolved oxygen criterion for maintaining warm water permanent fish life propagation. There was no seasonal pattern to these low values but most of the low DO readings were taken at or near the bottom of the lake (see Appendix A for depth profile data). This is most likely due to bacteria using oxygen during the decomposition of organic matter on the bottom of the lake. This is not unusual for a lake in South Dakota and as long as there is sufficient oxygen at other depths it is not considered a problem for fish.

During the four sampling days when DO concentrations were below the standard criterion, there appeared to be adequate oxygen concentrations at other depths or locations in the lake for two of those days (7/30/01 and 8/30/01). The other two days

(3/1/01 and 3/12/01) were at the end of winter when there was still ice cover on the lake. There did not appear to be sufficient refuge during these dates to protect the fishery and aquatic life.

However, lack of a fish kill that year and lack of recurring winter (or summer) fish kills indicate that there must be refuge somewhere in the lake. Gill net data from 2003 nettings by the South Dakota Department of Game, Fish & Parks (http://www.sdgfp.info/Wildlife/fishing/NELakes/Blackcrappiegillnet.htm) indicated the second highest number/net of black crappie out of seventeen northeastern lakes sampled. Additional game fish were also collected. So it appears that occasional low dissolved oxygen levels did not destroy the major fishery in the lake. Nevertheless, because these two days appeared to lack areas of sufficient DO, a TMDL should be done for DO for White Lake.

Oxygen deficits in lakes are often a result of decomposition of organic matter that originates in the watershed or from decomposing algae produced in the lake. Because algae are often influenced by phosphorus, the proposed phosphorus TMDL might indirectly address the dissolved oxygen issue because nutrient loadings are likely the root cause of excess algae. Addressing the phosphorus problem might also prevent or minimize dangerously low dissolved oxygen levels in the lake. Presumably phosphorus control will result in less algae and therefore less organic matter to decompose and less oxygen demand by bacteria.

Lake aeration is also recommended. Lake aeration is a well documented method of preventing fish kills due to low dissolved oxygen concentrations (Cooke et al., 1986). Although aeration is admittedly a short term solution that only addresses the problem rather than the source of the problem, aeration should protect the lakes aquatic life from lethal levels of dissolved oxygen until the effects of phosphorus reductions are realized.

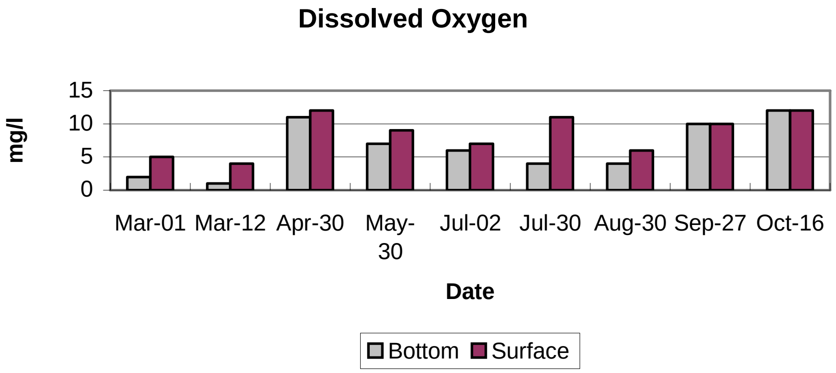

Figure 4. Average dissolved oxygen concentrations for White Lake, Marshall County, South Dakota, 2001.

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. At neutral (pH of 7) acid ions (H+) equal the base ions (OH-). Values less than 7 are considered acidic (more H+ ions) and greater than 7 are basic (more OH- ions). Algal and macrophyte photosynthesis act to increase a lake's pH. The decomposition of organic matter will reduce the pH. The extent to which this occurs is affected by the lakes ability to buffer against changes in pH. The presence of a high alkalinity (>200 mg/l) represents considerable buffering capacity and will reduce the effects of both photosynthesis and decay in producing large fluctuations in pH.

pH values in White Lake ranged from 7.2 to 8.9 and averaged 8.4. All samples had pH levels within the criteria for maintaining the permanent fish life propagation use. There did not appear to be any clear relationship between chlorophyll a and pH, and there was little seasonal variation in pH (Figure 5).

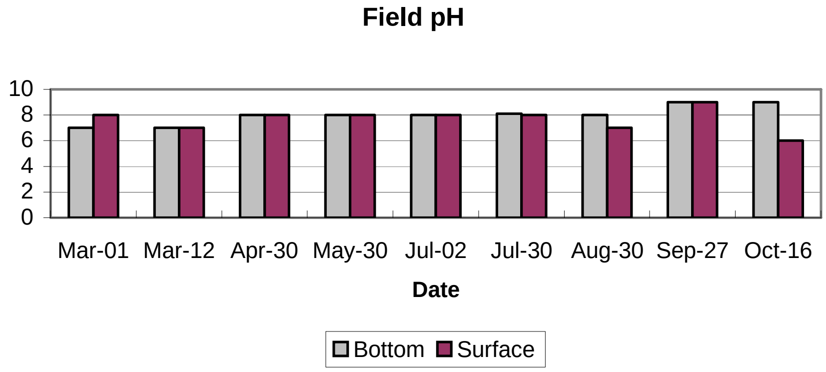

Figure 5. Average pH values for White Lake, Marshall County, South Dakota, 2001.

Conductivity

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

Conductivity readings ranged from 688 to 1,958 µmhos/cm and were generally higher during March, 2001. Conductivity during the remainder of the year was relatively constant at around 1,000 µmhos/cm (Figure 6). State standards for fish and wildlife propagation and stock watering require that conductivity does not equal or exceed 7,000 µmhos/cm on any single day. All conductivity readings at White Lake were less than the State standard.

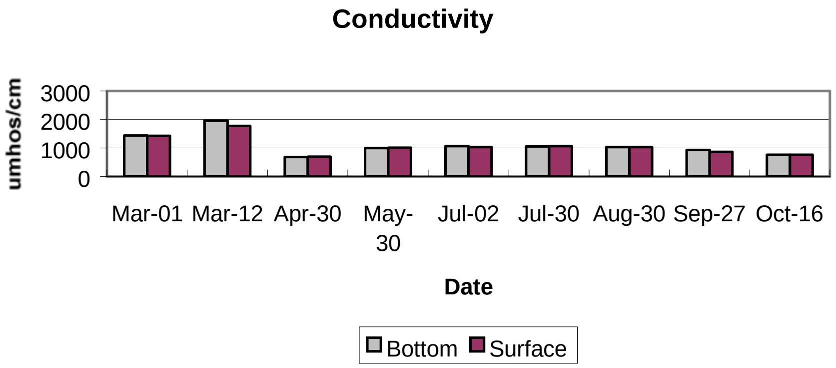

Figure 6. Average conductivity readings for White Lake, Marshall County, South Dakota, 2001.

Secchi Depth

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

Secchi transparency readings in White Lake averaged 0.9 meters with the greatest readings found during March, 2001 (Figure 7). This is probably due to the late winter/early spring conditions being unfavorable for algae growth. The mean Secchi transparency reading during the primary growing season (May 15 – September 15) was equivalent to a TSI value of 62.88. This was slightly less than the mean TSI value of 64.02 for reservoirs in this ecoregion (Stueven et al., 2000), which means White Lake isn't particularly very clear or very turbid relative to other lakes in the region. Regression analyses did not reveal any strong relationships between Secchi transparency and either chlorophyll *a* (algae) or suspended solids concentration (R^2 less than 0.20 for both regressions).

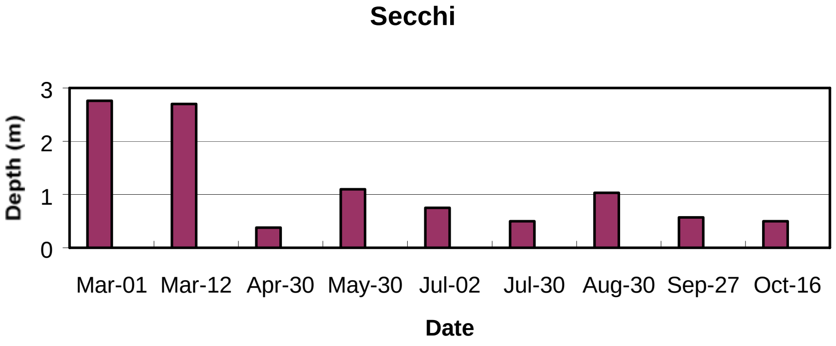

Figure 7. Average Secchi depths for White Lake, Marshall County, South Dakota, 2001.

Alkalinity

A lakes total alkalinity affects the ability of its water to buffer against changes in pH. Total alkalinity consists of all dissolved electrolytes (ions) with the ability to accept and neutralize protons (Wetzel, 2000). Due to the abundance of carbon dioxide (CO_2) and carbonates, most freshwater contains bicarbonates as their primary source of alkalinity. It is commonly found in concentrations as high as 200 mg/l or greater. Total alkalinty can also used in the estimation procedure for calculating the amount of alum necessary for phosphorus precipitation.

The total alkalinity in White Lake averaged around 200 mg/l (Figure 8) and varied from a low of 173 mg/l during April 30, 2001 to a peak value of 260 mg/l during March 12, 2001. These values are typical for lakes in South Dakota. The alkalinity standard was never exceeded.

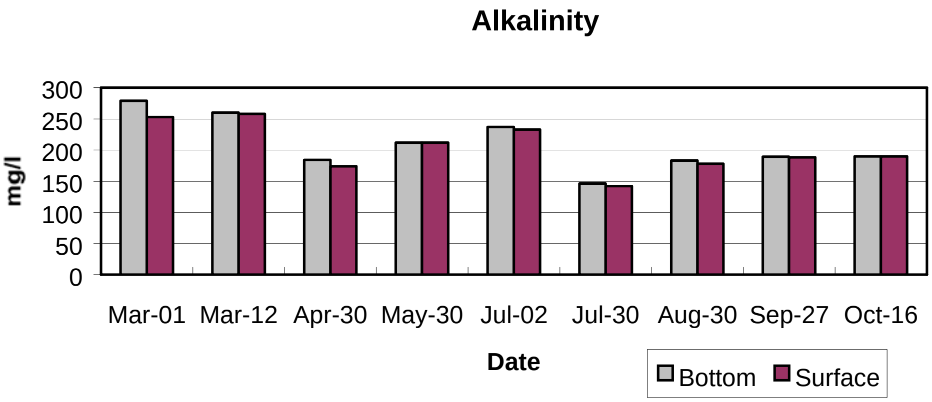

Figure 8. Average alkalinity concentrations for White Lake, Marshall County, South Dakota, 2001.

Solids

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

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

White Lake exhibited seasonal variation in total solids concentrations with the greatest values occurring during March 1, 2001 (Figure 9). Suspended solids concentrations in White Lake remained fairly stable at around 20 to 30 mg/l throughout the course of the year. One sample taken on April 30, 2001 had a total suspended solids concentration of 470 mg/l but this is thought to be an anomaly (perhaps due to sampling or laboratory error) and was not used.

Volatile suspended solids followed the same temporal trend as total suspended solids but with concentrations usually around 10 mg/l. Most of the samples analyzed for total suspended solids contained less than 50% organic matter.

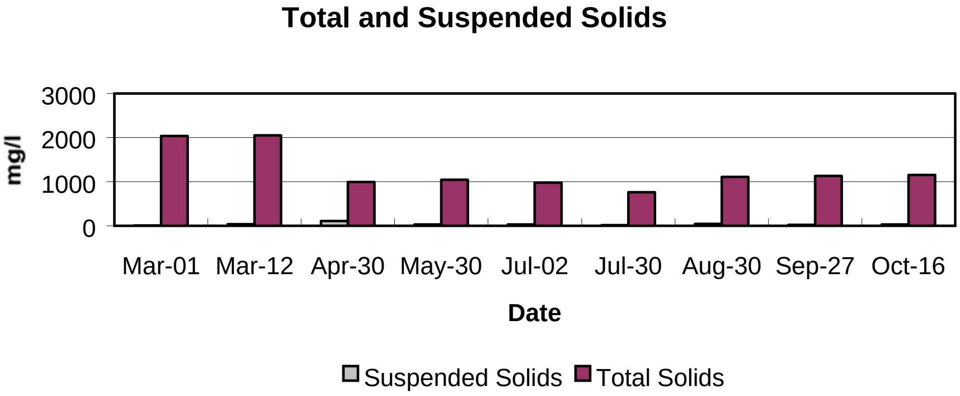

Figure 9. Average total and suspended solids concentrations for White Lake, Marshall County, South Dakota, 2001.

Nitrogen

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

Eighty percent of the samples collected from White Lake and analyzed for nitrates/nitrites had concentrations at or below the 0.1 mg/l detection limit. The remaining 20% of the samples were collected during spring run-off and had nitrate/nitrite concentrations around 0.2 or 0.3 mg/l (see Appendix A). Ammonia concentrations were at or below the 0.02 mg/l detection limit seven times (15% of the samples) and none of these samples were limited to one particular season of the year. Ammonia concentrations averaged 0.24 mg/l and ranged from below the 0.02 mg/l detection limit to 0.67 mg/l (Table 6). The highest ammonia concentrations coincided with dissolved oxygen levels less than 5.0 mg/l and may indicate ammonification and release of ammonia from the bottom sediments during times of low oxygen. The lowest average ammonia concentrations occurred during May 30, 2001; a time when spring runoff had ceased. Unionized ammonia concentrations never exceeded the State standard criteria.

Total nitrogen in White Lake averaged 1.53 mg/l and ranged from 0.53 mg/l to 2.99 mg/l. Most of the samples (70%) had total nitrogen concentrations between 1 mg/l and 2 mg/l, which is typical of lakes in South Dakota. The samples collected during 5/30/01 were less than 1 mg/l and probably reflected a post-runoff/pre-algae growth period.

Table 6. Total ammonia concentrations (mg/l) for White Lake, Marshall County, South Dakota during 2001.

Date	WL1 Surface	WL1 Bottom	WL2 Surface	WL2 Bottom	WL3 Surface	WL3 Bottom
3/01/01			.56	.67	.55	
3/12/01	.53	.58				
4/30/01	.19	.25	.20	.28	.19	.23
5/30/01	<.02	.03	<.02	<.02	<.02	.13
7/02/01	.09	.10	.13	.17	.14	.13
7/30/01	<.02	.28	<.02	.26	<.02	.27
8/30/01	.32	.32	.29	.41	.31	.47
9/27/01	.18	.19	.25	.50	.25	.24
10/16/01	.18	.16	.23	.21	.23	.25

Phosphorus

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

The average in-lake total phosphorus concentration during the assessment was 0.16 mg/l. Total phosphorus concentrations between 0.1 and 0.2 mg/l are generally regarded as indicative of mesotrophic conditions (USEPA, 1974). Mesotrophic conditions indicate moderate lake productivity and do not indicate an excess amount of phosphorus in the lake. This is relatively good for a lake in South Dakota, where an excess of phosphorus seems to be the norm. Total phosphorus concentrations were generally lowest during the spring and highest during the summer and bottom samples were usually higher in total phosphorus concentration than the surface samples (Table 7). Some of this difference may be due to natural release of phosphorus from the sediments and some from sediment disturbance during sampling.

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.

Unlike total phosphorus, average total dissolved phosphorus concentrations were reasonably high during spring run-off and decreased to a low during May 30, 2001, when spring run-off had ceased (Table 8). On the average, total dissolved phosphorus made up approximately 48% of the total phosphorus and the percentage varied little from season to season. The greatest differences were observed during April 1 and 12, 2001, when the percentage of total dissolved phosphorus reached as high and 89%. This may be due to run-off, low algal productivity and low uptake of dissolved phosphorus during this time.

Table 7. Total phosphorus concentrations (mg/l) for White Lake, Marshall County, South Dakota during 2001.

Date	WL1 Surface	WL1 Bottom	WL2 Surface	WL2 Bottom	WL3 Surface	WL3 Bottom
3/01/01			0.108	0.178	0.102	
3/12/01	0.101	0.112				
4/30/01	0.177	0.219	0.173	0.230	0.175	0.173
5/30/01	0.059	0.075	0.062	0.061	0.059	0.140
7/02/01	0.198	0.300	0.126	0.309	0.164	0.207
7/30/01	0.220	0.213	0.302	0.197	0.003	0.002
8/30/01	0.072	0.149	0.123	0.176	0.127	0.201
9/27/01	0.134	0.148	0.121	0.134	0.121	0.119
10/16/01	0.132	0.132	0.130	0.132	0.130	0.203

Table 8. Total dissolved phosphorus concentrations (mg/l) for White Lake, Marshall County, South Dakota during 2001.

Date	WL1 Surface	WL1 Bottom	WL2 Surface	WL2 Bottom	WL3 Surface	WL3 Bottom
3/01/01			.096	.145	.09	
3/12/01	.086	.097				
4/30/01	.076	.077	.079	.071	.078	.075
5/30/01	.032	.034	.03	.029	.031	.06
7/02/01	.113	.117	.126	.124	.122	.12
7/30/01	.095	.097	.077	.077	.104	.104
8/30/01	.072	.075	.073	.09	.096	.11
9/27/01	.043	.041	.05	.051	.048	.047
10/16/01	.032	.033	.037	.036	.047	.038

Fecal Coliform Bacteria

White Lake is listed for the beneficial use of immersion recreation which requires that no single sample exceed 400 colonies/100ml or the 30 day geometric mean (consisting of at least 5 samples) be no more than 200 colonies/100ml. No exceedences of the state standard were observed during the project. Samples collected and analyzed by the State Health Lab for fecal coliform were consistently at or below the detection limit of 10 colonies per 100 ml (see Appendix A). The only sample collected that indicated the presence of fecal coliform was collected on July 2, 2001 and had a concentration of 20 colonies per 100 ml.

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 and algal uptake of nitrogen from the atmosphere. 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.

The average total nitrogen (TN) to total phosphorus (TP) ratio for the water samples collected from White Lake was 10.4 with a range of 5.1 to 18.4 (Appendix A). There was little seasonality to the TN:TP ratios. TN:TP ratios during the summer did not particularly favor phosphorus or nitrogen.

Chlorophyll *a*

There were a limited number of samples analyzed for chlorophyll *a*. The data indicated relatively low concentrations during the spring and an algae bloom during July, 2001 at all three sites and during mid-October at site WL1. The concentrations were typical of other lakes in the ecoregion.

Table 9. Chlorophyll *a* concentrations (mg/m^3) for White Lake, Marshall County, South Dakota during 2001.

Date	WL1 Surface	WL2 Surface	WL3 Surface
3/01/01			0.70
4/30/01	15.42	5.71	9.71
5/30/01	1.90	.20	1.20
7/02/01	21.13	16.92	3.61
7/30/01	74.99	132.97	108.14
9/27/01	21.23	22.03	19.12
10/16/01	113.24	18.72	23.23

Trophic State

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

Lakes with TSI values less than 35 are generally considered to be oligotrophic and contain very small amounts of nutrients, little plant life, and are generally very clear. Lakes that have a score of 35 to 50 are considered 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 may severely impair their beneficial use and aesthetic beauty.

Table 10. Trophic state and TSI values.

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

White Lake is classified for warmwater permanent fish life propagation and as determined in "Targeting Impaired Lakes in South Dakota" (Lorenzen, 2005), lakes or reservoirs with this use should have a median growing season (May 15 – September 15) Secchi/chlorophyll *a* TSI value of 58.4 or less to fully support their beneficial uses. During the study the median Secchi/chlorophyll *a* TSI during the growing season was 60.00, placing it within the eutrophic category and as not supporting its uses.

Phytoplankton

Algae populations were not monitored during the study. However, limited data collected during a previous statewide monitoring effort may provide insights into the algae of White Lake. Surface algae samples were collected mid-lake on 3 dates during June 26 and July 30, 2000 and March 1, 2001. A total of 22 taxa including one 'unidentified algae' category were collected during this short survey (see Appendix A for the original data).

Flagellated (motile) algae belonging to five phyla were the most diverse group of planktonic algae in White Dam Lake with nine taxa observed, including an unidentified microflagellate. Cryptomonad flagellates (Cryptophyta), euglenoids (Euglenophyta), and green flagellates (Chlorophyta) were equally distributed with two species each, whereas yellow-brown flagellates (Chrysophyta) and dinoflagellates (Pyrrhophyta) contributed one taxon apiece.

Non-motile green algae (Chlorophyta) represented the second most diverse algal group with six taxa collected, followed by diatoms (Bacillariophyta) and blue-green algae (Cyanophyta) with three taxa each.

White Lake summer algal biovolume averaged 13,599,557 µm3/ml, of which nearly 91% was contributed by blue-green algae, almost entirely *Aphanizomenon flos-aquae*. Algal abundance (density) for June and July averaged 112,295 cells/ml, nearly 97% of which was contributed by blue-green algae.

The summer blue-green algae population (almost all *Aphanizomenon*) present in White Lake on July 30, 2000, consisting of 145,708 cells/ml and 17,047,836 μm^3/ml of biovolume, represents what is considered a dense bloom. Limited algae data obtained in past years suggest these blue-green blooms were considerably smaller in White Lake during the last two decades, e.g. 3,761,512 μm^3/ml in early August 1979 and 4,093,011 μm^3/ml in late July 1989 (Stueven and Stewart, 1996; Koth, 1981). The data further suggest that while there was little significant change in the size of algae populations between 1979 and 1989, the last decade White Lake summer blue-green populations appear to have increased by at least 4-fold.

Sediment Survey

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

A sediment survey was conducted on White Lake during mid-winter of 2000/2001. A total of 246 holes were drilled through the ice. At each hole, the water depth was recorded and a piece of rebar was pushed into the sediment as far as possible and the length of rebar from the end back to the surface ice was noted. The difference between that measurement and the water depth equals the sediment depth.

Figures 11 and 12 provide contour maps of water depth and sediment depth. Water depth ranged from 0 to 24 feet (7.32 meters). The sediment depths ranged from 0 to 6 feet (1.83 meters) but were mostly around 2 feet (0.61 meters). These sediment depths are not considered unusual for a South Dakotan reservoir. However, lake depth could be increased, possibly up to 25%, if this sediment was removed. This might create conditions more favorable for stratification, remove sediment that could otherwise release nutrients into the water column, and extend the life of the lake.

Elutriate Testing

An elutriate test was run on sediment and water samples collected from mid-lake during 3/1/2001. Sediment was collected with a Petite Ponar sampler and water was collected with a Van Dorn sampler. The samples were shipped to the State Health Lab for analysis. The sediment was mixed with lake water and the resultant elutriate was analyzed for the same parameters as the receiving water.

The elutriate and receiving water tests indicated many of the parameters were below their respective detection limits and none of the results indicated problematic conditions concerning these parameters (Tables 11 and 12).

Table 11. Parameters that were at or below their respective detection limits for White Lake elutriate test samples, 3/1/2001.

Alachlor	Chlorodane	Endrin	Heptachlor
Heptachlor Epoxide	Methoxychlor	Toxaphene	Aldrin
Dieldrin	PCB screen (various Arochlors)	Diazinon	DDD
DDT	DDE	Beta BHC	Gamma BHC
Alpha BHC	Endosulfan II	Atrazine	Cadmium
Lead	Silver		

Table 12. Elutriate test results for White Lake, Marshall County, South Dakota, during 3/1/2001.

Parameter	Elutriate Water	Receiving Water
COD	54.7 mg/l	63.2 mg/l
Total Phosphorus	0.048 mg/l	0.085 mg/l
TKN	2.42 mg/l	1.62 mg/l
Hardness	1280 mg/l	1280 mg/l
Nitrate	0.1 mg/l	0.2 mg/l
Nitrite	0.04 mg/l	<0.02 mg/l
Ammonia	1.31 mg/l	0.52 mg/l
Aluminum	1.6 µg/l	<0.5 µg/l
Arsenic	4.6 µg/l	3.2 µg/l
Copper	3.1 µg/l	8.3 µg/l
Total Mercury	<0.1 µg/l	0.2 µg/l
Nickel	8.4 µg/l	10.0 µg/l
Selenium	1.6 µg/l	1.7 µg/l
Zinc	45.1 µg/l	8.2 µg/l

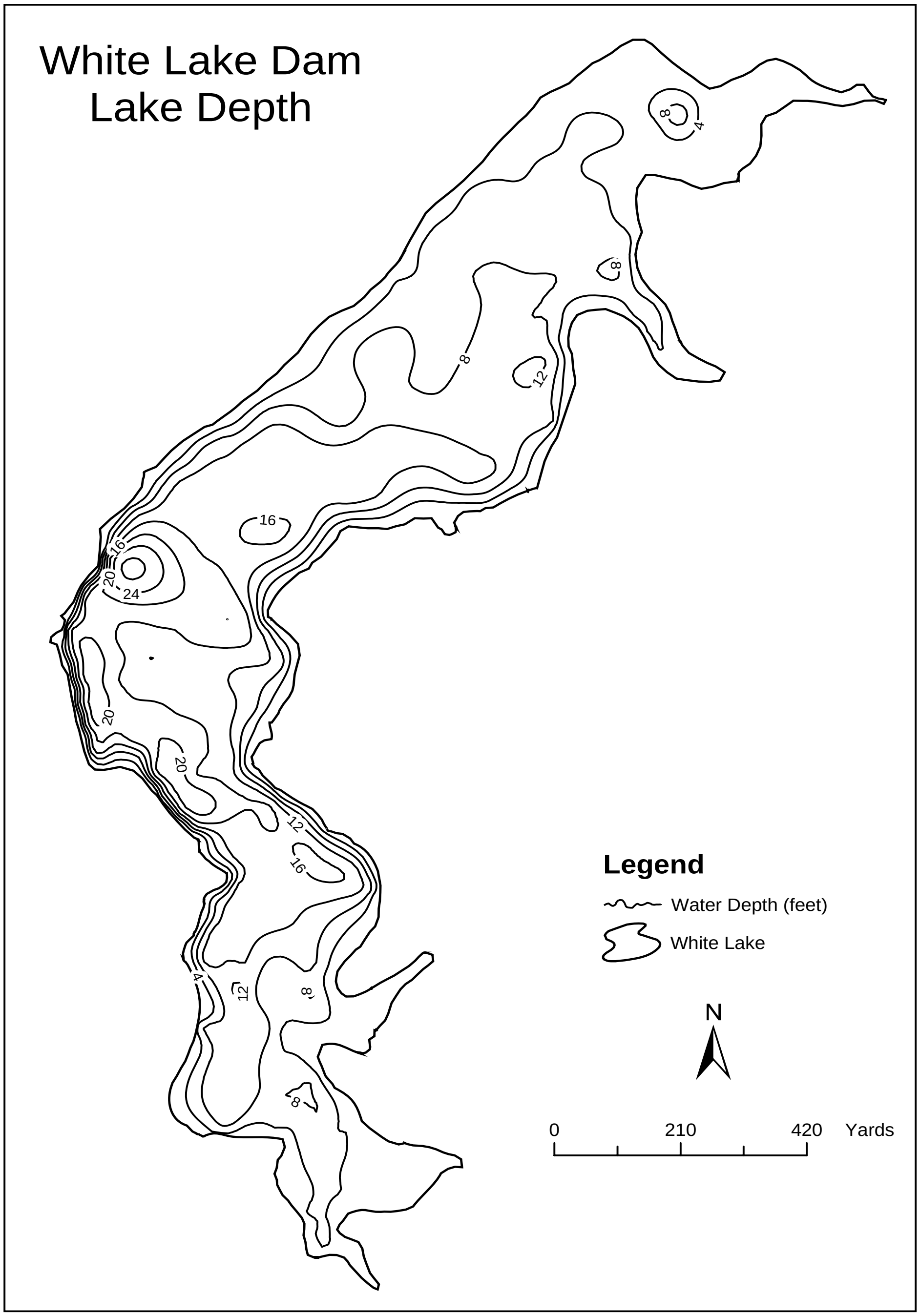

Figure 10. Water depths for White Lake, Marshall County, South Dakota, 2001.

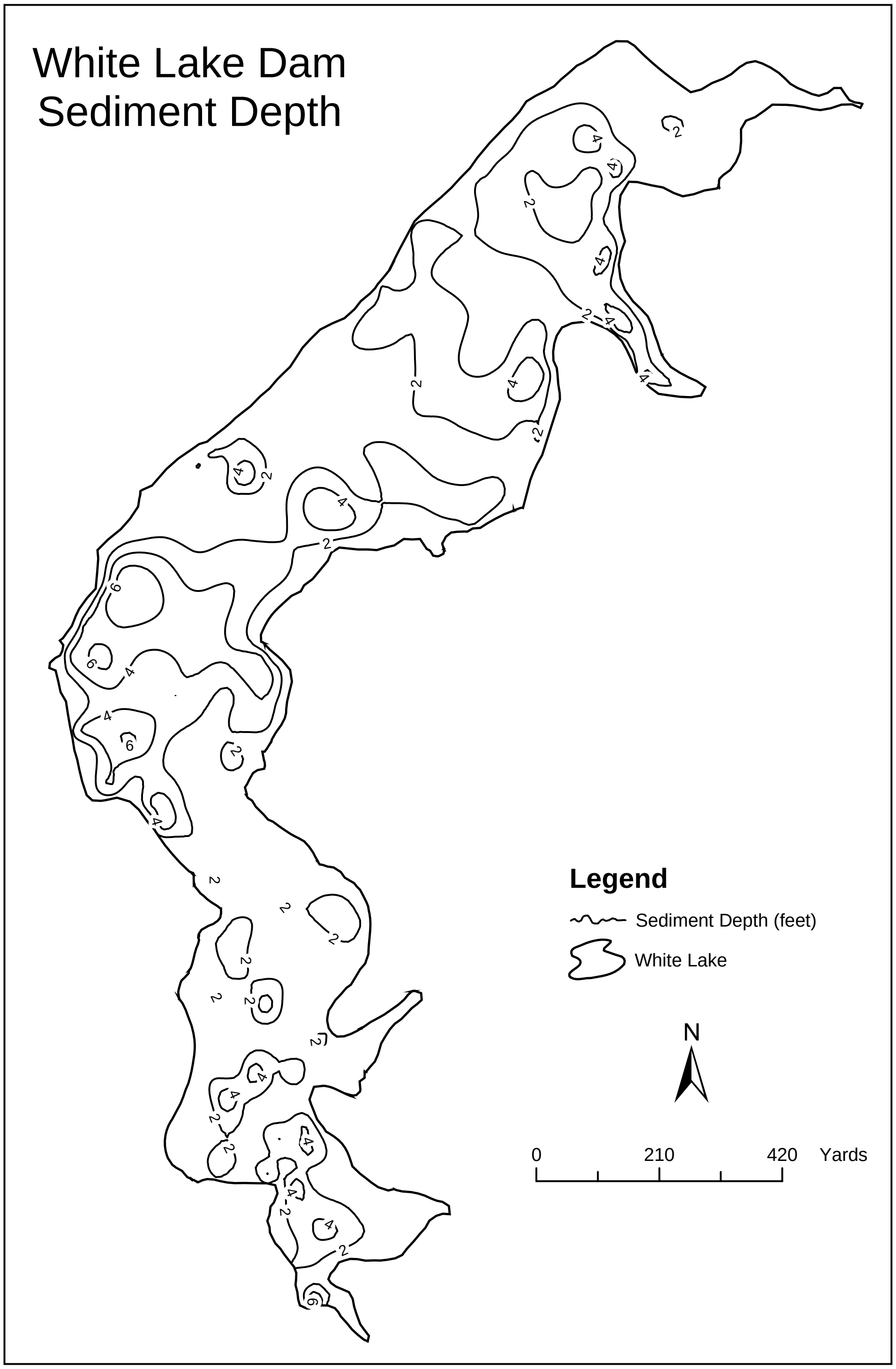

Figure 11. Sediment depths for White Lake, Marshall County, South Dakota, 2001.

Macrophyte Survey

A macrophyte/shoreline condition survey was conducted during August 2003. Fourteen locations were established approximately equidistant from each other around the perimeter of the lake. At each location, the bank stability, vegetative cover, and vegetative zone width were rated from 0 to 10 (10 being the optimal condition). Three macrophyte survey points were also established at each location with the nearest point being approximately ten feet from the shoreline and the farthest point 30-40 feet away from the shoreline. At each point, a weighted garden rake handle was thrown in four directions. The relative percent recovery of plant species on the rake was noted and the relative plant density at each point was judged from the four rake pulls.

The shoreline of White Lake was judged above average. The rating scores for bank stability, vegetative cover, and vegetative zone width averaged scores of 8.2, 8.6 and 6.9 respectively. This means that the lake had very good bank stability and vegetative cover. The lower vegetative zone width score and was due to the west side of the lake having relatively steep banks with little room for vegetative growth along the shore. The west shoreline is not impacted greatly by the prevailing westerly winds so erosion of this shoreline from wave action is minimal.

The macrophyte survey indicated few macrophytes in the lake. Only one rake toss out of fifty-six tosses retrieved a macrophyte (unidentified pondweed) and so macrophytes were not considered a problem in the lake.

Threatened and Endangered Species

The only one species on the federal list of threatened and endangered species likely to occur in the White Lake watershed is the bald eagle (Haliaeetus leucocephalis), which is listed as threatened. No bald eagles were encountered during this study; however, care should be taken when conducting mitigation projects in the White Lake watershed.

Nesting bald eagles have not been documented in the project area but there could be eagles migrating through the area, especially during the fall waterfowl migration. 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.

OBJECTIVE 2 – Tributary Water Chemistry and Loadings to White Lake

Tributary Sampling Schedule, Methods, and Materials

A total of ten tributary monitoring sites were selected along the main tributaries that lead to White Lake (Figure 12). The sites were selected to determine which portions of the watershed were contributing the greatest amount of nutrient and sediment load to the lake. Seven of the sites (sites WLO01, WLT02, WLT03, WLT04, WLT05, WLT06, WLT07, and WLT08) were equipped with Stevens Type F stage recorders. The remaining three sites (sites WLT7N, WLT9, and WLT10) were equipped with ISCO Flow meters attached to a GLS auto-sampling unit. Water stages were monitored and recorded to the nearest 1/100th of a foot for each of the sites. A March-McBirney Model 210D flow meter was used to determine flows at various stages during spring run-off. The stages and flows were then used to create a stage/discharge relationship for each site.

Sampling at tributary sites began March 12, 2001 and continued on a weekly basis through May, and at least monthly thereafter and after significant rainfall, with completion on September 26, 2001. Most samples were collected using a suspended sediment sampler. Sites WLT7N, WLT09, and WLT10 were equipped with ISCO auto-sampling units to automatically collect samples based on increase of flow but the sampler decided to use the suspended sediment sampler instead of the automatically collected samples. Water samples were then filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD according to the Standard Operating Procedures For Field Samplers (Stueven, et al., 2000).

The laboratory analyzed the samples for the following parameters:

Fecal coliform bacteria
Total solids
Total suspended solids
Nitrate
Total phosphorus
Alkalinity
Total volatile suspended solids
Ammonia
Total Kjeldahl nitrogen (TKN)
Total dissolved phosphorus

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

Precipitation
Odor
Dead fish
Turbidity
Water depth
Water color
Wind
Septic
Film
Width
Ice cover

Parameters measured in the field by sampling personnel were:

Water temperature
Conductivity
Field pH
Air temperature
Dissolved oxygen

Total nutrient and sediment loads were calculated with the use of the Army Corps of Engineers eutrophication model known as FLUX (Walker, 1999). FLUX uses individual sample data in correlation with daily discharges to develop loading calculations for total phosphorus, total nitrogen, and total solids.

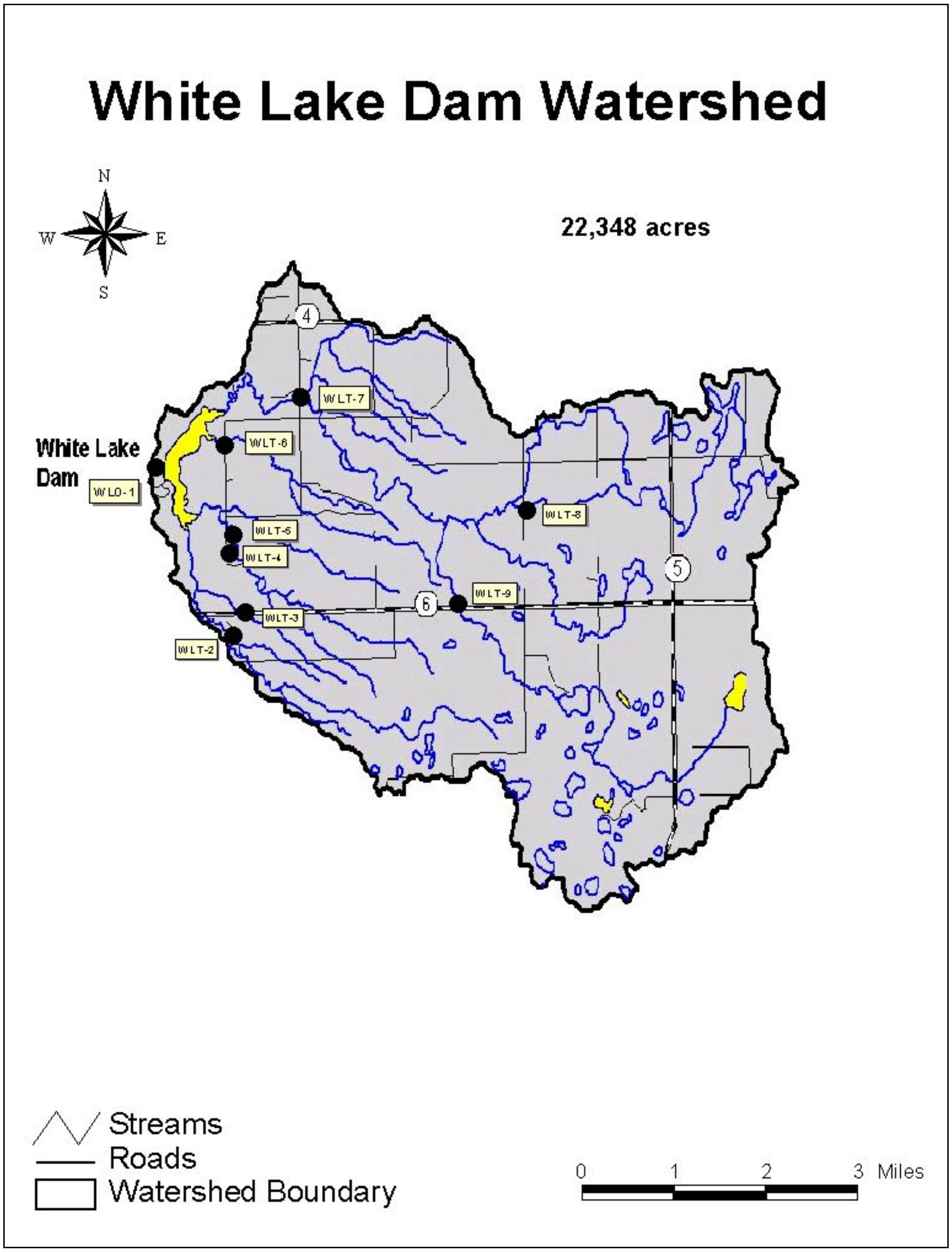

Figure 12. Stream sampling sites in the White Lake watershed.

Tributary Sampling Results

Fecal Coliform Bacteria

Fecal coliform are bacteria that are found in the digestive tract of warm-blooded animals. Some common types of bacteria are *E. coli*, *Salmonella,* and *Streptococcus,* which are associated with livestock, wildlife, and human waste (Novotny, 1994). Major sources of fecal coliform bacteria in the White Lake drainage are most likely cattle, wildlife, and humans (septic systems).

Approximately 42% of the samples had fecal coliform bacteria concentrations at or below the 10 colonies/100 ml detection limit (Table 13). Although no fecal coliform standard exists for the tributaries, 19% of the samples (15 samples) had concentrations above the 400 colonies/100 ml criterion for immersion recreation and 9% (7 samples) were above the 2000 colonies/100 ml criterion for limited contact recreation. The relatively high counts in these seven samples are thought to be due to either livestock or septic systems.

Table 13. Fecal coliform concentrations (colonies/100ml) in White Lake tributaries, Marshall County, South Dakota during 2001.

Date	WL01	WLT-2	WLT-3	WLT-4	WLT-5	WLT-6	WLT-7	WLT-7N	WLT-8	WLT-9
3/29/01								<10		
4/02/01		<10	<10	10	<10	<10	<10	<10		
4/09/01	250	10	20	10	10	10	210	10	40	10
4/12/01	40						80		30	100
4/18/01	<10	180	20	<10	<10	<10	<10	<10	<10	10
4/25/01	<10	470	50	10	<10	<10	30	<10	<10	10
5/07/01	200	60000	63000	1200	80	20	380	50	20	200
5/14/01	70	700	100	180	20	40	30	20	<10	60
6/14/01	20	3400	500	400	300	700	200	10	1400	2600
7/16/01									19000	
8/15/01	10			1100					3900	
9/26/01	<10			850					2200	

Alkalinity

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

Alkalinity concentrations in White Lake's tributaries varied from as high as 369 mg/l to as low as 94 mg/l (Table 14). The state standard for alkalinity is a maximum of 750 mg/l as a geometric mean or 1,313 mg/l in a single sample. None of the tributary samples exceeded 1313 mg/l. The mean concentrations from the sampling sites ranged from 164 mg/l to 287 mg/l. These concentrations are generally typical of streams in South Dakota.

Table 14. Total alkalinity concentrations (mg/l) for White Lake tributaries, Marshall County, South Dakota during 2001.

Date	WL01	WLT-2	WLT-3	WLT-4	WLT-5	WLT-6	WLT-7	WLT-7N	WLT-8	WLT-9
3/29/01								176		
4/02/01		164	225	228	207	176	160	141		
4/09/01	94	132	236	149	263	166	109	157	109	121
4/12/01	133						116		123	116

Table 14. Continued.

Date	WL01	WLT-2	WLT-3	WLT-4	WLT-5	WLT-6	WLT-7	WLT-7N	WLT-8	WLT-9
4/18/01	177	161	302	175	362	285	136	307	141	145
4/25/01	166	188	252	208	262	211	156	190	151	153
5/07/01	182	220	239	230	266	234	184	204	204	194
5/14/01	194	251	369	254	354	346	237	364	237	220
6/14/01	218	200	353	307	295	275	257	380	263	240
7/16/01	232								263	
8/15/01	174			196					273	
9/26/01	197			351					311	
Mean	176	164	282	233	287	242	169	240	208	187

Solids

Total solids are the sum of all dissolved and suspended as well as organic and inorganic materials. Dissolved solids are typically found in higher concentrations in groundwater. Tables 15 and 16 list the total solids and suspended solids concentrations found in the White Lake tributaries.

Table 15. Total solids concentrations (mg/l) for White Lake tributaries, Marshall County, South Dakota during 2001.

Date	WL01	WLT-2	WLT-3	WLT-4	WLT-5	WLT-6	WLT-7	WLT-7N	WLT-8	WLT-9
3/29/01								1171		
4/02/01		819	724	1387	1762	772	885	827		
4/09/01	504	609	790	796	2346	664	539	924	571	585
4/12/01	763						531		565	419
4/18/01	1106	751	1136	946	3317	1198	559	2040	525	510
4/25/01	896	916	847	1264	2616	1063	794	1401	682	689
5/07/01	951	1087	774	1404	2470	1148	975	1535	990	859
5/14/01	1006	1142	1220	1424	3396	1375	1041	2419	1093	833
6/14/01	1086	1195	993	2279	3035	1157	1161	1821	1342	999
7/16/01	1141								1218	
8/15/01	1093			1889					1180	
9/26/01	1136			2539					1202	
Mean	868	931	926	1548	2706	1047	686	1371	937	699

Table 16. Suspended solids concentrations (mg/l) for White Lake tributaries, Marshall County, South Dakota during 2001.

Date	WL01	WLT-2	WLT-3	WLT-4	WLT-5	WLT-6	WLT-7	WLT-7N	WLT-8	WLT-9
3/29/01								5		
4/02/01		12	3	8	5	17	11	11		
4/09/01	25	24	3	8	6	1	102	10	46	4
4/12/01	23						66		47	26
4/18/01	18	12	1	3	2	3	19	1	10	3
4/25/01	32	14	4	5	4	3	44	4	10	5
5/07/01	40	34	8	7	5	6	40	7	6	2
5/14/01	21	32	4	6	6	7	12	10	2	7
6/14/01	17	25	2	6	7	4	11	7	15	15
7/16/01	2								76	
8/15/01	18			11					66	
9/26/01	18			17					24	
Mean	21	22	4	8	5	6	38	7	30	9

The mean annual total solids concentrations for the tributaries ranged from 686 to 2706 mg/l with site WLT-5, one of the smaller tributaries, having the greatest mean of 2706 mg/l. By contrast, Wild Rice Creek (sites WLT07, WLT-7N, WLT08, and WLT-9) had relatively low annual mean total solids concentrations of 686, 1371, 937, and 699 mg/l respectively. There was no clear seasonal pattern to the total solids concentrations although the samples taken from early April appeared to have the lowest concentrations.

Total suspended solids ranged from 1 to 102 mg/l and usually comprised only about 5% or less of the total solids. There is no State standard for total suspended solids that applies to the tributaries.

Nitrogen

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

Inorganic nitrogen is the form of nitrogen most readily available for plant growth. The total inorganic nitrogen concentrations were highest during the April spring run-off period and decreased to levels generally at or below 0.12 mg/l throughout the summer (Table 17). The 0.12 mg/l concentration is equal to the 0.1 mg/l detection limit for nitrate/nitrite plus the .02 mg/l detection limit for ammonia. These low values are probably a reflection of diminished runoff during the summer months.

Table 17. Total inorganic nitrogen concentrations (mg/l) for White Lake tributaries, Marshall County, South Dakota during 2001.

Date	WL01	WLT-2	WLT-3	WLT-4	WLT-5	WLT-6	WLT-7	WLT-7N	WLT-8	WLT-9
3/29/01								1.37		
4/02/01		1.93	0.64	0.98	1.1	1.03	0.78	1.36		
4/09/01	1.19	1.05	0.79	1.66	0.82	0.52	1.37	1.88	0.85	0.91
4/12/01	0.9							1.01	0.6	0.86
4/18/01	0.85	0.74	0.22	1.18	0.12	0.12	0.9	0.42	0.75	0.82
4/25/01	0.79	0.42	0.12	0.58	0.62	0.22	0.35	0.32	0.22	0.32
5/07/01	0.37	0.23	0.12	0.42	0.12	0.12	0.12	0.32	0.12	0.12
5/14/01	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
6/14/01	0.18	0.15	0.12	0.22	0.12	0.12	0.12	0.12	0.12	0.12
7/16/01	0.23								0.37	
8/15/01	0.15			0.12					0.18	
9/26/01	0.33			0.12					0.12	

Total organic nitrogen concentrations (Table 18) showed the opposite trend as inorganic nitrogen with the highest concentrations during the summer and lowest during the April spring run-off period. Organic nitrogen usually made up 70% or more of the total nitrogen during the summer and anywhere between 20% and 80% during spring run-off. This is probably a reflection of summer plant growth in the tributaries

Table 18. Total organic nitrogen concentrations (mg/l) for White Lake tributaries, Marshall County, South Dakota, 2001.

Date	WL01	WLT-2	WLT-3	WLT-4	WLT-5	WLT-6	WLT-7	WLT-7N	WLT-8	WLT-9
3/29/01								1.06		
4/02/01		0.53	0.50	0.49	0.54	0.62	0.49	0.77		
4/09/01	0.62	0.78	0.42	1.13	0.83	0.34	0.83	0.63	0.55	0.52
4/12/01	0.81							0.65	0.64	0.63
4/18/01	0.74	0.76	0.41	0.7	0.66	0.34	0.95	0.67	0.54	0.53
4/25/01	0.91	1.04	0.51	0.96	0.87	0.53	0.84	0.88	0.78	0.9
5/07/01	1.09	1.04	1.5	1.13	1.21	0.70	1.04	0.93	0.95	1.07
5/14/01	1.36	1.26	0.77	0.99	1.01	0.52	1.03	0.99	0.87	1.06
6/14/01	0.86	1.00	1.25	1.18	1.11	0.92	1.21	1.93	1.19	1.25
7/16/01	0.62								0.92	
8/15/01	1.32			0.91					1.21	
9/26/01	1.16			0.50					0.34	

Phosphorus

Phosphorus is one of the macronutrients required for primary production. In comparison to carbon, nitrogen, and oxygen, it is the least abundant in natural systems (Wetzel, 2000). Phosphorus loading to lakes can be either internal or external. External loading refers to surface runoff, dust, and precipitation. Internal loading refers to the transfer of phosphorus from the bottom sediments to the water column of the lake. Total phosphorus is the sum of all attached and dissolved phosphorus in the lake.

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

The total phosphorus concentrations in the tributaries ranged from 0.056 to 0.666 mg/l and averaged .205 mg/l (Table 19). The greatest concentrations generally occurred during April, the month of highest flows.

Table 19. Total phosphorus concentrations (mg/l) for White Lake tributaries, Marshall County, South Dakota during 2001.

Date	WL01	WLT-2	WLT-3	WLT-4	WLT-5	WLT-6	WLT-7	WLT-7N	WLT-8	WLT-9
3/29/01								0.666		
4/02/01		0.187	0.179	0.200	0.311	0.294	0.151	0.473		
4/09/01	0.376	0.260	0.138	0.340	0.294	0.123	0.451	0.220	0.241	0.163
4/12/01	0.231						0.323		0.217	0.271
4/18/01	0.201	0.156	0.097	0.264	0.109	0.079	0.263	0.146	0.189	0.188
4/25/01	0.195	0.106	0.065	0.171	0.165	0.070	0.187	0.119	0.099	0.091
5/07/01	0.172	0.128	0.194	0.169	0.153	0.086	0.175	0.156	0.061	0.068
5/14/01	0.146	0.129	0.188	0.166	0.063	0.069	0.102	0.113	0.065	0.060
6/14/01	0.074	0.112	0.433	0.214	0.183	0.136	0.063	0.254	0.077	0.119
7/16/01	0.171								0.216	
8/15/01	0.091			0.140					0.221	
9/26/01	0.117			0.110					0.056	

Total dissolved phosphorus (Appendix A) made up anywhere from 11% to 100% of the total phosphorus. The percentages varied so much that seasonality or differences between sites were not discernible.

Tributary flows and nutrient and sediment loadings

Discharge from the Wild Rice River, and rainfall, are the two primary sources of water for White Lake, while very little groundwater enters the lake. For this reason groundwater will not be considered a major contributor of hydrologic loads.

Table 20 exhibits the total inflows to White Lake during the period of flow. April clearly had the most flow (73.25% of the total annual flow). Of the remaining flow, March and May accounted for an additional 20.70% while the remaining summer and autumn months only accounted for 6% or so of the total annual inflow. Given that many of the nutrients discussed in the previous section also peaked during April, it is clear that most of the nutrient loading occurs during the spring run-off period.

Table 20. Monthly total inflows from the tributaries to White Lake, Marshall County, South Dakota, 2001.

Total Flow (Acre feet)	Month	Percentage of Annual Flow
17,241	March	10.46
120,740	April	73.25
16,875	May	10.24
4,404	June	2.67
1,843	July	1.12
1,636	August	0.99
1,492	September	0.91
601	October	0.36

Sediment and nutrient loads were calculated through the use of FLUX (Army Corps of Engineers Loading Model) for those sites that directly or in combination with an adjoining tributary, enter White Lake (Table 21). There is one main tributary, Wild Rice Creek, and three minor tributaries. Sites WL07 and WL07N combine for one inflow from Wild Rice Creek. Sites WL02 and WL03 combine for one inflow from a minor tributary. And sites WL05 and WL06 are on separate, minor tributaries. Sites 4, 8, and 9 had no meaningful stage discharge relationships and sediment and nutrient loads were not calculated for these sites.

The majority of the annual phosphorus, nitrogen, and sediment loads clearly comes from Wild Rice Creek and makes up approximately 86% or more of those loads (Tables 21 - 23). The minor tributary containing sites WL02 and WL03 had the second highest annual loads between 5% and 10% of the annual loads. The annual loads from the tributaries containing sites WL05 and WL06 were negligible.

Areal mass loadings also indicated that Wild Rice Creek was clearly the most important in terms of areal loads and best management practices should be prioritized in the Wild Rice Creek watershed.

Table 21. Annual mass loading (kg/year) of various parameters to White Lake, Marshall County, South Dakota, 2001.

Parameter	Units	WL02+WL03	WL05	WL06	Wild Rice Creek	TOTAL
Total P	kg/yr	227.8	42.3	51.6	3,042.6	3,364.3
Total Diss. P	kg/yr	126.7	36.9	43.9	1,844.3	2,051.8
Total N	kg/yr	2,160.8	296.2	408.4	18,338.5	21,203.9
Inorganic N	kg/yr	1,004.0	136.1	160.9	10,065.3	11,366.3
Susp. Solids	kg/yr	29,075	916	1,826	537,257	569,074

Table 22. Annual areal loading (mg/m²/year) of various parameters to White Lake, Marshall County, South Dakota, 2001.

Parameter	Units	WL02+WL03	WL05	WL06	Wild Rice Creek	TOTAL
Total P	mg/m²/yr	14.9	8.0	7.9	203.3	234.1
Total Diss. P	mg/m²/yr	8.3	7.7	6.7	123.2	145.9
Total N	mg/m²/yr	141.0	61.8	62.2	1,225	1,490
Inorganic N	mg/m²/yr	65.5	28.4	24.5	672.6	791
Susp. Solids	mg/m²/yr	1.90	191.2	278.2	35,899	36,370

Table 23. Percent annual mass loadings of selected parameters for those tributaries entering White Lake, Marshall County, South Dakota.

Parameter	WL02 + WL03	WL05	WL06	Wild Rice Creek
Total Phosphorus	6.77	1.26	1.53	90.44
Total Dissolved P	6.18	1.80	2.14	89.89
Total Nitrogen	10.19	13.71	1.93	86.49
Inorganic Nitrogen	8.83	1.20	1.42	88.55
Total Suspended Solids	5.11	0.16	0.32	94.41

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 the tributaries. Loading data were taken from the results of the FLUX model calculated at the inlets to the lake. Atmospheric loads were provided by SDDENR.

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

Table 24 and Figure 13 show the trophic state response to various percent reductions in the phosphorus load. The observed and predicted water quality is listed in the first three columns and the other columns represent a percent reduction in total phosphorus load to the lake and the predicted trophic state (relative to the amount originally predicted in the lake).

A discrepancy is present because South Dakota's current TSI goals are based on median TSI values whereas the BATHTUB models predict mean TSI values. There is a four point difference between the median Secchi-chlorophyll TSI and the mean value. This is not uncommon for data from natural systems where the data are often not normally distributed. To compensate for this difference, the TSI goal was adjusted upward four points so the BATHTUB model results could be compared to a TSI goal. The adjusted TSI goal (62) is four points higher than the original TSI goal of 58 for warm water permanent fish life propagation waters.

Table 24. Trophic state values from White Lake in response to incremental percent reductions in total phosphorus loadings from sites WL02+WL03 and Wild Rice Creek.

	Actual Median	Actual Mean	Predicted Mean	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
TP TSI		76.8	72.5	72.0	71.5	71.0	70.5	69.9	69.3	68.6	67.9	67.1	66.7
Chla TSI		64.8	65.0	64.8	64.6	64.4	64.2	64.0	63.7	63.4	63.1	62.7	62.5
Secchi TSI		63.2	63.4	63.2	63.0	62.8	62.6	62.4	62.2	61.9	61.6	61.3	61.1
Sec-Chl TSI	60.00	64.0	64.2	64.0	63.8	63.6	63.4	63.2	62.95	62.65	62.35	62.0	61.8

The TSI values exhibited a relatively steady (but small) decrease for each ten percent decrease in phosphorus loading. The target Sec-Chl TSI of 62 was not reached until nearly 85% of the phosphorus was removed. The original annual phosphorus load was 3364 kg/yr so the annual phosphorus load needs to be decreased by 2859 kg/yr to reach the acceptable new load (TMDL) of 505 kg/yr. This is clearly not realistic and it appears that a site specific target needs to be used instead of the one based on Lorenzen (2005).

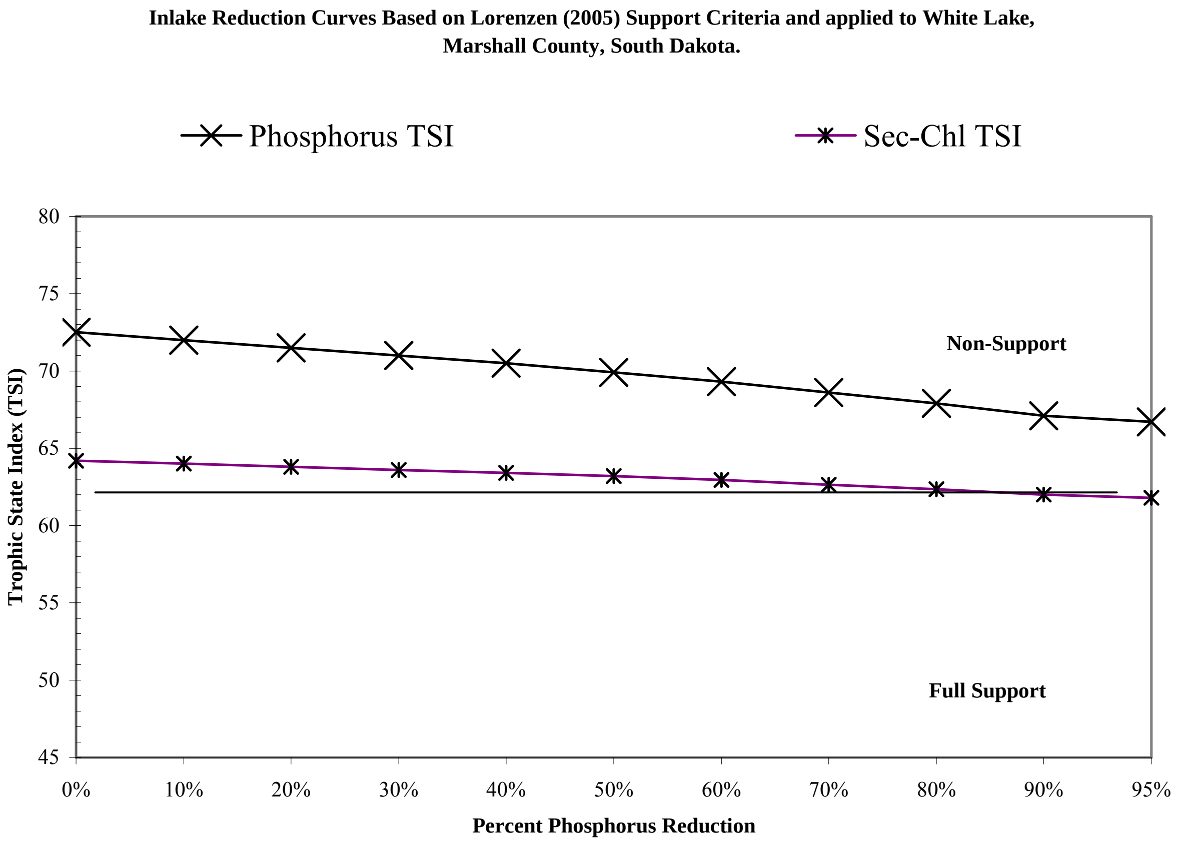

Figure 13. Graphical presentation of trophic state values in response to incremental percent reductions in total phosphorus loadings from the incoming tributaries.

Long-Term Trends

Data from this report are included in Figure 14 as well as total phosphorus and Secchi transparency TSI values calculated during previous sampling efforts. Chlorophyll *a* based TSI values were not included due to a lack of historical data.

The trend of the TSI values is towards an increase in TSI value and hence a decrease in lake quality. White Lake is listed on the state's 2004 303(d) list as an impaired waterbody with a declining trend in water quality as a result of nonpoint source pollution.

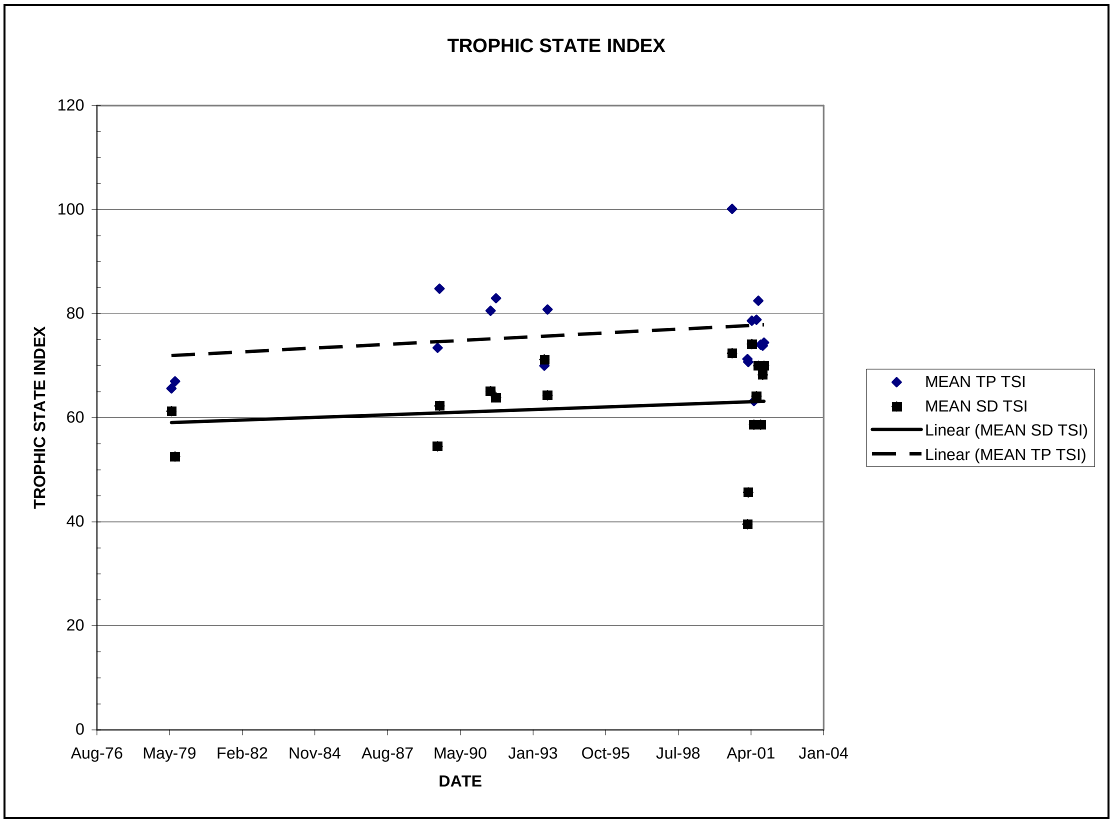

Figure 14. Trends in total phosphorus and Secchi transparency trophic state indices in White Lake, South Dakota.

Lorenzen's (2005) targeting criteria is based on a median Secchi-chlorophyll *a* TSI and lack of historical chlorophyll *a* data precludes using these criteria for the trend analysis. Even so, the historical total phosphorus TSIs are clearly greater than Lorenzen's (2005) Sec-Chl TSI target of 58 for warm-water permanent fish life propagation waters and are usually greater than the adjusted TSI target of 62 when mean values are used. The trend is for increasing phosphorus. The Secchi TSI also showed an increasing trend and the historical data also indicated that Lorenzen's (2005) target of 58 has not been reached (assuming the Secchi TSIs alone are representative of Sec-Chl TSIs if chlorophyll *a* data were available).

Reductions in nutrient and sediment load to the lake may help to reverse this trend and shift the lakes Sec-Chl TSI to the TSI target value. It is thought that any significant decrease in total phosphorus would also likely be accompanied by a decrease in chlorophyll *a* and an increase in Secchi transparency (decrease in Secchi and chlorophyll *a* TSIs).

OBJECTIVE 3 - Quality Assurance Reporting

Quality Assurance/ Quality Control (QA/QC) samples were collected for at least 10% of the total number of samples taken. One hundred thirty-seven samples were collected during the project and an additional were 13 blank samples and 12 duplicate samples collected from the lake and tributaries sites for QA/QC purposes (Table 25). The industrial statistic "%I" was used to assess the data precision; where precision (%I) = difference between duplicate analytical values divided by the sum of the values, multiplied by 100. Values greater than 10% were considered problematic and further investigation may be needed to correct the problem.

The field blanks were consistently at or below the detection limits of the parameters tested except for three blank samples analyzed for total solids. This may be due to laboratory error or due to contamination of the water used for the blank samples. Because most of the blank samples were satisfactory, it is felt that no further action needs to be taken to investigate reasons for the errant data.

The duplicate samples were generally satisfactory but two parameters, total suspended solids and total Kjeldahl nitrogen, had average industrial statistics greater than 10%. There are no obvious reasons for these results and so further investigation may be needed to resolve this issue.

Table 25. Field blanks and duplicates for the White Lake assessment project.

SITE	DATE	Type	DEPTH	TALKA	TSOL	TSSOL	AMMO	NIT	TKN	TP	TDP	FEC
QA/QC	04-Apr-01	Blank		<6	<7	<1	<0.02	<0.1	<0.36	<0.002	<0.002	<10
WLT8	09-Apr-01	Blank		<6	<7	<1	<0.02	<0.1	<0.36	<0.002	<0.002	<10
WLT8	09-Apr-01	Duplicate	SURFACE	109	572	60	0.25	0.6	0.62	0.244	0.148	20
WLT8	09-Apr-01	Sample	SURFACE	109	571	46	0.25	0.6	0.80	0.241	0.154	40
%I				0%	.09%	13.2%	0%	0%	12.7%	.62%	1.99%	.33%
WLT5	18-Apr-01	Blank		<6	<6	<1	<0.02	0.1	<0.36	0.002	0.002	<10
WLT-5	18-Apr-01	Duplicate	SURFACE	358	3274	5	<0.02	0.05	0.67	0.108	0.104	<10
WLT-5	18-Apr-01	Sample	SURFACE	362	3317	2	<0.02	0.1	0.68	0.109	0.105	<10
%I				.56%	.65%	42.9%	0%	33.3%	.74%	.46%	.48%	0%
WLT-7n	25-Apr-01	Blank		<6	<7	<1	<.02	<0.1	<.36	<.002	<.002	<10
WLT-7n	25-Apr-01	Duplicate	SURFACE	190	1209	7	<0.02	0.3	0.79	0.116	0.103	20
WLT-7n	25-Apr-01	Sample	SURFACE	190	1401	4	<0.02	0.3	0.90	0.119	0.107	<10
%I				0%	7.36%	27.3%	0%	0%	6.51%	1.28%	1.90%	50.0%
WLT-2	30-Apr-01	Blank		<6	<7	<1	<0.02	<0.1	<0.36	<0.002	<0.002	<10
WLT-2	30-Apr-01	Duplicate	SURFACE	175	907	26	0.20	0.3	0.95	0.170	0.080	<10

WLT-2	30-Apr-01	Sample	SURFACE	175	910	27	0.20	0.3	0.97	0.173	0.079	10
%I				0%	0.17%	1.89%	0%	0%	1.04%	0.87%	0.63	0%
WLT-9	07-May-01	Blank		<6	<7	<1	<0.02	<0.1	<0.36	0.002	<0.002	<10
WLT-9	07-May-01	Duplicate	SURFACE	194	867	4	<0.02	0.1	0.84	0.070	0.049	110
WLT-9	07-May-01	Sample	SURFACE	194	859	2	<.0.02	0.1	1.09	0.068	0.049	200
%I				0%	0.46%	50.0%	0%	0%	13.0%	1.45%	0%	29.0%
WLT-3	14-May-01	Blank		<6	9	<1	<0.02	<0.1	<0.36	<0.002	<0.002	<10
WLT-3	14-May-01	Duplicate	SURFACE	374	1220	4	<0.02	0.1	0.83	0.177	0.155	100
WLT-3	14-May-01	Sample	SURFACE	369	1220	4	<0.02	0.1	0.79	0.188	0.156	100
%I				.67%	0%	0%	0%	0%	61.7%	3.01%	0.32%	0%
WLT-4	14-Jun-01	Blank		<6	<7	<1	<0.02	<0.1	<0.36	<0.002	<0.002	<10
WLT-4	14-Jun-01	Duplicate	SURFACE	308	2280	7	<0.02	0.2	1.27	0.344	0.257	500
WLT-4	14-Jun-01	Sample	SURFACE	307	2279	6	<0.02	0.2	1.20	0.264	0.214	400
%I				.16%	.02%	7.69%	0%	0%	2.83%	13.2%	9.13%	11.1%
WLO1	16-Jul-01	Blank		<6	<7	<1	<0.02	<0.1	<0.36	<0.002	0.003	<10
WLO1	16-Jul-01	Duplicate	SURFACE	232	1148	9	0.14	<0.1	0.76	0.169	0.132	50
WLO1	16-Jul-01	Sample	SURFACE	232	1141	2	0.13	<0.1	0.75	0.171	0.139	40
%I				0%	.31%	63.6%	3.70%	0%	0.66%	0.59%	2.58%	11.1%
WL3	30-Jul-01	Blank		<6	<7	<1	<0.02	0.1	<0.36	<0.002	0.003	<10
WL3	30-Jul-01	Duplicate	SURFACE	223	1147	21	<0.02	<0.1	2.21	0.227	0.104	<10
WL3	30-Jul-01	Sample	SURFACE	223	1146	23	<0.02	<0.1	3.81	0.244	0.104	<10
%I				0%	0.04%	4.54%	0%	0%	0.28%	3.61%	0%	0%
WL3	30-Jul-01	Blank		<6	<7	<1	<0.02	0.1	<0.36	<0.002	<0.002	<10
WL3	30-Jul-01	Duplicate	BOTTOM	218	1149	31	0.26	<0.1	1.41	0.206	0.077	<10
WL3	30-Jul-01	Sample	BOTTOM	219	1152	34	0.33	<0.1	2.05	0.216	0.102	<10
%I				0.23%	0.13%	4.62%	11.9%	0%	18.5%	2.37%	14.0%	0%
WL2	30-Jul-01	Blank		<6	8	<1	<0.02	0.1	<0.36	0.002	<0.002	<10
WL2	30-Jul-01	Duplicate	SURFACE	227	1137	24	<0.02	<0.1	2.56	0.237	0.077	10
WL2	30-Jul-01	Sample	SURFACE	227	1150	32	<0.02	<0.1	4.62	0.302	0.088	<10
%I				0%	0.57%	14.3%	0%	0%	28.7%	12.1%	6.67%	0%
WL2	30-Jul-01	Blank		<6	8	<1	<0.02	0.1	<0.36	<0.002	<0.002	<10
WL2	30-Jul-01	Duplicate	BOTTOM	219	1147	27	0.27	<0.1	1.33	0.206	0.104	<10
WL2	30-Jul-01	Sample	BOTTOM	217	1138	16	0.29	<0.1	1.78	0.197	0.086	<10
%I				0.46%	0.39%	25.6%	3.57%	0%	14.5%	2.23%	9.47%	0%
				TALKA	TSOL	TSSOL	AMMO	NIT	TKN	TPO4	DPO4	FEC
AVG %I				0.17	0.85	21.3	1.60	2.78	13.4	3.48	3.93	8.46

OBJECTIVE 4- 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 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 of the watershed.

In order to objectively assess the impact of the watershed use animal feeding operations located within the watershed, the Annualized AGNPS (ANNAGNPS) feedlot assessment subroutine was employed. A complete evaluation was conducted on all animal-feeding areas with a defined drainage to White Lake. Animal lots with drainages confined to small areas and having no defined discharges were not rated during the assessment. Lots that were rated were assessed for a 25-year, 24-hour storm event in the drainage area. This is the largest event that waste systems in the area are designed to handle. The lots were given a score and prioritized. DENR has used a score of 50 to denote critical feedlots. The results of the ANNAGNPS model runs are summarized in Tables 26 and 27.

Table 26. ANNAGNPS predicted loads (tons/yr) of various parameters for different land use scenarios in the White Lake watershed, Marshall County, South Dakota.

	Diss. P	Attchd P	Total P	Diss. N	Attchd N	Total N	Sediment
Original condition	17,285	367	17,652	5,980	301	6,281	67
If all pastures poor	25,501	418	25,919	6,625	337	6,962	94
If all pastures good	15,418	359	15,777	5,851	284	6,135	63
Small grain uses No-till	10,841	111	10,952	4,394	82	4,476	9
Row crops use No-till	16,579	149	16,728	5,744	126	5,870	17
Without feedlots	17,283	367	17,650	5,964	292	6,256	67
Crops now CRP	4,320	90	4,410	3,134	45	3,179	4

Table 27. Percent change in the loads of various parameters for different land use scenarios in the White Lake watershed, Marshall County, South Dakota.

	Diss. P	Attchd. P	Total P	Diss. N	Attchd. N	Total N	Sediment
Original condition	0	0	0	0	0	0	0
If all pastures poor	+48%	+14%	+47%	+11%	+12%	+11%	+40%
If all pastures good	-11%	-2%	-11%	-2%	-6%	-2%	-6%
Small grains use No-till	-37%	-70%	-38%	-27%	-73%	-29%	-86%
Row crops use No-till	-4%	-59%	-5%	-4%	-58%	-7%	-75%
Without feedlots	-1%	0%	0%	-0.3%	-3%	-0.4%	0%

The results in Tables 26 and 27 show a number of valuable points. Taking out the feedlots had a negligible effect on nutrient or sediment loads. The model results indicate feedlots are not a serious problem. This is partially supported by the feedlot assessment subroutine. Only four of eleven lots had scores of 50 or more and one of these had a high score only because there was a relatively large area upslope of the lot. The lot with the highest score (87) had been suggested to be in need of improvement by the project coordinator and DENR personnel and it might be a problem even though the ANNAGNPS run did not indicate so. All four lots should be visually inspected and assessed for their potential and need for erosion/nutrient controls.

The original condition of the pastures was “fair”. Changing the pastures to a poor condition showed the effect of having poor condition pastures. Dissolved phosphorus and sediment increased by about 40%. Interestingly, changing the pastures from fair to good condition only resulted in a relatively minor decrease in nutrients and sediments (2% - 11% decreases).

Adopting no-till use on small grain crops produced a large (86%) decrease in sediment loading. The nutrients were also significantly reduced; anywhere from 27% to 73%. This shows the value of no-till in reducing erosion and subsequent nutrient loading.

Adopting no-till use on row crops also had a large (75%) decrease in sediment loading. Its impact on nutrients was mixed and varied from 4% to 59%. Nevertheless, no-till use on row crops is still valuable for sediment and nutrient control.

Changing all of the crops to grass (CRP) resulted in a 75% reduction of phosphorus. However, it is doubtful that all crops would be changed to CRP so a combination of no-till, pasture improvements, CRP plantings and perhaps in-lake restoration practices will need to be implemented to meet the TMDL.

It should be noted, however, that implementing no-till on all small grain and row crops, eliminating all feedlot impacts, and converting all pastures to a good condition will only achieve a 54% reduction in phosphorus loading. This could be increased somewhat by converting some of that cropland to CRP instead of implementing no-till residue management but even this scenario is not particularly realistic. It appears the TMDL target of an 85% reduction is not realistic and should be changed to conform to the social and economic limitations in the watershed while still supporting the lakes beneficial uses.

OBJECTIVE 5 - Public Participation

State Agencies

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

The South Dakota Department of Game, Fish and Parks provided information about threatened and endangered species and a copy of the latest Fishery Report on White Lake.

Federal Agencies

The Environmental Protection Agency (EPA) provided the primary source of funds for the completion of the assessment on White Lake. The Natural Resource Conservation Service (NRCS) provided technical assistance. The Farm Service Agency allowed access to historical records to obtain data for this project report.

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

The Marshall County Conservation District sponsored the project, and provided the accounting services during the course of this project. Public involvement consisted of individual meetings with landowners that provided a great deal of historic perspective on the watershed. There was a newspaper publication in May of 2001 for public awareness. Marshall County Conservation District Supervisory meetings were attended by project participants, to give updates of the progress of the project. Matching funds came from several groups to complete the project at White Lake. Table 28 depicts the funding sources, the proposed budget from each of these sources, total expenditures, and the percentage of the proposed budget that was utilized. In-kind match came primarily from the Marshall Conservation District members using their time to manage and direct the project. Only 25% of the budgeted local in-kind match was met. This was likely due to an overestimation of project management load for the Marshall Conservation District. The final federal:nonfederal expenditure ratio was 61.75 to 38.25.

Table 28. Funding sources and funds utilization for the White Lake Assessment Project.

Organization	Budget	Cash	In-Kind	% utilized
Federal EPA 319	66,786.00	66,786.00		100%
Wild Rice River Water Development District	1,000.00	1,000.00		100%
James River Water Development District	10,000.00	10,000.00		100%
South Dakota Dept. Env. Nat. Res.	29,374.00	29,374.00		100%
Marshall County Conservation District	4,050.00		1,002.77	25%

RECOMMENDATIONS

The BATHTUB model indicated approximately a 85% reduction in phosphorus loading is needed for White Lake to reach the target TSI, based on Lorenzen's (2005) target for waters with a warmwater permanent fish life propagation beneficial use and adjusted for mean TSI values. And the ANNAGNPS model runs indicated that a 85% reduction in phosphorus is not realistic. It is also clear that implementing no-till residue management on <u>all</u> small grain and row crops, eliminating <u>all</u> feedlot effects, and creating good condition in <u>all</u> pastures is also not realistic nor will these activities add up to a 85% reduction in total phosphorus (TP) loading. Therefore, it is recommended that a target be established that reflect and recognize the social and economical constraints within the watershed while still supporting the lakes beneficial uses.

Realistic targets for White Lake should be based on BMP induced nutrient reductions within the watershed resulting in watershed specific targets. It is reasonable to believe that half of the small grain and row crops can use no-till and half of the pastures could be improved to a good condition. This will result in a 27% reduction in TP loading. If an additional 3% reduction could be obtained by converting some of the remaining "non" no-till crops to CRP then a 30% reduction in TP loading is achieved. As illustrated in Figure 15, a 30% reduction in TP loading will result in a TP TSI value of 71. Therefore, it is recommended the target for White Lake be changed from a median growing-season Sec-Chl TSI value of 58 or greater for full support to a mean TP TSI of 71 or greater for full support.

Based on an approach that recognizes the social and economic limitations in the watershed, it is proposed that the TMDL be 2355 kg/yr. This load is a 1009 kg/yr decrease from the original TP load of 3364 kg/yr and a 30% reduction in TP loading is needed to achieve the TMDL. Figure 15 graphically shows the trophic state responses to incremental TP load reductions.

To achieve the phosphorus loading reduction, the following restoration activities are recommended for the White Lake watershed.

1. Rangeland BMP
    a. Grazing and Rangeland Management
    b. Alternative Livestock Watering Sources
    c. Windbreak/ Shelterbelt Establishment
2. Cropland BMP
    a. Grassed Waterways
    b. Crop Residue Management
    c. Filter Strips
    d. Integrated Crop Management
    e. Conservation Crop Rotation
    f. CRP Program

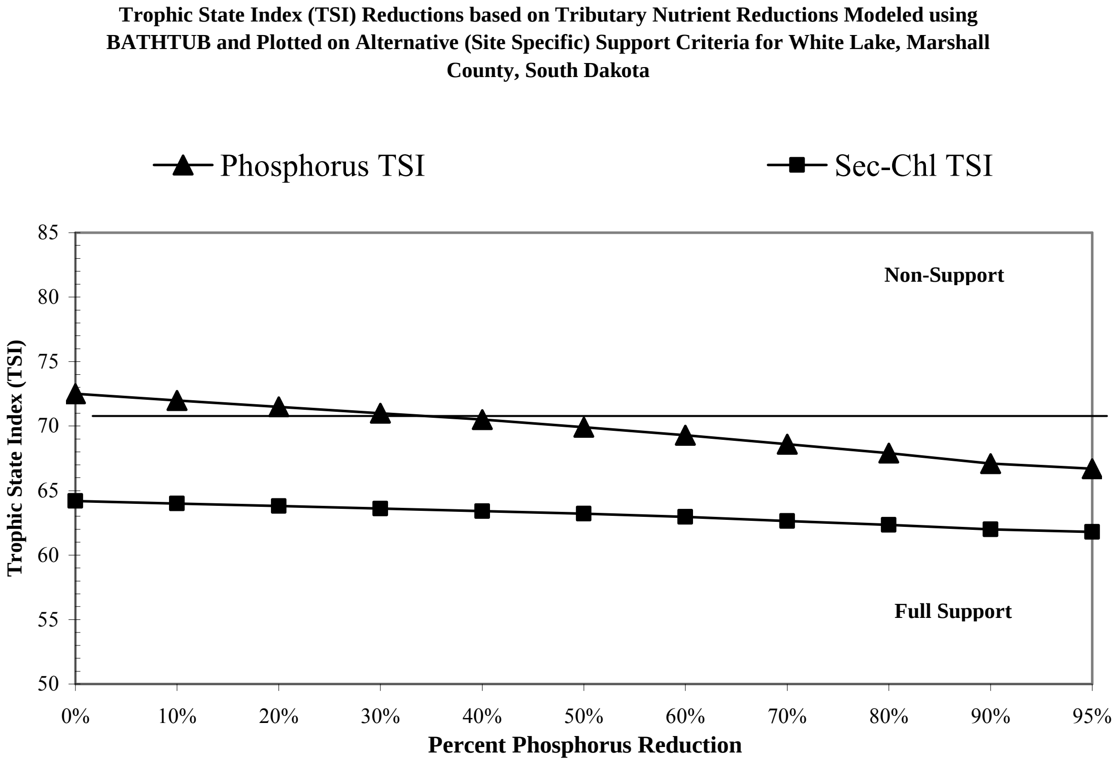

Figure 15. Graphical presentation of trophic state values in response to incremental percent reductions in total phosphorus loadings from the tributaries and alternative TSI target level.

It should be pointed out the recommended TMDL was based on a "measured" TP load and the TP load may vary from year to year. During the study, the annual rainfall in Britton was 20.67 inches. This compared favorably to a 1971-2000 annual average of 20.68 inches so the study did represent an "average" rainfall year and presumably an "average" TP load, limnological conditions, etc. Given the variable conditions in nature, additional activities may need to be implemented to provide a margin of safety for phosphorus control.

Based on the ANNAGNPS model run, 56 cells out of 360 cells (16%) were designated as high priority because they had phosphorus loadings of 50 or more lbs/year (Figure 16). These 56 cells accounted for 80% of the total phosphorus cell loads and approximately 22% of the watershed area. The remaining cells were designated as secondary priority.

Secondary activities such as implementing animal waste management systems (if visual inspections reveal problem situations), in-lake aeration to alleviate dangerously low dissolved oxygen concentrations at the bottom of the lake, and alum applications to precipitate phosphorus and prevent internal phosphorus loading should also be considered. Implementing one or more of these could supplement the phosphorus loading decreases produced by the rangeland and cropland BMPs.

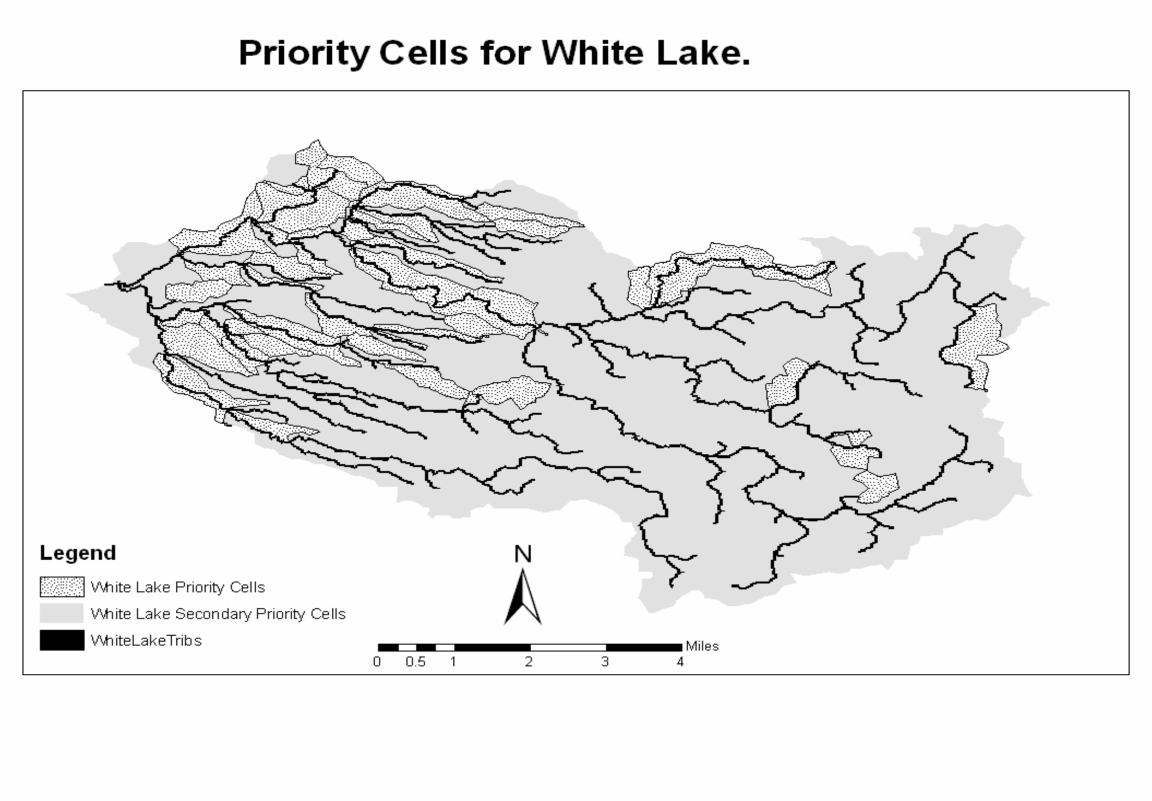

Figure 16. Priority cells within the White Lake watershed.

ASPECTS OF THE PROJECT THAT DID NOT WORK WELL

All of the objectives proposed for the project were met in an acceptable fashion and in a reasonable time frame. The only flaw in an otherwise excellent effort arose because the outlet flows were not monitored. Originally, the lake elevation was going to be measured and flows calculated from a known relationship between elevation and flows at the spillway. However, the spillway underwent modifications during the project and this precluded using those measurements.

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APPENDIX A

Water Quality Data for the White Lake Assessment Project

Table 29. Water quality data for White Lake, Marshall County, South Dakota.

WL01

DATE	DEPTH	WAT Tº	AIR Tº	CONDO	SECC	DO	pH	ALKA	TS	TSS	VSS	NH3	N03	TKN	TP	TDP	FC	E COLI	CHL A	CHLORC	TN	TIN	TN:TP	ON
3/1/2001																								
3/1/2001																								
3/12/2001	S	1.67	2.5	1780	2.7	4.25	7.31	258	2052	8	2	0.53	0.2	1.66	0.101	0.086	<10	<1			1.86	0.73	18.4	1.13
3/12/2001	B 4.0M	4.35	2.5	1958		0.52	7.22	260	2055	6	1	0.58	0.2	1.95	0.112	0.097					2.15	0.78	19.1964	1.37
4/30/2001	S	13.86	22.22	691	0.33		8.2	173	901	24	9	0.19	0.3	0.91	0.177	0.076	<10	5.2	15.42	28.091	1.21	0.49	6.83616	0.72
4/30/2001	B 3.5M	13.86	22.22	688			8.04	194	1346	470	45	0.25	0.3	1.15	0.219	0.077	<10	13.4			1.45	0.55	6.621	0.9
5/30/2001	S	17.09	16.11	1005	1.05	9.54	8.15	212	1034	9	4	<0.02	<0.1	0.45	0.059	0.032	<10	3.1	1.902	7.714	0.55	0.12	9.32203	0.43
5/30/2001	B 5.17M	14.69	16.11	1002		7.49	8.1	213	1082	58	11	<0.03	<0.1	0.65	0.075	0.034	<10	1			0.75	0.13	10	0.62
7/2/2001	S	22.7	20	1023	0.75	7.36	8.15	235	1143	18	6	0.09	0.1	1.05	0.198	0.113	<10	1	21.13	30.484	1.15	0.19	5.80808	0.96
7/2/2001	B 4.87M	22.43	20	1069		6.81	8.17	235	1161	39	7	0.1	0.1	1.5	0.3	0.117	<20	1			1.6	0.2	5.33333	1.4
7/30/2001	S	25.48	31.11	1070	0.5	12.54	8.56	212	1141	20	16	<0.02	<0.1	2.89	0.22	0.095	<10	<1	74.99	538.684	2.99	0.12	13.5909	2.87
7/30/2001	B 4.87M	23.95	31.11	1052		4.99	8.17	215	1142	23	7	0.28	<0.1	1.93	0.213	0.097	<10	<1			2.03	0.38	9.53052	1.65
8/30/2001	S	23.53	22.22	1022	1	6.87	8.38	180	1084	11	3	0.32	<0.1	1.39	0.131	0.072	<10	2			1.49	0.42	11.374	1.07
8/30/2001	B 4.74M	23.24	22.22	1019		6.87	8.09	181	1115	35	9	0.32	<0.1	1.35	0.149	0.075	<10	4.1			1.45	0.42	9.73154	1.03
9/27/2001	S	14.97	18.33	860	0.5	10.7	8.93	188	1118	21	11	0.18	0.1	1.45	0.134	0.043	10	<1	21.23	37.579	1.55	0.28	11.5672	1.27
9/27/2001	B 5.0M	14.94	18.33	860		10.61	8.74	191	1155	47	14	0.19	0.1	1.5	0.148	0.041	<10	5.2			1.6	0.29	10.8108	1.31
10/16/2001	S	8.96	3.88	753	0.5	12.76	8.82	189	1149	25	10	0.18	0.1	1.57	0.132	0.032	<10	<1	113.2	47.025	1.67	0.28	12.6515	1.39
10/16/2001	B 3.15M	8.91	3.88	757		12.69	8.8	190	1152	26	11	0.16	0.1	1.49	0.132	0.033	<10	2			1.59	0.26	12.0455	1.33

WL02

DATE	DEPTH	WAT TEI	AIR TEM	CONDO	SECC	DO	pH	ALKA	TS	TSS	VSS	AMMO	NIT	TKN	TP	TDP	FC	E COLI	CHL A	CHLORC	TN	TIN	TN:TP	
3/1/2001	S	1.5	3	1435	3.25	4.79	7.6	252	1983	4	1	0.56	0.2	1.52	0.108	0.096	<10	1			1.72	0.76	15.9259	0.96
3/1/2001	B 5.0M	3.85	3	1435		2.09	7.49	279	2121	12	2	0.67	0.1	1.6	0.178	0.145					1.7	0.77	9.55056	0.93
3/12/2001	S																							
3/12/2001	B																							
4/30/2001	S	14.48	22.22	694	0.4	11.69	8.21	175	910	27	3	0.2	0.3	0.97	0.173	0.079	10	4.1	5.707	15.799	1.27	0.5	7.34104	0.77
4/30/2001	B 5.125M	13.68	22.22	691		9.13	8.06	183	963	76	16	0.28	0.3	1.41	0.23	0.071	10	6.3			1.71	0.58	7.43478	1.13
5/30/2001	S	16.95	17.77	1009	1.25	9.32	8.28	211	1038	8	7	<0.02	<0.1	0.43	0.062	0.03	<10	3	0.2	6.187	0.53	0.12	8.54839	0.41
5/30/2001	B 5.165M	14.68	17.77	1003		7.38	8.12	210	1034	8	7	<0.02	<0.1	0.56	0.061	0.029	<10	1			0.66	0.12	10.8197	0.54
7/2/2001	S	22.88	21.11	1027	0.75	7.09	8.24	231	1136	14	2	0.13	0.1	1.7	0.171	0.126	<10	<1	16.92	22.688	1.8	0.23	10.5263	1.57
7/2/2001	B 5.114M	22.65	21.11	1072		5.78	8.18	238	1174	50	8	0.17	0.1	1.63	0.309	0.124	<10	1			1.73	0.27	5.59871	1.46
7/30/2001	S	25.33	28.88	1072	0.5	10.47	8.46	214	1137	24	19	<0.02	<0.1	2.56	0.237	0.077	10	9.6	133	600.518	2.66	0.12	11.2236	2.54
7/30/2001	B 5.148M	23.79	28.88	1051		4.14	8.1	218	1149	31	6	0.26	<0.1	1.41	0.206	0.077	<10	<1			1.51	0.36	7.3301	1.15
8/30/2001	S	23.66	22.22	1027	1.1	5.63	8.19	177	1094	8	5	0.29	<0.1	1.41	0.123	0.073	<10	<1			1.51	0.39	12.2764	1.12
8/30/2001	B 5.129M	23.32	22.22	1025		1.76	7.84	186	1141	82	18	0.41	<0.1	1.46	0.176	0.09	<10	<1			1.56	0.51	8.86364	1.05
9/27/2001	S	14.83	19.44	856	0.6	10.05	8.7	187	1123	17	8	0.25	0.1	1.41	0.121	0.05	<10	<1	22.03	40.342	1.51	0.35	12.4793	1.16
9/27/2001	B 5.5M	14.78	19.44	1062		9.68	8.61	189	1127	23	10	0.5	0.1	1.59	0.134	0.051	<10	4.1			1.69	0.6	12.6119	1.09
10/16/2001	S	9.5	5	764	0.5	11.94		190	1144	23	5	0.23	0.1	1.58	0.13	0.037	10	1	18.72	28.38	1.68	0.33	12.9231	1.35
10/16/2001	B 4.988M	9.12	5	757		11.16	8.79	188	1151	23	6	0.21	0.1	1.6	0.132	0.036	10	<1			1.7	0.31	12.8788	1.39

WL03

DATE	DEPTH	WAT TEI	AIR TEM	CONDO	SECC	DO	pH	ALKA	TS	TSS	VSS	AMMO	NIT	TKN	TP	TDP	FC	E COLI	CHL A	CHLORC	TN	TIN	TN:TP	
3/1/2001	S	1.38	3	1431		4.67	7.56	254	2004	4	1	0.55	0.2	1.63	0.102	0.09	<10	<1.0	0.701	0	1.83	0.75	17.9412	1.08
3/1/2001																								
3/12/2001	S																							
3/12/2001																								
4/30/2001	S	14.96	22.22	701	0.4	12.22	8.25	175	908	27	7	0.19	0.3	1	0.175	0.078	<10	1	9.712	15.881	1.3	0.49	7.42857	0.81
4/30/2001	B 4.127M	13.91	22.22	689		10.3	8.14	176	925	29	4	0.23	0.3	0.88	0.173	0.075	<10	8.6			1.18	0.53	6.82081	0.65
5/30/2001	S	16.41	20	1011	1	9.02	8.24	214	1041	12	5	<0.02	<0.1	0.67	0.059	0.031	<10	3.1	1.202	8.91	0.77	0.12	13.0508	0.65
5/30/2001	B 5.145M	14.2	20	1004		6.39	8.03	213	1055	35	11	0.13	0.1	1.1	0.14	0.06	<10	2			1.2	0.23	8.57143	0.97
7/2/2001	S	23.02	22.22	1030	0.75	6.87	8.24	234	1132	11	2	0.14	0.1	1.03	0.164	0.122	<10	3.1	3.605	16.129	1.13	0.24	6.89024	0.89
7/2/2001	B 5.15M	22.43	22.22	1075		6.08	8.2	238	1162	40	8	0.13	0.1	0.95	0.207	0.12	<10	3.1			1.05	0.23	5.07246	0.82
7/30/2001	S	25.19	23.33	1067	0.5	10.52	8.36	215	1147	21	15	<0.02	<0.1	2.21	0.227	0.104	<10	3.1	108.1	205.59	2.31	0.12	10.1762	2.19
7/30/2001	B 5.144M	23.68	25.19	1076		3.05	8.03	218	1147	27	6	0.27	<0.1	1.33	0.206	0.104	<10	5.2			1.43	0.37	6.94175	1.06
8/30/2001	S	23.68	23.33	1029	1.2	5.51	8.15	178	1084	10	5	0.31	<0.1	1.23	0.127	0.096	<10	<1			1.33	0.41	10.4724	0.92
8/30/2001	B 4.862	23.27	23.33	1025		2.18	7.92	183	1125	110	18	0.47	<0.1	1.77	0.201	0.11	10	2			1.87	0.57	9.30348	1.3
9/27/2001	S		14.74	857	0.6	10.26		188	1123	19	8	0.25	0.1	1.39	0.121	0.048	<10	4.1	19.12	23.843	1.49	0.35	12.314	1.14
9/27/2001	B 5.0M	14.63	19.44	855		10.24	8.63	187	1124	17	9	0.24	0.1	1.44	0.119	0.047	<10	4.1			1.54	0.12	12.9412	1.42
10/16/2001	S	9.4	5	763		11.86	8.84	192	1154	23	7	0.23	0.1	1.52	0.13	0.047	<10	1	23.23	28.999	1.62	0.33	12.4615	1.29
10/16/2001	B 4.561M	9.12	5	758		11.29	8.83	193	1160	36	9	0.25	0.1	1.74	0.203	0.038	<10	<1			1.84	0.35	9.06404	1.49

Table 30. Water quality data for White Lake's tributaries, Marshall County, South Dakota.

WLO01

DATE	WAT T°	AIR T°	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
4/9/2001	4.58	5.55	405	15.59		94	504	25	7	0.29	0.9	0.91	0.376	0.206	613	250	1.81	1.19	4.81383	0.547872	0.62	0.342541
4/12/2001	2.35	6.11	592	13.6	7.92	133	763	23	10	0.3	0.6	1.11	0.231	0.133	40	49.6	1.71	0.9	7.402597	0.575758	0.81	0.473684
4/18/2001	4.22	10.55	679	11.14	7.81	177	1106	18	5	0.45	0.4	1.19	0.201	0.134	<10	8.6	1.59	0.85	7.910448	0.666667	0.74	0.465409
4/25/2001	6.26	11.11	575	10.39	8.01	166	896	32	<1	0.39	0.4	1.3	0.195	0.108	<10	2	1.7	0.79	8.717949	0.553846	0.91	0.535294
5/7/2001	13.08	6.66	718	10.2	8.17	182	951	40	10	0.07	0.3	1.16	0.172	0.039	200	131	1.46	0.37	8.488372	0.226744	1.09	0.746575
5/14/2001	16.54	23.88	820	12.03	8.24	194	1006	21	5	0.02	0.1	1.38	0.146	0.038	70	98.8	1.48	0.12	10.13699	0.260274	1.36	0.918919
6/14/2001	20.46	17.22	945	6.98	8.27	218	1086	17	5	0.08	<0.1	0.94	0.074	0.039	20	4.1	1.04	0.18	14.05405	0.527027	0.86	0.826923
7/16/2001	24.46	24.44	1074	10.15	8.13	225	1141	2	<1	0.13	<0.1	0.75	0.171	0.139	40	24.4	0.85	0.23	4.97076	0.812865	0.62	0.729412
8/15/2001	23.69	19.44	1013	8.75	8.35	173	1093	18	11	0.05	<0.1	1.37	0.091	0.022	10	0.022	1.47	0.15	16.15385	0.241758	1.32	0.897959
9/26/2001	14.62	18.33	862	11.34	8.5	187	1136	18	8	0.23	0.1	1.39	0.117	0.048	<10	17.3	1.49	0.33	12.73504	0.410256	1.16	0.778523

WLT02

DATE	WAT T°	AIR T°	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
4/2/2001	0.91	1.66	277	9.58	7.46	164	819	12	1	0.13	1.8	0.66	0.187	0.087	<10	7.3	2.46	1.93	13.15508	0.465241	0.53	0.215447
4/9/2001	2.45	5.55	245	14.66	7.56	132	609	24	7	0.45	0.6	1.23	0.26	0.153	<10	74.9	1.83	1.05	7.038462	0.588462	0.78	0.42623
4/18/2001	4.09	8.33	474	12.63	7.88	161	751	12	4	0.14	0.6	0.9	0.156	0.106	180	124	1.5	0.74	9.615385	0.679487	0.76	0.506667
4/25/2001	6.82	7.77	593	12.02	7.95	188	916	14	2	<0.02	0.4	1.06	0.106	0.045	470	866	1.46	0.42	13.77358	0.424528	1.04	0.712329
5/7/2001	11.01	9.44	764	11.04	7.98	220	1087	34	8	0.03	0.2	1.07	0.128	0.041	60000	>2420	1.27	0.23	9.921875	0.320313	1.04	0.818898
5/14/2001	18.86	25	957	10.56	8.16	251	1142	32	6	<0.02	<0.1	1.28	0.129	0.035	700	727	1.38	0.12	10.69767	0.271318	1.26	0.913043
6/14/2001	17.37	15	947	7.79	7.85	200	1195	25	6	0.05	<0.1	1.05	0.112	0.053	3400	>2420	1.15	0.15	10.26786	0.473214	1	0.869565

WLT03

DATE	WAT T°	AIR T°	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
4/2/2001	0.06	1.66	251	7.14	7.53	225	724	3	<1	0.04	0.6	0.54	0.179	0.134	<10	4.1	1.14	0.64	6.368715	0.748603	0.5	0.438596
4/9/2001	1.21	5.55	575	13.79	7.65	236	790	3	1	0.09	0.7	0.51	0.138	0.247	20	9.8	1.21	0.79	8.768116	1	0.42	0.347107
4/18/2001	1.41	8.33	650	10.47	7.69	302	1136	1	<1	<0.02	0.2	0.43	0.097	0.094	20	27.5	0.63	0.22	6.494845	0.969072	0.41	0.650794
4/25/2001	3.36	7.77	528	11.74	7.83	252	847	4	<1	<0.02	0.1	0.53	0.065	0.057	50	16.8	0.63	0.12	9.692308	0.876923	0.51	0.809524
5/7/2001	6.44	9.44	524	10.52	7.82	239	774	8	6	<0.02	0.1	1.52	0.194	0.156	63000	>2420	1.62	0.12	8.350515	0.804124	1.5	0.925926
5/14/2001	16.06	25.55	1010	5.51	7.64	369	1220	4	1	<0.02	0.1	0.79	0.188	0.156	100	88.8	0.89	0.12	4.734043	0.829787	0.77	0.865169
6/14/2001	16.24	15	819	2.48	7.56	353	993	2	1	0.02	<0.1	1.27	0.433	0.444	500	1120	1.37	0.12	3.163972	1	1.25	0.912409

WLT04

DATE	WAT T°	AIR T°	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
4/2/2001	0.17	1.66	431	0.89	7.58	228	1387	8	1	0.18	0.8	0.67	0.2	0.171	10	13.5	1.47	0.98	7.35	0.855	0.49	0.333333
4/9/2001	1.64	5.55	580	14.62	7.61	149	796	8	3	0.66	1	1.79	0.34	0.253	10	8.5	2.79	1.66	8.205882	0.744118	1.13	0.405018
4/18/2001	5.84	10.55	623	12.22	7.74	175	946	3	1	0.38	0.8	1.08	0.264	0.216	<10	3.1	1.88	1.18	7.121212	0.818182	0.7	0.37234
4/25/2001	7.89	11.11	821	12.44	7.84	208	1264	5	<1	0.08	0.5	1.04	0.171	0.143	10	7.4	1.54	0.58	9.005848	0.836257	0.96	0.623377
5/7/2001	10.16	10.55	955	11.12	7.8	230	1404	7	2	<0.02	0.4	1.15	0.169	0.146	1200	1300	1.55	0.42	9.171598	0.863905	1.13	0.729032
5/14/2001	20.61	29.44	1233	11.74	7.85	254	1424	6	1	<0.02	<0.1	1.01	0.166	0.145	180	167	1.11	0.12	6.686747	0.873494	0.99	0.891892
6/14/2001	16.57	16.11	1625	5.47	7.6	307	2279	6	3	<0.02	0.2	1.2	0.264	0.214	400	579	1.4	0.22	5.30303	0.810606	1.18	0.842857
8/15/2001	20.16	22.22	1495	5.81	7.72	196	1889	11	6	<0.02	0.1	0.93	0.14	0.091	1100	1300	1.03	0.12	7.357143	0.65	0.91	0.883495
9/26/2001	10.36	19.44	1537	6.22	7.69	351	2539	17	7	<0.02	0.1	0.52	0.11	0.062	<850	4920	0.62	0.12	5.636364	0.563636	0.5	0.806452

Table 30. Continued.

WLT05

DATE	WAT Tº	AIR Tº	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
4/2/2001	2.18	1.66	550	0.89	7.6	207	1762	5	1	0.2	0.9	0.74	0.311	0.277	<10	<1	1.64	1.1	5.273312	0.890675	0.54	0.329268
4/9/2001	6.54	5.55	1640	11.54	7.52	263	2346	6	4	<0.02	0.8	0.85	0.294	0.268	10	1	1.65	0.82	5.612245	0.911565	0.83	0.50303
4/18/2001	6.86	10.55	1785	12.63	7.7	362	3317	2	1	<0.02	0.1	0.68	0.109	0.105	<10	<1	0.78	0.12	7.155963	0.963303	0.66	0.846154
4/25/2001	9.11	11.11	1548	8.87	7.77	262	2616	4	<1	<0.02	0.6	0.89	0.165	0.144	<10	13.5	1.49	0.62	9.030303	0.872727	0.87	0.583893
5/7/2001	9.55	11.11	1476	10.7	7.74	266	2470	5	4	<0.02	<0.1	1.23	0.153	0.116	80	26.2	1.33	0.12	8.69281	0.75817	1.21	0.909774
5/14/2001	17.92	29.44	2315	8.28	7.44	354	3396	6	2	<0.02	<0.1	1.03	0.063	0.057	20	13.5	1.13	0.12	17.93651	0.904762	1.01	0.893805
6/14/2001	16.44	16.11	2017	6.36	7.62	295	3035	7	1	0.02	<0.1	1.13	0.183	0.157	300	435	1.23	0.12	6.721311	0.857923	1.11	0.902439

WLT06

DATE	WAT Tº	AIR Tº	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
4/2/2001	0.16	13.33	251	0.96	7.67	176	772	17	2	0.03	1	0.65	0.294	0.238	<10	2	1.65	1.03	5.612245	0.809524	0.62	0.375758
4/9/2001	5.2	5.55	549	13.14		166	664	1	<1	<0.02	0.5	<0.36	0.123	0.114	10	2	0.86	0.52	6.99187	0.926829	0.34	0.395349
4/18/2001	6.11	9.44	760	11.92	7.84	285	1198	3	<1	<0.02	0.1	0.36	0.079	0.068	<10	<1	0.46	0.12	5.822785	0.860759	0.34	0.73913
4/25/2001	7.5	12.22	696	10.86	7.74	211	1063	3	1	<0.02	0.2	0.55	0.07	0.063	<10	<1	0.75	0.22	10.71429	0.9	0.53	0.706667
5/7/2001	9.22	11.11	773	11.66	7.81	234	1148	6	4	<0.02	0.1	0.72	0.086	0.066	20	50.4	0.82	0.12	9.534884	0.767442	0.7	0.853659
5/14/2001	22.07	28.88	1219	12.48	7.73	346	1375	7	1	<0.02	<0.1	0.54	0.069	0.05	40	23.1	0.64	0.12	9.275362	0.724638	0.52	0.8125
6/14/2001	16.36	15.55	903	7.17	7.72	275	1157	4	1	<0.02	<0.1	0.94	0.136	0.081	700	>2420	1.04	0.12	7.647059	0.595588	0.92	0.884615

WLT07

DATE	WAT Tº	AIR Tº	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
4/2/2001	0.09	2.78	286	9.79	7.85	160	885	11	6	0.08	0.7	0.57	0.151	0.116	<10	30.1	1.27	0.78	8.410596	0.768212	0.49	0.385827
4/9/2001	1.46	5.55	355	16.18	7.82	109	539	102	16	0.67	0.7	1.5	0.451	0.236	579	210	2.2	1.37	4.878049	0.523282	0.83	0.377273
4/18/2001	4.07	9.44	365	13.11	8.04	136	559	19	4	0.5	0.4	1.45	0.263	0.206	<10	8.5	1.85	0.9	7.034221	0.78327	0.95	0.513514
4/25/2001	6.09	9.99	506	11.09	7.96	156	794	44	3	0.05	0.3	0.89	0.187	0.101	30	41	1.19	0.35	6.363636	0.540107	0.84	0.705882
5/7/2001	11.14	10.55	688	10.18	8.11	184	975	40	7	<0.02	0.1	1.06	0.175	0.087	380	461	1.16	0.12	6.628571	0.497143	1.04	0.896552
5/14/2001	17.75	27.22	874	10.85	8.3	237	1041	12	2	<0.02	0.1	1.05	0.102	0.066	30	16.1	1.15	0.12	11.27451	0.647059	1.03	0.895652
6/14/2001	17.19	15.55	930	8.19	8.06	257	1161	11	3	0.02	0.1	1.23	0.063	0.046	200	345	1.33	0.12	21.11111	0.730159	1.21	0.909774

WLT07N

DATE	WAT Tº	AIR Tº	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
3/29/2001	0.34	5	92	3.05		176	1171	5	4	0.67	0.7	1.73	0.666	0.638	<10	14.2	2.43	1.37	3.648649	0.957958	1.06	0.436214
4/2/2001	0.9	2.78	241	0.27		141	827	11	1	0.16	1.2	0.93	0.473	0.42	<10	9.6	2.13	1.36	4.503171	0.887949	0.77	0.361502
4/9/2001	6.41	5.55	734	13.42	7.64	157	924	10	4	0.08	1.8	0.71	0.22	0.189	10	27.5	2.51	1.88	11.40909	0.859091	0.63	0.250996
4/12/2001	2.38	6.11	404	14.06	7.93	116	531	66	16	0.51	0.5	1.16	0.323	0.186	80	60.9	1.66	1.01	5.139319	0.575851	0.65	0.391566
4/18/2001	4.33	9.44	1145	12.24	7.68	307	2040	1	1	<0.02	0.4	0.69	0.146	0.125	<10	5.2	1.09	0.42	7.465753	0.856164	0.67	0.614679
4/25/2001	6.68	9.99	785	11.38	7.82	190	1401	4	<1	<0.02	0.3	0.9	0.119	0.107	<10	11	1.2	0.32	10.08403	0.89916	0.88	0.733333
5/7/2001	8.83	10.55	805	12.55	7.87	204	1535	7	4	<0.02	0.3	0.95	0.156	0.122	50	60.9	1.25	0.32	8.012821	0.782051	0.93	0.744
5/14/2001	16.92	27.22	1762	7.42	7.71	364	2419	10	<1	<0.02	0.1	1.01	0.113	0.093	20	14.3	1.11	0.12	9.823009	0.823009	0.99	0.891892
6/14/2001	16.72	15.55	1304	7.21	7.69	380	1821	7	<1	<0.02	<0.1	1.95	0.254	0.212	10	5.1	2.05	0.12	8.070866	0.834646	1.93	0.941463

Table 30. Continued.

WLT08

DATE	WAT Tº	AIR Tº	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
4/9/2001	0.55	5.55	392	16.5		109	571	46	8	0.25	0.6	0.8	0.241	0.154	40	27.2	1.4	0.85	5.809129	0.639004	0.55	0.392857
4/12/2001	2.67	6.11	440	14.04	7.9	123	565	47	11	0.3	0.3	0.94	0.217	0.119	30	11.9	1.24	0.6	5.714286	0.548387	0.64	0.516129
4/18/2001	3.71	7.22	348	13.34	7.93	141	525	10	3	0.45	0.3	0.99	0.189	0.136	<10	2	1.29	0.75	6.825397	0.719577	0.54	0.418605
4/25/2001	5.92	8.88	450	11.52	7.96	151	682	10	<1	<0.02	0.2	0.8	0.099	0.06	<10	5.1	1	0.22	10.10101	0.606061	0.78	0.78
5/7/2001	8.48	10.55	668	12.6	8.04	204	990	6	3	<0.02	<0.1	0.97	0.061	0.04	20	30.5	1.07	0.12	17.54098	0.655738	0.95	0.88785
5/14/2001	17.87	13.33	923	10.68	8.16	237	1093	2	<1	<0.02	<0.1	0.89	0.065	0.054	<10	26.2	0.99	0.12	15.23077	0.830769	0.87	0.878788
6/14/2001	16.04	15	1017	8.94	8.1	263	1342	15	1	<0.02	<0.1	1.21	0.077	0.054	1400	1203	1.31	0.12	17.01299	0.701299	1.19	0.908397
7/16/2001	19.5	23.88	980	21.78	7.37	263	1218	76	12	0.07	0.3	0.99	0.216	0.041	19000	>2420	1.29	0.37	5.972222	0.189815	0.92	0.713178
8/15/2001	19.04	20.55	969	5.47	7.83	273	1180	66	21	0.08	0.1	1.29	0.221	0.026	3900	>2420	1.39	0.18	6.289593	0.117647	1.21	0.870504
9/26/2001	10.45	15	814	9.72	8.5	311	1202	24	5	0.02	0.1	0.36	0.056	0.013	2200	>2420	0.46	0.12	8.214286	0.232143	0.34	0.73913

WLT09

DATE	WAT Tº	AIR Tº	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
4/9/2001	0.33	5.55	431	13.43	7.36	121	585	4	2	0.21	0.7	0.73	0.163	0.133	10	11	1.43	0.91	8.773006	0.815951	0.52	0.363636
4/12/2001	3.63	6.11	358	12.49	7.73	116	419	26	8	0.46	0.4	1.09	0.271	0.234	100	461	1.49	0.86	5.498155	0.863469	0.63	0.422819
4/18/2001	2.11	7.22	330	12.81	7.75	145	510	3	1	0.42	0.4	0.95	0.188	0.147	10	5.2	1.35	0.82	7.180851	0.781915	0.53	0.392593
4/25/2001	5.67	8.33	442	11.09	7.29	153	689	5	1	<0.02	0.3	0.92	0.091	0.064	10	19.9	1.22	0.32	13.40659	0.703297	0.9	0.737705
5/7/2001	8.26	9.99	601	11.25	7.75	194	859	2	1	<0.02	0.1	1.09	0.068	0.049	200	172	1.19	0.12	17.5	0.720588	1.07	0.89916
5/14/2001	18.26	26.11	739	9.23	7.77	220	833	7	<1	<0.02	<0.1	1.08	0.06	0.04	60	31.8	1.18	0.12	19.66667	0.666667	1.06	0.898305
6/14/2001	16.3	15	804	7.27	7.86	240	999	15	1	<0.02	0.1	1.27	0.119	0.062	2600	1990	1.37	0.12	11.51261	0.521008	1.25	0.912409

WLT10

DATE	WAT Tº	AIR Tº	CONDO	DO	pH	ALKA	TS	TSS	VSS	AMMON	NIT	TKN	TP	TDP	FC	E COLI	TN	TIN	TN:TP	TDP/TP	TON	TON/TN
3/29/2001	0.49	5		7.5		96	401	6	4	0.18	1.2	0.96	0.383	0.358	<10	1	2.16	1.38	5.639687	0.934726	0.78	0.361111
4/2/2001		5				93	525	33	7	0.14	1.8	0.97	0.502	0.398	10	12.2	2.77	1.94	5.517928	0.792829	0.83	0.299639
4/9/2001	4.35	5.55	550	14.41	7.79	114	677	92	18	0.23	1.5	1.08	0.473	0.273	291	190	2.58	1.73	5.454545	0.577167	0.85	0.329457
4/12/2001	3.22	6.11	476	13.67	7.78	130	840	132	32	0.31	1.1	0.88	0.477	0.278	560	411	1.98	1.41	4.150943	0.582809	0.57	0.287879
4/18/2001	5.62	12.22	591	12.63	7.96	160	965	28	4	0.28	0.5	0.81	0.202	0.135	<10	12.1	1.31	0.78	6.485149	0.668317	0.53	0.40458
5/7/2001	11.21	9.44	699	11.14	8.03	179	1093	55	9	0.08	0.5	1.41	0.266	0.142	2800	>2420	1.91	0.58	7.180451	0.533835	1.33	0.696335
5/14/2001	21.31	29.44	1028	17.14	8.43	212	1118	8	1	<0.02	<0.1	1.08	0.113	0.067	190	131	1.18	0.12	10.44248	0.59292	1.06	0.898305
6/14/2001	17.9	17.78	968	7.61	7.81	210	1168	19	1	<0.02	0.4	1.25	0.164	0.138	1300	980	1.65	0.42	10.06098	0.841463	1.23	0.745455
7/16/2001	23.13	24.44	2014	6.49	7.81	145	2553	136	22	0.14	<0.1	1.33	0.271	0.116	24000	>2420	1.43	0.24	5.276753	0.428044	1.19	0.832168
8/15/2001	23.1	24.44	1656	9.96	8.23	117	1978	37	10	<0.02	<0.1	1.41	0.148	0.058	1600	1200	1.51	0.12	10.2027	0.391892	1.39	0.92053
9/26/2001	15.15	19.44	2348	11.82	8.73	110	3335	19	8	0.04	<0.1	1.43	0.165	0.026	960	1730	1.53	0.14	9.272727	0.157576	1.39	0.908497

Table 31. YSI probe data for Site WL01, White Lake, Marshall County, South Dakota.

Date	Time	Temp (ºC)	SpCond (mS)	DO (mg/l)	Depth (m)	pH
3/12/2001	131000	1.67	1.780	4.25	1.000	7.31
3/12/2001	131500	4.35	1.958	0.52	4.000	7.22
4/30/2001	130440	14.82	0.858	11.38	0.705	8.19
4/30/2001	130538	14.49	0.860	11.21	1.176	8.16
4/30/2001	130631	13.98	0.874	10.51	2.153	8.11
4/30/2001	130751	13.84	0.876	9.58	3.157	8.05
5/30/2001	95737	17.09	1.005	9.54	1.180	8.15
5/30/2001	95829	17.08	1.005	9.31	2.137	8.22
5/30/2001	95914	17.08	1.005	9.24	3.132	8.25
5/30/2001	95950	17.04	1.005	9.20	4.141	8.26
5/30/2001	100117	14.69	1.002	7.49	5.171	8.10
7/2/2001	123619	22.68	1.070	7.35	1.157	8.17
7/2/2001	123729	22.62	1.071	7.13	2.166	8.19
7/2/2001	123819	22.55	1.071	7.03	3.155	8.19
7/2/2001	123902	22.50	1.070	7.04	4.149	8.20
7/2/2001	123939	22.43	1.069	6.81	4.868	8.17
7/30/2001	130241	25.43	1.060	12.46	0.649	8.56
7/30/2001	130438	25.22	1.064	11.01	1.141	8.50
7/30/2001	130543	25.12	1.065	10.00	2.131	8.46
7/30/2001	130715	24.42	1.071	6.88	3.129	8.29
7/30/2001	130823	24.22	1.072	6.38	4.137	8.25
7/30/2001	131000	23.96	1.073	5.00	4.872	8.17
8/30/2001	104039	23.55	1.051	6.88	1.139	8.30
8/30/2001	104210	23.46	1.053	5.34	2.151	8.15
8/30/2001	104452	23.36	1.054	5.15	3.140	8.12
8/30/2001	104604	23.26	1.054	5.06	4.153	8.10
8/30/2001	104723	23.24	1.054	4.96	4.737	8.09
9/27/2001	110313	14.96	1.064	10.72	1.121	8.86
9/27/2001	110416	14.96	1.064	10.64	2.150	8.79
9/27/2001	110455	14.94	1.065	10.57	3.137	8.76
9/27/2001	110544	14.94	1.065	10.53	4.122	8.75
9/27/2001	110643	14.94	1.065	10.62	4.626	8.74

Table 32. YSI probe data for Site WL02, White Lake, Marshall County, South Dakota.

Date	Time	Temp (ºC)	SpCond (mS)	DO (mg/l)	Depth (m)	pH
3/1/2001	182446	1.40	2.609	4.63	0.959	7.59
3/1/2001	182550	2.25	2.589	4.35	2.002	7.57
3/1/2001	183129	3.05	2.648	2.09	3.958	7.41
3/1/2001	183254	2.96	2.711	2.05	4.419	7.37
4/30/2001	133028	14.45	0.868	11.69	0.641	8.22
4/30/2001	133124	13.98	0.875	10.74	2.141	8.14
4/30/2001	133205	13.88	0.877	10.40	3.123	8.13
4/30/2001	133256	13.79	0.879	10.13	4.127	8.11
4/30/2001	133404	13.68	0.882	9.10	5.127	8.06
5/30/2001	101824	16.95	1.009	9.32	1.172	8.28
5/30/2001	101856	16.93	1.008	9.25	2.163	8.28
5/30/2001	101933	16.89	1.009	9.19	3.140	8.28
5/30/2001	102016	16.83	1.010	9.12	4.149	8.28
5/30/2001	102154	14.68	1.003	7.38	5.165	8.12
7/2/2001	130250	22.89	1.070	7.06	1.138	8.23
7/2/2001	130340	22.84	1.070	6.94	2.142	8.23
7/2/2001	130441	22.81	1.070	6.81	3.165	8.23
7/2/2001	130522	22.80	1.070	6.73	4.160	8.22
7/2/2001	130702	22.65	1.072	5.78	5.114	8.18
7/30/2001	123747	25.31	1.065	10.47	0.661	8.46
7/30/2001	123820	25.31	1.064	10.59	1.151	8.46
7/30/2001	123947	25.03	1.065	9.74	2.147	8.43
7/30/2001	124134	24.32	1.073	7.05	3.136	8.26
7/30/2001	124334	23.96	1.074	5.43	4.149	8.18
7/30/2001	124517	23.80	1.077	4.14	5.149	8.10
8/30/2001	110952	23.66	1.054	5.64	1.145	8.17
8/30/2001	111118	23.60	1.054	5.34	2.155	8.14
8/30/2001	111245	23.55	1.054	5.13	3.139	8.12
8/30/2001	111338	23.51	1.054	4.92	4.130	8.11
8/30/2001	111625	23.32	1.058	1.80	5.136	7.86
9/27/2001	112613	14.80	1.062	10.03	1.152	8.67
9/27/2001	112716	14.79	1.062	9.92	2.147	8.63
9/27/2001	112808	14.79	1.062	9.81	3.127	8.62
9/27/2001	112858	14.78	1.062	9.82	4.125	8.61
9/27/2001	113008	14.78	1.062	9.68	5.140	8.61

Table 33. YSI probe data for Site WL03, White Lake, Marshall County, South Dakota.

Date	Time	Temp (ºC)	SpCond (mS)	DO (mg/l)	Depth (m)	pH
3/1/2001	170227	1.57	2.606	6.57	0.997	7.54
3/1/2001	170302	2.06	2.591	4.79	1.989	7.55
3/1/2001	170333	2.02	2.618	4.65	3.001	7.52
3/1/2001	170839	2.37	2.663	3.41	4.000	7.43
4/30/2001	134849	14.89	0.866	12.13	0.647	8.25
4/30/2001	134938	14.53	0.866	11.54	1.127	8.22
4/30/2001	135034	13.99	0.871	10.81	2.117	8.16
4/30/2001	135126	13.93	0.874	10.42	3.135	8.14
4/30/2001	135230	13.90	0.874	10.30	4.128	8.14
5/30/2001	104305	16.41	1.011	9.02	1.139	8.24
5/30/2001	104342	16.34	1.011	8.89	2.153	8.23
5/30/2001	104426	16.28	1.013	8.80	3.156	8.23
5/30/2001	104511	16.24	1.014	8.77	4.141	8.23
5/30/2001	104658	14.20	1.004	6.39	5.145	8.03
7/2/2001	133048	23.00	1.071	6.89	1.173	8.24
7/2/2001	133205	22.76	1.073	5.86	2.166	8.18
7/2/2001	133256	22.62	1.072	6.24	3.130	8.20
7/2/2001	133347	22.54	1.073	6.42	4.085	8.21
7/2/2001	133433	22.43	1.075	6.08	5.151	8.20
7/30/2001	114712	25.17	1.067	10.47	0.770	8.35
7/30/2001	114830	25.13	1.070	9.23	1.153	8.28
7/30/2001	114939	25.09	1.072	8.67	2.157	8.27
7/30/2001	115126	24.06	1.074	5.96	3.150	8.17
7/30/2001	115336	23.82	1.075	4.41	4.137	8.09
7/30/2001	115443	23.68	1.076	3.05	5.144	8.03
8/30/2001	113850	23.69	1.055	5.52	1.139	8.15
8/30/2001	113959	23.67	1.055	5.44	2.147	8.14
8/30/2001	114105	23.65	1.055	5.29	3.151	8.13
8/30/2001	114307	23.47	1.057	4.38	4.158	8.05
8/30/2001	114441	23.27	1.060	2.13	4.866	7.88
9/27/2001	115250	14.75	1.066	10.24	1.170	8.66
9/27/2001	115336	14.72	1.066	10.20	2.145	8.65
9/27/2001	115412	14.67	1.066	10.10	3.161	8.64
9/27/2001	115447	14.64	1.066	10.10	4.123	8.63
9/27/2001	115557	14.63	1.067	10.16	4.875	8.63

TSI, Dissolved Oxygen TMDLs

WHITE LAKE WATERSHED
(HUC 09020105)

MARSHALL COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

JUNE, 2005

White Lake Total Maximum Daily Load

Waterbody Type:	**Lake (impounded)**
303(d) Listing Parameter:	**TSI trend due to nonpoint source pollution**
Designated Uses:	**Domestic water supply** **Warm water permanent fish life propagation,** **Immersion recreation,** **Limited contact recreation, and** **Fish and Wildlife propagation, recreation and stock watering**
Size of Waterbody:	**186.8 acres**
Size of Watershed :	**22,348 acres**
Water Quality Standards:	**Narrative and Numeric**
Indicators:	**Secchi-chlorophyll and total phosphorus TSIs, dissolved oxygen**
Analytical Approach:	**ANNAGNPS, BATHTUB, FLUX**
Location:	**HUC Code: 09020105**
Goal:	**30 % reduction in the phosphorus load**
Target:	**TP TSI <71 average during the growing season, dissolved oxygen concentration of 5 mg/l**

Objective:

The purpose of this TMDL summary is to clearly state the problems with White Lake and the magnitude of those problems. This will facilitate the US Environmental Protection Agency (EPA) review and approval of the TMDL.

In addition, it documents the concern and support by the public for studying and restoring White Lake to full beneficial use status. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

White Lake is a 186.8-acre man-made impoundment located in Marshall County, South Dakota (Figure 1). The 2004 South Dakota 303(d) Waterbody List identified White Lake as a high priority for TMDL development because of an unsatisfactory trophic state index (TSI) due to nonpoint source pollution.

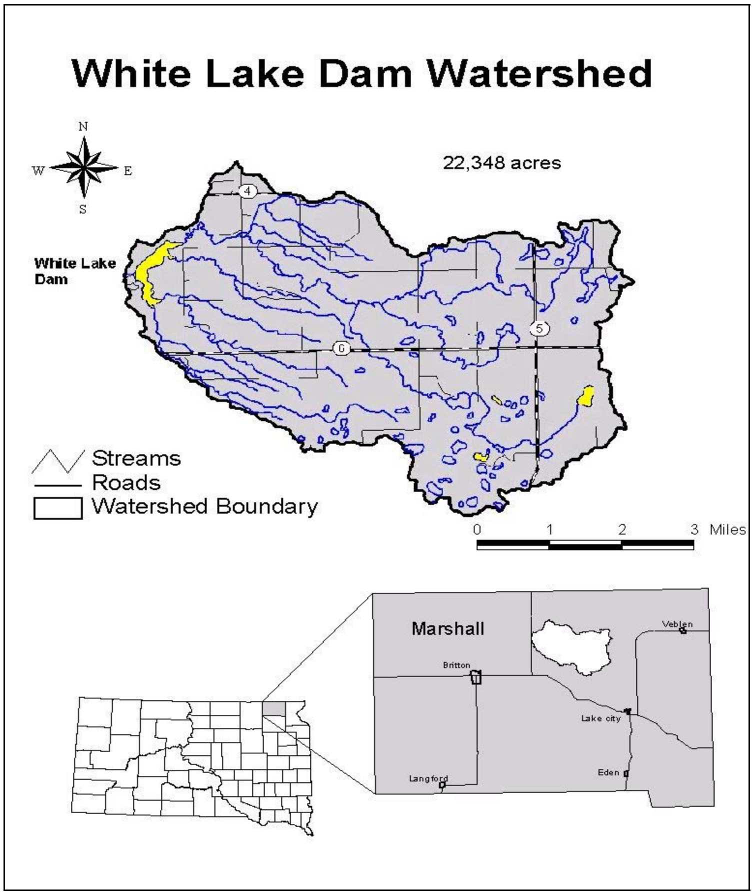

Figure 1. White Lake Dam watershed.

The lake has an average depth of 8 feet (2.44 meters), a maximum depth of 20 feet (6.10 meters). The lake outlet drains into Wild Rice Creek, which eventually reaches Silver Lake in North Dakota.

Problem Identification

Wild Rice Creek is the primary tributary to White Lake and drains predominantly grazing lands with some cropland acres. Winter feeding areas for livestock are present in the watershed. The stream carries nutrient loads, which degrade water quality in the lake and cause increased eutrophication, including dangerously low dissolved oxygen concentrations. The assessment study did not find impairment to White Lake from macrophytes or accumulated sediment.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

White Lake has been assigned the following beneficial uses by the state of South Dakota Surface Water Quality Standards regulations: domestic water supply; warmwater permanent fish life propagation; immersion recreation; limited contact recreation; and fish and wildlife propagation, recreation and stock watering.

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.

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 entering the lake from external sources is a sign of eutrophication. Based on TSI values, White Lake was identified as not supporting its beneficial uses in the 2004 South Dakota 305(b) Water Quality Assessment and as non-supporting in the "Targeting Impaired Lakes in South Dakota" document (Lorenzen, 2005).

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.

The South Dakota Department of Environment and Natural Resources (SD DENR) also uses surrogate measures. To assess the trophic status of a lake, SD DENR uses the median growing season Secchi-chlorophyll *a* TSI (Lorenzen, 2005). This protocol was used to assess impairment and determine a numeric target for White Lake. For White Lake the target is a median growing season Secchi-chlorophyll *a* TSI value of $\leq$58.4 for full support.

During the assessment White Lake had a median growing season Secchi-chlorophyll *a* TSI of 60.0, which indicated non-support of beneficial uses. Monitoring indicated the primary cause of the high productivity is high phosphorus loads from the watershed. In addition, numerous dissolved oxygen readings were below the 5.0 mg/l standard criterion for warm water permanent fish life propagation and were indicative of non-support of the fish life propagation use.

To reach the TSI target of 58.4, a 95% reduction in total phosphorus loading is needed. This was deemed unrealistic and unachievable and a TMDL was calculated based on socio-economic constraints in the watershed while still supporting the lakes beneficial uses. An alternate total phosphorus based TSI target of $\leq$70 was proposed. The dissolved oxygen target is the current water quality standard of 5.0 mg/l for warm water permanent fish life propagation.

The proposed phosphorus TMDL might indirectly address the dissolved oxygen issue because nutrient loadings are likely the root cause of excess algae and the subsequent loss of dissolved oxygen through decomposition of dead algae and other organic matter. Addressing the phosphorus problem might also prevent or minimize dangerously low dissolved oxygen levels in the lake. Presumably phosphorus control will result in less algae and therefore less organic matter to decompose and less oxygen demand by bacteria. In addition, aeration is recommended to directly alleviate the low dissolved oxygen problem.

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

The BATHTUB model predicted a total phosphorus loading rate of 3,364 kg/yr. This load is deemed to come from either non-point or natural sources. Lack of outlet flow data precluded development of a lake nutrient budget and estimation of lake internal loading. The sediment survey of the lake did not reveal any unusual or extreme sediment accumulation in the lake.

Linkage Analysis

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

The impacts of phosphorus reductions on the condition of White Lake were calculated using BATHTUB, an Army Corps of Engineers model. The model predicted that a 95% reduction of phosphorus from the incoming tributaries is necessary to get the lake to the target TSI of 58.

The Annualized Agriculture Nonpoint Pollution Source (ANNAGNPS) model was used to assess various land use scenarios and their effect of nutrient and sediment loading. The ANNAGNPS feeding area subroutine was used to provide comparative values for each of the animal feeding operations located in the watershed.

Various land use scenarios were explored for their capability of producing a 95% reduction in total phosphorus yield from the land. From this exercise, it became clear that a 95% reduction was not a realistic goal given the social and economic constraints in the watershed. Based on a reasonable projection of what was feasible in the watershed, an alternative numeric target was developed. The alternative target was based on a total phosphorus TSI of $\leq$70 for full support. Using this target, a 30% reduction in total phosphorus loading is needed. This means the phosphorus loading needs to be decreased by 1009 kg/yr of phosphorus to meet the alternative TMDL of 2355 kg/yr.

TMDL and Allocations

0 kg/yr. of total phosphorus	(WLA) point sources
3,364 kg/yr. of total phosphorus	(LA) nonpoint sources + natural
Implicit	(MOS)
2,355 kg/yr. of total phosphorus	(TMDL) target load

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.

Load Allocations (LAs)

A 27% reduction in the phosphorus load to White Lake may be obtained through improving half of the existing pastures to a good condition and using no-till residue management on half of the small grain and row crops. An additional 3% reduction can come from converting some existing cropland to CRP. This will reduce total phosphorus loading by 1009 kg/yr to result in a TMDL load of 2,355 kg/yr, the load that will produce a total phosphorus TSI of 70 in the lake.

Dissolved Oxygen

The proposed phosphorus TMDL might indirectly address the dissolved oxygen issue because nutrient loadings are likely the root cause of excess algae and the subsequent loss of dissolved oxygen through decomposition of dead algae and other organic matter. Addressing the phosphorus problem might also prevent or minimize dangerously low dissolved oxygen levels in the lake. Presumably phosphorus control will result in less algae and therefore less organic matter to decompose and less oxygen demand by bacteria. Aeration is recommended as a solution to the low DO levels.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and agricultural practices. Seasonality was determined for the tributaries with most the nutrient and sediment loading occurring during the spring run-off period. Seasonality in the lake was typical for a lake in northeastern South Dakota with summer peaks in algae. Thermal stratification did not occur but oxygen depletion at the bottom of the lake may threaten aquatic life if it becomes more prevalent.

Margin of Safety

The margin of safety is implicit as conservative estimations were used in the development of the phosphorus loads from the rangeland and cropland best management practices applied in the ANNAGNPS model. It was recommended that additional restoration activities such as alum treatment, lake aeration, and animal waste management system improvements be explored.

It should be pointed out the recommended TMDL was based on a "measured" TP load and the TP load may vary from year to year. During the study, the annual rainfall in Britton was 20.67 inches. This compared favorably to a 1971-2000 annual average of 20.68 inches so the study did represent an "average" rainfall year and presumably an "average" TP load, limnological conditions, etc. Given the variable conditions in nature, additional activities such as those mentioned above may need to be implemented to provide a margin of safety for phosphorus control.

Critical Conditions

The impairments to White Lake are most severe during the late summer. This is the result of warm water temperatures and peak algal growth as well as peak recreational use of the lake. Oxygen depletion can occur at any time but was most critical during late winter, prior to ice break-up.

Follow-Up Monitoring

As part of the implementation effort, ANNAGNPS modeling should be used to predict the nutrient and sediment load reductions from BMP implementation. The model will indicate whether sufficient BMPs have been implemented to reach the targeted phosphorus loading reduction.

Once the implementation project is completed, the lake will be monitored as part of South Dakota's Statewide Lakes Assessment Project to see if the TMDL had been reached and full support of the beneficial uses was achieved.

Public Participation

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

1. Monthly meetings of the Marshall Conservation District Board.
2. Individual contact with landowners in the watershed.

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

Implementation Plan

The South Dakota DENR is working with the Marshall County Conservation District to develop and initiate an implementation project. It is expected that the District will request USEPA Section 319 funding to assistance with BMP implementation efforts.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
999 18TH STREET- SUITE 300
DENVER, CO 80202-2466
Phone 800-227-8917
http://www.epa.gov/region08

August 30, 2006

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
Corsica Lake
Medicine Creek
Sheridan Lake
White Lake

Dear Mr. Pirner:

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

Based on our review, we feel the separate elements of the TMDLs listed in the enclosed table adequately address the pollutants of concern as given in the table, taking into consideration seasonal variation and a margin of safety. In the enclosed table, we have distinguished between TMDLs developed under Section 303(d)(1) *vs.* Section 303(d)(3) of the Clean Water Act. Section 303(d)(1) TMDLs are those for waterbodies that are water quality limited for the pollutant(s) of concern. The determination of whether a particular TMDL is (d)(1) or (d)(3) is made on a waterbody-by-waterbody and pollutant-by-pollutant basis.

Some of the TMDLs designated on the enclosed table as Section 303(d)(1) TMDLs, as distinguished from Section 303(d)(3) TMDLs, may be for waters not found on the current state 303(d) waterbody list. EPA understands that such waters would have been included on the list had the state been aware, at the time the list was compiled, of the information developed in the context of calculating these TMDLs. This information demonstrates that the non-listed water is in fact a water quality limited segment in need of a TMDL. The state need not include these waters that have such TMDLs associated with them on its next Section 303(d) list for the pollutant covered by the TMDL.

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

Sincerely,

/s/ by Max H. Dodson

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

Remediation

Enclosures

ENCLOSURE 1

APPROVED TMDLS

Waterbody Name*	TMDL Parameter/ Pollutant	Water Quality Goal/Endpoint	TMDL	Section 303(d)1 or 303(d)3 TMDL	Supporting Documentation (not an exhaustive list of supporting documents)
Corsica Lake*	Phosphorous	Maintain a mean annual TSI (N/Chl-*a*/SD) at or below 64.5	5,613 kg/yr total phosphorous (15% reduction in average annual total phosphorous loads)	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Corsica Lake, Douglas County, South Dakota (SD DENR, February 2005)
Medicine Creek*	Total Suspended Solids	TSS ≤ 263 mg/L daily maximum	20,172,490 kg/yr TSS (20.1% reduction in average annual TSS loads)	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report and TMDL, Medicine Creek, Lyman and Jones Counties, South Dakota (SD DENR, August 2005)
	Fecal Coliform	Fecal coliform ≤ 2000 cfu/100mL	3.89×10^{13} cfu/fecal season (18.3% reduction in average annual fecal coliform loads)	Section 303(d)(1)	
Sheridan Lake*	Phosphorous	Maintain a mean annual Total Phosphorous TSI at or below 45.0	251 kg/yr total phosphorous (43% reduction in average annual total phosphorous loads)	Section 303(d)(1)	■ Total Maximum Daily Load Evaluation for Sheridan Lake, Pennington County, South Dakota (SD DENR, May 2006)

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)
White Lake*	Phosphorous	Maintain a mean annual Total Phosphorous TSI at or below 70.0	2,355 kg/yr total phosphorous (30% reduction in average annual total phosphorous loads)	Section 303(d)(1)	■ Watershed Assessment/TMDL Final Report, White Lake, Marshall County, South Dakota (SD DENR, June 2005)
	Dissolved Oxygen	Dissolved oxygen ≥ 5.0 mg/L		Section 303(d)(1)	

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

Enclosure 5

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**White Lake Assessment Final Report**
Submitted by:	**Gene Stueven, SD DENR**
Date Received:	**March 28, 2006**
Review Date:	**May 12, 2006**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Formal – Final Approval**

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

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

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

1. Water Quality Impairment Status

Criterion Description – Water Quality Impairment Status

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

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

SUMMARY – White Lake is a 187 acre man-made lake located in the Western Wild Rice River Basin, Marshall County, South Dakota. The Wild Rice River is within the larger Red River Basin. It is listed on South Dakota's 2004 303(d) list as impaired for trophic state index (TSI) due to nonpoint sources and is ranked as priority 1 (i.e., high priority) for TMDL development. The watershed is approximately 22,348 acres and drains predominantly cropland and pastureland. Approximately 20% of the landuse is cropland and 70% is pastureland in the watershed. The mean phosphorous TSI during the period of the project assessment was 76.8, and is not currently meeting its designated beneficial use for warmwater permanent fish life propagation. The assessment report (pp 22-23) also indicates that the dissolved oxygen (DO) standard is not being met in the lake.

2. Water Quality Standards

Criterion Description – Water Quality Standards

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

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

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

The numeric standard for dissolved oxygen is ≥ 5.0 mg/L (single sample minimum).

Other applicable water quality standards are included on pages 13 and 14 of the assessment report.

3. Water Quality Targets

Criterion Description – Water Quality Targets

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

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SUMMARY – Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In June 2005, SD DENR published *Targeting Impaired Lakes in South Dakota*. This document proposed targeted median growing season Secchi disk/chlorophyll *a* Trophic State Index (TSI) values for each beneficial use designation category. 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 actual Secchi/chlorophyll *a* TSI for White Lake during the period of the assessment was 68.27. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 95% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use median Secchi/chlorophyll *a* TSI target of 58.4 or less. However, White 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, a site specific total phosphorous TSI of ≤ 70 was chosen for White Lake which will fully support its beneficial uses and is achievable given the expected landowner participation in the watershed. The amount of phosphorous reduction needed to meet the TSI target, along with mechanical aeration of the lake, is also expected to improve the dissolved oxygen concentrations in the lake to levels above the state standard.

The proposed water quality target for this TMDL is: **maintain a mean annual total phosphorous TSI**
≤ 70; dissolved oxygen ≥ 5.0 mg/L.

4. Significant Sources

Criterion Description – Significant Sources

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

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SUMMARY – The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed. In particular, a loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors. Cropland and grazing are the primary sources identified. Approximately 20% of the landuse is cropland and 70% is pastureland in the watershed.

5. Technical Analysis

Criterion Description – Technical Analysis

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

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SUMMARY – The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 30% reduction in average annual total phosphorous loads to White Lake. Based on the loads measured during the period of the assessment the total phosphorous load should be 2,355 kg/yr to achieve the proposed TSI target. This reduction is based in large part on the BATHTUB mathematical modeling of the lake and its predicted response to nutrient load reductions.

The FLUX model was used to develop nutrient and sediment loadings for the White Lake inlet and outlet sites. This information was used to derive export coefficients for nutrients and sediment to target areas within the watershed with excessive loads of these pollutants.

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 high priority cells. The analysis shows that 56 out of 360 cells (16%) had phosphorus loadings greater or equal to 50 lb/yr. These same cells accounted for 80% of the total phosphorus mass loading and only about 22% of the watershed area. These cells are defined as a high priority, and all other cells were deemed secondary priority.

The document indicates that the dissolved oxygen levels in the lake were usually sufficient to maintain the minimum requirement to support the warmwater permanent fish life propagation classification of the lake during the period of assessment. The report provides a linkage between low dissolved oxygen and the decomposition of algae and other organic matter in the lake. Production of algae is often influenced by phosphorous. The TMDL for dissolved oxygen is linked to phosphorous reduction in the lake as well as mechanical aeration to meet the water quality standard.

Recent TMDL language developed by the Utah Department of Environmental Quality provides further linkage analysis for dissolved oxygen and phosphorous reduction:

Addendum for the linkage betwecn lake/reservoir oxygen depletion and nutrients for East Canyon Reservoir, Minersville Reservoir, Kents Lake, LaRaron Reservoir, Mantua Reservoir and Puffer Lake.

The purpose of this addendum is to provide a definitive linkage between nutrient loads to Utah lakes/reservoirs and indirect oxygen depletions that occur as a result of excess blue-green algae blooms. This linkage will be used to further support and gain complete approval for the recently (April 2000) submitted TMDL's for Scofield Reservoir, East Canyon Reservoir, Mantua Reservoir, Minersville Reservoir, LeBaron Reservoir, Puffer Lake, and Kents Lake.

In a review of scientific literature, Carpenter et al. (1998), has shown that non-point sources of phosphorous (P) has lead to eutrophic conditions for many lake/reservoirs across the U.S. One consequence of eutrophication is oxygen depletions caused by decomposition of algae and aquatic p1ants. They also document that a reduction in nutrients will eventually lead to the reversal of eutrophication and attainment designated beneficial uses. Although, the rates of recovery are variable among lakes/reservoirs. This supports the Division of Water Quality's (DWQ) viewpoint that decreased nutrient loads at the watershed level will result in improved oxygen levels, the concern is that this process rakes a significant amount of time (5-15 years).

In Lake Erie, heavy loading of phosphorous has impacted the lake severely. Monitoring and research from the 1960's has shown that depressed hypolimnctic DO levels were responsible for large fish kills and large mats of decaying algae. Binationa1 programs to reduce nutrients into the lake have resulted in a downward trend of the oxygen depletion rate since monitoring began in the 1970's. The trend of oxygen depletion has lagged behind that of P reduction, but this was expected **(See http://www.epa.gov/glnpo/lakeerie/dostory.html).**

Nurnberg (1995, 1995a, 1996, 1997), developed a model that quantified duration (days) and extent .of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual local phosphorous (TP) concentrations. The AF may also be used to quantify response to watershed restoration measures which makes it very useful for TMDL development. Nurnberg (1996) developed several regression models that show nutrients (P and N) control all trophic state indicators related to oxygen and phytoplankton in lakes/reservoirs. These models were developed from water quality characteristics using a suite of North American lakes. The DWQ has calculated rnorphometric parameters such as surface area (A_o), mean depth (z), and the ratio of mean depth to surface area ($z/A_o^{0.5}$) for the concerned lakes and reservoirs in Utah (see Table 1).

The results show that these parameters are within the range of lakes used by Nurnberg. Because of this we feel confident that Nurnberg's empirical nutrient-oxygen relationship holds true for Utah lakes and reservoirs. We are also convinced that prescribed BMP's will reduce external loading of nutrients to the lakes/reservoirs which will reduce algae blooms and therefore increase oxygen levels over time. In addition Nurnberg rejects absolute DO as a trophic state metric (e.g., see page 442, Nurnberg (1996) in particular for an observation that there are many oligotrophic lakes with zero DO). Numbers presents other variables and metrics that would predict trophic status which we are relying on besides DO, itself. It is the compilation of all these indicators that will allow for complete evaluation of the lake health and achievement of water quality standards. Included with this document are other papers by Nurnberg to support our rationale.

Utah's approach to treat the sources of nutrients and reduce/eliminate nutrient loads to impaired waterbodies is consistent with accepted watershed strategies to treat sources rather than symptoms **(**low dissolved oxygen**)**. However, if after treatment of sources and a sufficient period for recovery (10+ years) dissolved oxygen concentrations are not improving, than in-lake treatments may be investigated and implemented. However, in-lake treatments should not be implemented without control of nutrient sources within the watershed. This view is also supported by Carpenter et al. (1998).

Table 1. Morphometry data for Utah lakes and reservoirs.

Lake	Nurnberg Range	Mantua	Scofield	East Canyon	Minersville	Kents Lake	Lebaron	Puffer
z (m)	1.8 – 200	4.27	7.9	23	8.1	6.2	3.23	4.5
A_o (hectars)	5 – 6.2 10^6	224	1139	277	400	19.4	9.47	26.3
$z/A_o^{0.5}$ (m/km^2)	0.14 – 48.1	2.85	2.34	13.81	4.05	8.77	10.49	8.77

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety and Seasonality

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

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

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

7. TMDL

Criterion Description – Total Maximum Daily Load

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

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SUMMARY – The TMDL established for White Lake is a 2,355 kg/yr total phosphorus load to the lake (30% reduction in annual total phosphorus load). This is the "measured load" which is based on the flow and concentration data collected during the period of the assessment. Since the annual loading varies from year-to-year, this TMDL is considered a long term average percent reduction in phosphorous loading.

8. Allocation

Criterion Description – Allocation

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

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

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SUMMARY – This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in White Lake. The allocation for the TMDL is a "load allocation" attributed to nonpoint sources. There are no significant point source contributions in this watershed. The source allocations for phosphorous are assigned to nonpoint source runoff from the watershed.

9. Public Participation

Criterion Description – Public Participation

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

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SUMMARY – The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed and has had individual contact with residents in the watershed. Also, the draft TMDL was posted on the State's internet site to solicit comments during the public notice period. The level of public participation is found to be adequate.

10. Monitoring Strategy

Criterion Description – Monitoring Strategy

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

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

11. Restoration Strategy

Criterion Description – Restoration Strategy

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

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SUMMARY – The South Dakota DENR is working with the Marshall County Conservation District to develop a plan for an implementation project for White Lake. Implementation of various best management practices will be necessary to meet or exceed the WQ and TMDL targets/goals. This includes improvements to pasture grazing practices, implementation of no-till residue management on small grain and row crop lands, converting some cropland to CRP, and mechanical aeration. Additional BMPs that could be implemented if necessary include construction of animal waste management systems, and alum treatment.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance

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

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

13. Miscellaneous Comments/Questions - None

Thirty copies of this document were printed by the Department of Environment and Natural Resources at a cost of $5.20 per copy.