PHASE I
WATERSHED ASSESSMENT
FINAL REPORT

ENEMY SWIM LAKE
DAY COUNTY, SOUTH DAKOTA

South Dakota Watershed Protection Program
Division of Financial and Technical Assistance
South Dakota Department of Environment and Natural Resources
Nettie H. Myers, Secretary

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Prepared By

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State of South Dakota
William J. Janklow, Governor

May, 2000

Executive Summary

Enemy Swim Lake is a 489.3 hectare (1,209 acre) glacial lake located in Day County. The total watershed for Enemy Swim Lake is 9,029 hectares (22,310 acres) reaching east into RobertS County. Enemy Swim Lake is classified as a warm water permanent fishery. Other beneficial uses include immersion recreation, limited contact recreation, and stock watering and wildlife propagation.

The Day Conservation District was the local sponsor for the Blue Dog/Enemy Swim Watershed Assessment Project. As local sponsor, the Conservation District hired the local coordinator and administered project funds. Funds for the project came from Section 319 Nonpoint Source of the Clean Water Act, administered by the Environmental Protection Agency (EPA). EPA granted the money to the State of South Dakota as the pass-through agency. The 40% local match for the project was provided by the Blue Dog Lake Association and the Enemy Swim Lake Sanitary District.

Due to lack of access and the presence of wetlands between every inlet and the lake, no tributary samples could be collected. The USDA Agricultural Nonpoint Source Pollution model (AGNPS) was used to estimate tributary inputs of nitrogen, phosphorus and sediment. Inlake samples were collected by the local coordinator and sent to the State Health Laboratory in Pierre, SD for analysis. A septic leachate survey was conducted in August of 1998 to see if leachate from failing private waste collection systems was reaching the lake.

Results from the study indicated that Enemy Swim has become more eutrophic over time. In the last decade, there was a marked increase in chlorophyll a concentrations in the lake. Man-induced causes of nutrient enrichment could be leaching septic tanks, unincorporated fertilizer, or waste from animal feeding areas.

Inlake water quality monitoring found relatively low sedimentation and low nutrient concentrations compared to more eutrophic lakes in the area. There was a slight thermal stratification with diminished hypolimnetic oxygen levels on warm summer days. The thermocline was most likely caused by shading from an algal bloom. The average phosphorus concentration (0.028 mg/L) was sufficient to produce algal blooms. Nitrate and ammonia concentrations were low to non-detectable. The limiting nutrient for algal production in Enemy Swim Lake was phosphorus. Algae populations in phosphorus-limited lakes are quicker to respond to reduced inlake phosphorus concentrations than nitrogen-limited lakes.

Suspended solids concentrations in Enemy Swim Lake consisted mostly of algae and not sediment or inorganic material. The small amount of sediment that came from the watershed was most likely settled out in the wetlands between the tributary inlets and the lake. Erosion from shoreline was also minimal. Most of the undeveloped shoreline around the lake was well protected by vegetation and rocks, however there were a few overgrazed pastures noted that had depleted the riparian vegetation causing minor bank erosion. Homeownerss around the lake that had cleared lakeside vegetation did experience moderate to severe erosion during a severe rainstorm in 1993. Better riparian management practices should be implemented for both the developed and undeveloped shorelines.

The Enemy Swim watershed had a larger proportion of pasture and CRP acreage compared to cropland. This proportion was most likely responsible for the small amount of sediment entering the lake. The areas that did show above average sediment delivery rates were located close to the lake. AGNPS did not take into consideration the effect of the wetlands located between the tributaries and the lake. The AGNPS model found that grain fields with 100% fertilizer availability were the main sources of nutrients to Enemy Swim Lake. There were also thirteen animal feeding areas identified as potential nutrient sources. Of these thirteen, seven rated higher than 50 and therefore were targeted for animal waste management systems.

The targeted nutrient reduction for Enemy Swim Lake was a 50% reduction in inlake phosphorus concentrations. This reduction would lower the chlorophyll *a* TSI from eutrophic to mesotrophic.

The majority of the recommendations needed to meet the targeted reductions are given by the AGNPS model. The AGNPS model predicted a 24% reduction in phosphorus loads to Enemy Swim Lake by incorporating fertilizer in all critical nitrogen and phosphorus cells. An additional 7% reduction of phosphorus could be reached by eliminating waste from the seven identified animal feeding areas in the watershed. Results from the septic leachate survey did not quantify the load from the septic tanks. However, the 40 suspected septic tank plumes, along with the sandy soils and high ground water elevations, were strong evidence that septic leachate was entering the lake. It was estimated that at least an additional 20% reduction could be reached by constructing a central collection system. Long-term monitoring should continue on Enemy Swim Lake to track trophic state trends and to document improvements if the recommendations are followed.

ACKNOWLEDGEMENTS

The cooperation of the following organizations and individuals was gratefully appreciated. The assessment of Enemy Swim Lake could not have been completed without their assistance.

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SD Department of Environment and Natural Resources – Water Rights
SD Department of Environment and Natural Resources – Environmental Services
SD Department of Environment and Natural Resources – Watershed Protection
ECOSCIENCE Inc., Moscow, PA

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Introduction

Enemy Swim Lake is a 489.3 hectare (1,209 acre) natural lake located on the eastern edge of Day County in northeast South Dakota (Figure 1). Enemy Swim Lake was most likely formed from a receding glacier during the Pleistocene Epoch. The maximum depth of Enemy Swim Lake is 7.9 meters (26 feet). Enemy Swim Lake has a mean depth of 4.9 meters (16 feet) and a shoreline length of 18.9 kilometers (11.8 miles).

Enemy Swim Lake

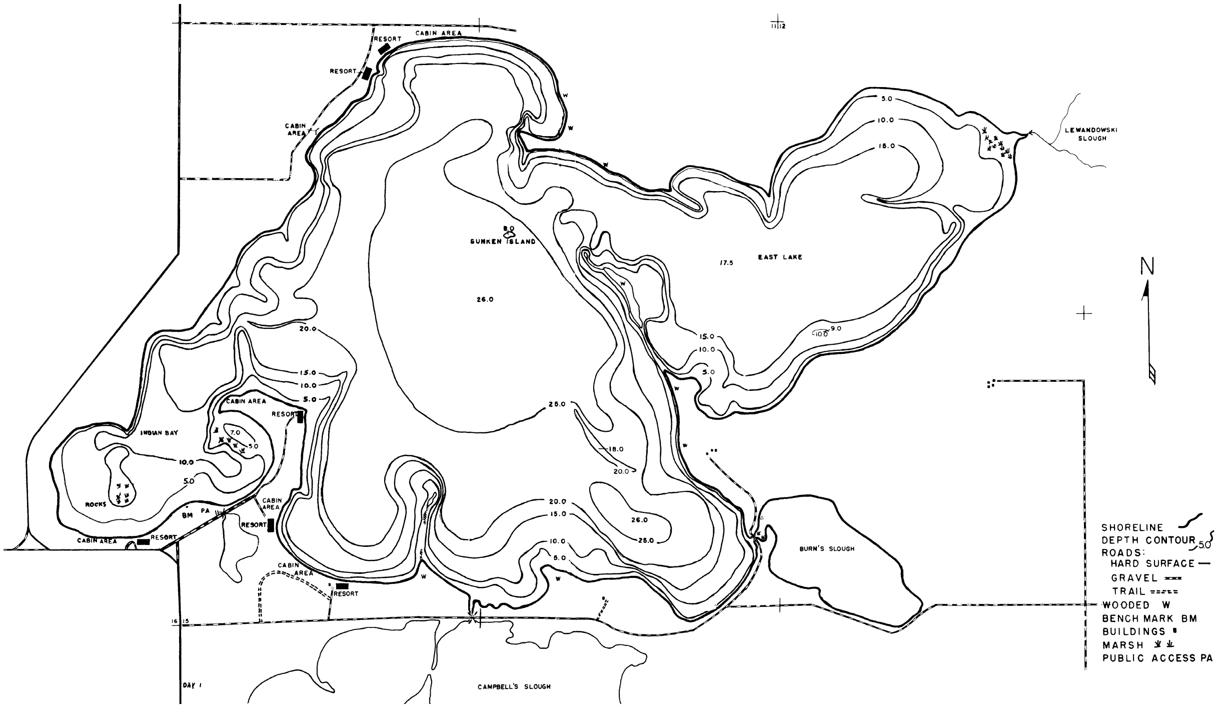


Figure 1. Enemy Swim Lake.

The total watershed for Enemy Swim Lake (Figure 2) is approximately 9,029 hectares (22,310 acres). The lake and western half of the watershed are located in eastern Day County and the rest of the watershed is located in western Roberts County. The watershed begins on the western edge of the Waubay Moraine. The Waubay Moraine was left after advancement of the second and third glaciers of the Pleistocene Epoch. The glacier movement formed the Coteau de Prairies, the major physiographic formation of northeastern South Dakota. The glacial meltwaters cut channels and deposited sand and gravel outwashes connecting most of the major lakes in the area through surface as well as groundwater (Leap, 1988).

Enemy Swim Watershed

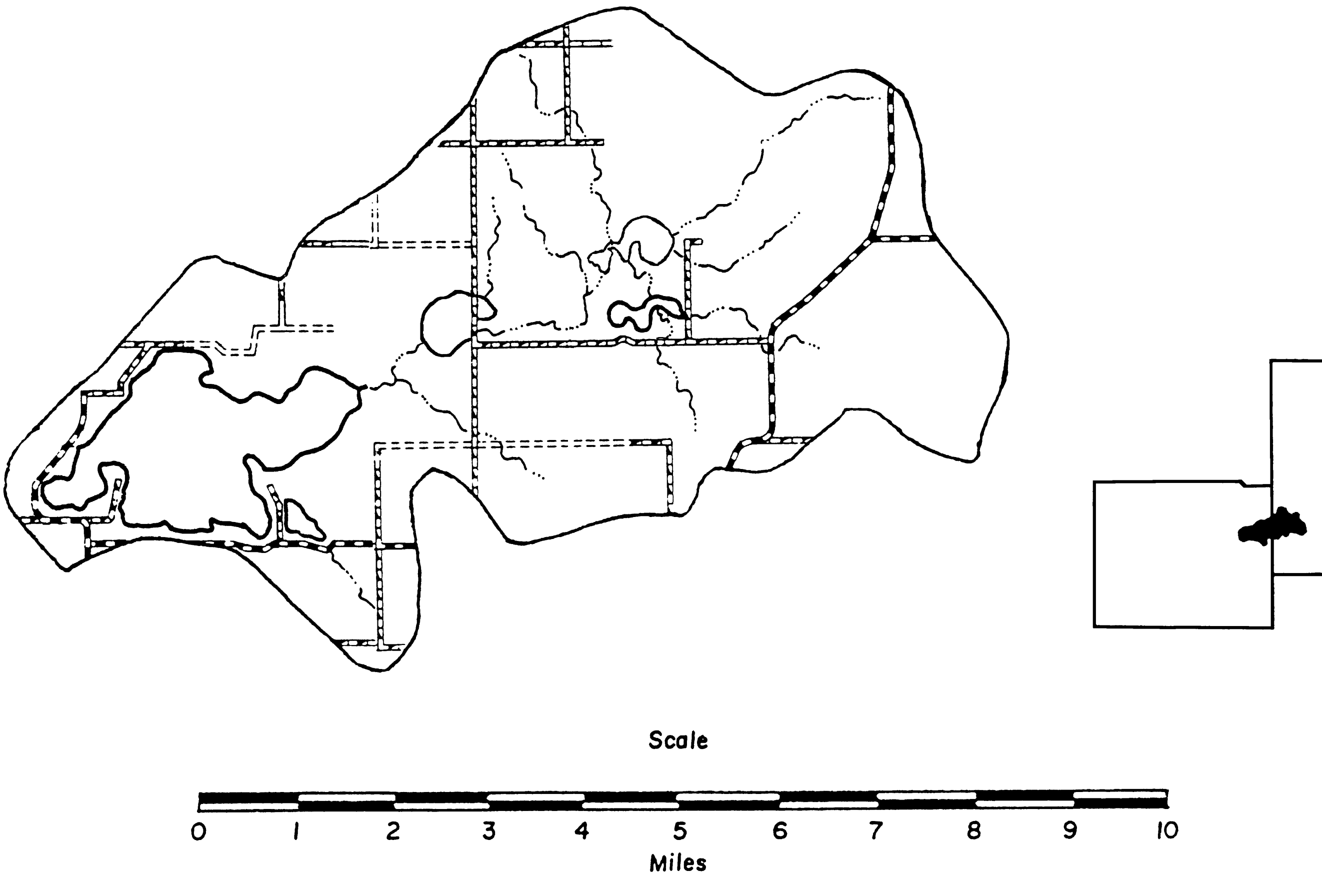


Figure 2. Enemy Swim Lake Watershed.

Enemy Swim Lake is well known for its relatively good water quality (low nutrient concentrations). Enemy Swim has been on the state's list of protection lakes. Protection lakes are those with good water quality that need to be protected, as opposed to impaired waters that need to be restored.

Purpose of the Study

The purpose of the Enemy Swim Lake Watershed Assessment was to identify and target the nutrient sources in the watershed that would increase the eutrophication of Enemy Swim Lake.

The Enemy Swim Lake Assessment was conducted along with the Blue Dog Lake Assessment. Initially, the State was contacted to conduct an assessment of Blue Dog Lake in 1995. Because of Enemy Swim Lake's close proximity and because it was within the same county, the state was asked by the Enemy Swim Sanitary District to include Enemy Swim in the assessment of Blue Dog Lake. The Day Conservation District agreed to sponsor the two-year study on both lakes. Although hired by the Day Conservation District, the salary for the coordinator was paid by both the Blue Dog Lake Association and the Enemy Swim Lake Sanitary District. The discussion of the Blue Dog Lake Report can be found in a separate document (Stueven, 1999).

Background/History

Enemy Swim Lake got its name from a battle in 1812 between the warring Sioux and Cheyenne Indian Tribes. A Cheyenne war party found a Sioux camp along the southern shores of the lake and started to attack. As the Sioux started winning the battle, the Cheyenne escaped by swimming to the north side of the lake around Shepherds point (Ochsenreiter, 1926). The first documented non-Indian settlement in the Waubay Township was a trapper's sod house in 1850. The area around Enemy Swim Lake was officially opened for white settlement in 1892. Fur, fish and game have historically been plentiful. Even in the early 1900's, the excellent fishing in Enemy Swim Lake was known across the state. The lake was and still may be the most used lake in the area. In the early 1900's, it was stated that all of the rental equipment from the resorts and hotels would be rented out for use on Enemy Swim Lake and more was needed. One piece of land located on the large peninsula on the southeastern part of the lake has been the location of many different establishments. It started as a biological research station for the Northern Normal Industrial School of Aberdeen, then a boy scout camp and a girl scout camp, a large resort (Camp Dakota), and is now a bible camp with additional lots for private residences. Currently the lake is home to 15 permanent homes, 198 seasonal cabins, one bible camp, and 3 resorts.

Shoreline

There is little erosion along Enemy Swim Lake's shoreline. Unpopulated areas were heavily vegetated and protected by rocks. Many of these areas were further protected by offshore stands of emergent bulrush (*Scirpus sp.*). Portions of the northern shore's riparian vegetation have been destroyed by overgrazing. In 1993, 3 to 4 feet of shoreline were lost on selected areas during a summer storm event. The thunderstorm dropped 7 to 10 inches of rain in a few hours. Damage was mainly along populated shorelines where the riparian vegetation had been removed and the shoreline "landscaped". Some repair has been made to these shorelines, however, Best Management Practices (BMPs) should be implemented to improve the riparian vegetation in the grazing areas and stop the bank erosion around the populated areas. Sedimentation from shorelines can increase the phosphorus concentrations in a lake and in some cases is a major source of sedimentation of a lake (Skadsen, 1999).

Land Use

Land use in the Enemy Swim watershed is primarily agricultural. The following graphics show the estimated percentages of the types of land use and ownership of the land in the watershed.

As can be seen from the Figure 3, the majority of the land use in the watershed is either rangeland or CRP (73%). There is very little crop farming in the watershed (13%). Most of the inlets to the lake are buffered by wetlands that act as filters, settling out suspended solids that might be coming from the watershed. Figure 4 shows that the majority of the land in the watershed is in private ownership.

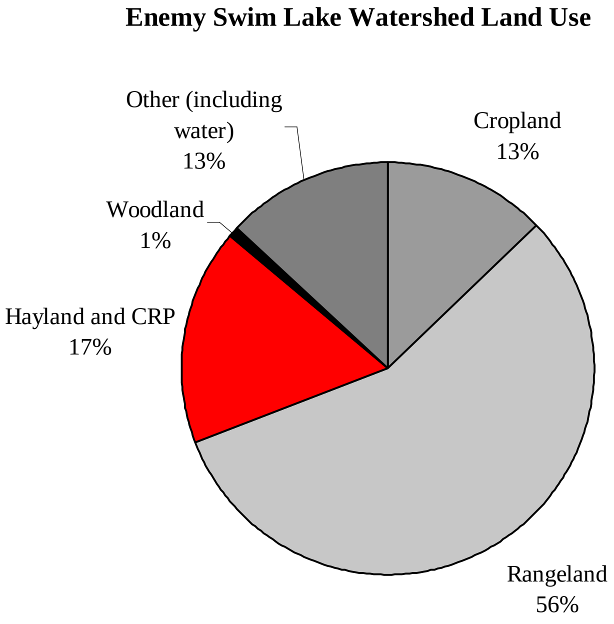


Figure 3. Watershed Land Use

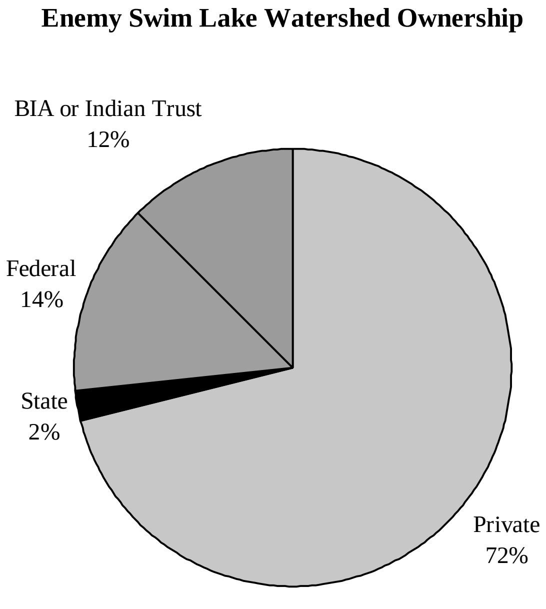


Figure 4. Watershed Ownership.

Sanitary Systems on Enemy Swim Lake

There are fifteen year-round homes around Enemy Swim Lake and 198 seasonal cabins occupied from May to September. In addition to the permanent homes, there is one camp with two year-round homes and 3 seasonal resorts. The homes at the resorts are equipped for year-round use.

There is no central wastewater collection system for any of the privately owned homes or the resorts. Only the church camp has tied their wastewater system to a lagoon system managed by the Sisseton-Wahpeton tribe.

In 1997, the Day Conservation District conducted a sanitary survey of the homes around the lake. Fifty-five percent of the residents responded to the mail survey. The following table displays the results.

Table 1. Results of Sanitary System Survey.

Type of System	Number
Septic tank with drywell	8
Septic tank with drainfield	88
Holding tank	10
Open bottom	3
Outhouse with open bottom	11
No response	93
Total	**213**

In addition to the 1997 Sanitary Survey, a septic leachate survey was conducted in August of 1998. Approximately 3.7 miles of shoreline were examined during the study. The purpose of the survey was to locate and qualitatively characterize suspected leachate plumes coming from sanitary systems around the lake. The fieldwork was conducted by ECOSCIENCE of Pennsylvania with assistance from the Day Conservation District. Water quality samples were sent to the State of South Dakota Health Laboratory in Pierre. Analysis of the data was conducted by ECOSCIENCE. A recap of the report summary is below, the complete ECOSCIENCE report can be found in Appendix A.

Executive Summary of Septic Leachate Survey
Conducted by ECOSCIENCE Inc.

> The following study was conducted for the Day Conservation District to locate and qualitatively characterize septic leachate plumes emanating from malfunctioning on-lot sanitary systems, i.e. septic tanks. The developed portions of the shoreline of Enemy Swim Lake (ESL) were intensively scanned using ECOSCIENCE's patented Septic Leachate Detection System during a period of peak wastewater loading, August 24-27, 1999.
>
> Leachate from poorly treated wastewater will adversely impact lake water quality by contributing growth-limiting nutrients, typically phosphorus or nitrogen. The input of bacteria-laden wastewater may also pose a health hazard to those pursuing contact

recreation. Improperly treated wastewater often contains potentially pathogenic nuisance forms of aquatic vegetation and accelerate the eutrophication, or “aging process” of the lake.

Over 40 suspected leachate plumes were identified at ESL during the present investigation. We also identified several shoreline areas of extended plume readings. For budgetary reasons, only 20 suspected septic leachate sites were sampled. Laboratory analyses of 26 sample stations, which included 4 background, one inlet, and discharge from a wetland revealed elevated total phosphorus (TP) and nitrogen (TKN) concentrations. Fecal contamination was also identified at over 30% of the selected sample stations.

In view of the study findings, we recommend the Day County Conservation District consider the following recommendations:

1. Seek immediate assistance from Local, State, and Federal Agencies to develop a comprehensive wastewater collection treatment system for Enemy Swim Lake (ESL). Basin topography, soil types and a number of other factors limit the effectiveness of on-lot sanitary systems as a wastewater disposal method for ESL.

2. Seek assistance from the South Dakota Department of Environment and Natural Resources, Sisseton-Wahpeton Sioux Tribe, and Enemy Swim Sanitary Sewer District, and Day County Health Department in enforcing violated sanitary codes.

3. Encourage the use of low or no phosphorus-containing detergents and household cleaners. A listing of the phosphate contents of some detergents is provided in Appendix B.

4. Encourage the use of water conservation devices in all households. A list of such items with percent water usage reductions is presented in Appendix C.

5. Prohibit the use of phosphorus-containing lawn fertilizer.

6. Continue to monitor selected water quality and bacteriological parameters on a routine basis. As a minimum, we recommend re-sampling the identified sites. The background stations should also be sampled. Water samples should be collected during peak wastewater loading conditions and analyzed for wastewater indicator parameters. The use of groundwater traces and well point samplers should also be employed at the identified locations to further quantify wastewater discharges.

7. A comprehensive in-lake water quality and watershed assessment of ESL has been completed and will be published by January, 2000. The nutrient budget calculated for ESL will be useful for determining the significance of phosphorus and nitrogen contributions from on-lot systems.

The entire Enemy Swim Lake Septic Leachate Survey can be found in Appendix A.

Fisheries

Enemy Swim Lake has a very diverse fish community. The fish community is supported by a diverse habitat including shallow bays, deep-water areas, sandy and rocky shorelines, submerged boulders, underwater rock bars, as well as submergent, floating, and emergent vegetation. This complex system makes it difficult for the South Dakota Department of Game, Fish and Parks (SD GFP) to alter the fishery to increase angler benefit (SD GFP, 1999).

Species found in fishing surveys include:

Walleye
Largemouth Bass
Black Bullhead
Logperch
Orangespotted Sunfish
Yellow Perch
Smallmouth Bass
Pumpkinseed
Johnny Darter
Bluegill
Black Crappie
White Sucker
Spottail Shiner
Fathead Minnow
Northern Pike
White Bass
Common Carp
Rock Bass

According to the 1998 Statewide Fish Survey, there were good numbers and natural reproduction of walleye, yellow perch, bluegill, smallmouth bass, and northern pike. Overall, the fishery of Enemy Swim Lake is very good for anglers, with a wide variety of game fish to choose from and relatively low numbers of rough fish (carp and black-bullhead). Species acceptable to fishermen can be found almost any time of the year in Enemy Swim Lake. The complete 1998 fishery survey can be found in Appendix B.

Methods and Materials for Tributary Analysis

Because of lack of access to tributary sites around Enemy Swim Lake, (Figure 2) there were no tributary monitoring sites placed in the watershed. In addition, large wetlands are located between the tributaries and the lake inlets. Changes in water quality through these wetlands would have given spurious tributary loadings. When an attempt was made to move the sites upstream, the lack of roads made access to other potential tributary sites impossible.

The Agricultural Nonpoint Source Pollution Model (AGNPS) model was used to predict nutrient and sediment loads from the watershed. Because AGNPS is a model, the actual numbers may not reflect actual concentrations in the watershed. However, by comparing one cell to another, areas of highest sediment and nutrient output cells can be identified.

Methods For AGNPS Analysis

Overview

The Agricultural Nonpoint Source model version 3.65 (AGNPS) was selected to further understand the nonpoint source (NPS) loadings in the Enemy Swim watershed, as well as, aid in predicting the impacts of Best Management Practices (BMPs). This model was developed by the USDA–Agricultural Research Service to analyze the water quality of runoff events in the watershed. The model predicts the total runoff volume as well as the runoff rate. Parameters analyzed include eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand (COD) concentrations in the runoff and sediment. The model was designed to utilize a single storm event of equal magnitude for all acres in the watershed. The model then analyzes the runoff data from the headwaters of the watershed to the chosen outlet cell. The pollutants are routed in a step-wise fashion so the flow at any point may be examined. The AGNPS model is used to objectively compare different subwatersheds and individual cells within one watershed, to other cells and watersheds within a drainage basin. The model is intended for watersheds up to about 320,000 acres (8,000 cells @ 40 acres/cell).

The model works by calculating loadings from individual cells.. These cells are uniform square areas that divide the watershed. Typically the cell size is 40 acres, however, the cells can be as small as 10 acres. The basic components of the model are hydrology, sediment erosion, and nutrient transport. Erosion from each cell is from two sources; 1) total upland erosion and 2) total channel erosion. Components of erosion are separated into five particle size classes (clay, silt, small aggregates, large aggregates, and sand). Nutrient transport is divided into soluble nutrients and nutrients attached to insoluble particles.

Collecting AGNPS Data

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

1) Detailed topographic map of the watershed (USGS map 1:24,000)
2) Establish the drainage boundaries.
3) Divide the watershed into cells (40 acre). Only those cells with greater than 50% of their area within the watershed boundary are included.
4) Number the cells consecutively beginning at the NW corner of watershed and preceding from west to east, then north to south.
5) Establish the watershed drainage pattern from each cell.

Once the preliminary examination is completed, the input data file can be established. The data file is composed of the following 22 inputs per cell:

Data input for each cell

1) **Cell number**
2) **Receiving cell number**
3) **SCS curve number:** runoff curve number (use antecedent moisture condition II)
4) **Land slope:** (topographic maps) average slope if irregular, water or marsh = 0
5) **Slope shape factor:** water or marsh = 1 (uniform)
6) **Field slope length:** water or marsh = 0, for S.D. assume slope length area 1
7) **Channel slope:** (average), topo maps, if no definable channel, channel slope = 1/2 land slope, water or marsh = 0
8) **Channel sideslope:** the average sideslope (%), assume 10% if unknown, water or marsh=0
9) **Manning roughness coefficient for the channel:** If no channel exists within the cell, select a roughness coefficient appropriate for the predominant surface condition within the cell

10) **Soil erodibility factor:** water or marsh = 0
11) **Cropping factor:** assume conditions at storm or worst case condition (fallow or seedbed periods), water or marsh = .00, urban or residential = .01
12) **Practice factor:** worst case = 1.0, water or marsh = 0 ,urban or residential = 1.0
13) **Surface condition constant:** a value based on land use at the time of the storm to make adjustments for the time it takes overland runoff to channelize
14) **Aspect:** a single digit indicating the principal direction of drainage from the cell (if no drainage = 0)
15) **Soil texture:** major soil texture and number to indicate each are:

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

16) **Fertilization level:** indication of the level of fertilization on the field.

Assume Fertilization (lb./acre)			
Level	N	P	Input
No fertilization	0	0	0
Low Fertilization	50	20	1
Average Fertilization	100	40	2
High Fertilization	200	80	3

For average manure application use – Low Fertilization
For high manure application use – Average Fertilization
For water or marsh use – 0
For urban or residential use – 0 (for average practices)

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

Of these 22 parameters, the most sensitive parameters affecting sediment and chemical yields are listed below in order of importance:

4) Land slope (LS)
10) Soil erodibility (K)
11) Cropping Factor ©
2) SCS curve number (CN)
12) Practice factor (P)

Also needed for calculation of nutrient and sediment are overall parameters for the model. These include:

a) Area of each cell in acres (cells must be the same size for each AGNPS run)
b) Total number of cells in watershed
c) Precipitation for a monthly, six-month, yearly, 5-year, and 25-year, 24-hour rainfall
d) Energy intensity value for the storm events previously selected

Data Output at the Outlet of Each Cell

Hydrology

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

Sediment Output

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

Chemical Output

Nitrogen	Phosphorus	Chemical Oxygen Demand
Mass associated with sediment	Mass associated with sediment	Concentration
Mass of soluble material	Mass of soluble material	Mass
Concentration of soluble material	Concentration of soluble material	

AGNPS Data Analysis

The primary objectives of running the AGNPS model on the Enemy Swim Lake watershed were to:

1. Evaluate and quantify NPS loadings from each subwatershed.
2. Define critical NPS cells within each subwatershed (elevated sediment, nitrogen, phosphorus).
3. Priority ranking of each animal feeding area and quantify the nutrient loadings from each area.

The Enemy Swim watershed was divided into 40-acre cells. Next, the direction of flow within each cell was determined. Based on the fluid flow directions and drainage patterns, twelve subwatersheds were delineated. Using the flow direction and the other 21 parameters collected for each cell, the model calculated the nonpoint source pollution loadings for each cell, subwatershed, and animal feeding area. The model also estimated hydrology runoff volume for each storm event modeled.

The storm events chosen for the model were typical for regional average annual rainfall. By using storm event intensities comparable to those commonly experienced in the Enemy Swim watershed, the AGNPS model more accurately represented nutrient and sediment loads to Enemy Swim Lake. Single storm events of variable intensity were then combined for a composite of an average year's rainfall events. Both the subwatershed and the critical single cell analysis were performed using the annualized (average year) sum of individual events. The animal feeding area analysis was performed using a single rainfall event of 25-year intensity. This storm event resulted in higher runoff volumes than the annualized event and produced a wider range in the AGNPS animal feeding area ranking which makes it more conducive to selecting a problem feedlot. The rainfall and energy intensity values associated with the annualized as well as the 25-year events can be found in Table 2. The values used for the energy of the storm events can be found in Table 3.

Table 2. Rainfall Specifications for the Enemy Swim Watershed.

Event Intensity	**Rainfall**	**Energy**
Monthly	0.8 inches	3.0
Six Month	1.5 inches	11.7
One Year	2.0 inches	21.8
Twenty Five Year	4.4 inches	121.2
NRCS R-factor for the Enemy Swim Lake watershed = 93		

Table 3 Annual Loading Calculation.

Event Intensity	**Number of Events**	**Energy**	**Total Energy**
Monthly	12	3.0	36.0
Six Month	3	11.7	35.1
One Year	1	21.8	21.8
TOTAL			**93**

Evaluate Subwatershed Loads

The first step in the analysis of a watershed using the AGNPS model was to delineate the watershed drainage for Enemy Swim Lake. Using a 7.5-minute quad map of the region, the watershed was delineated and then broken into 40-acre cells. Each of these 40-acre cells was assigned a runoff flow direction where it drained into an adjacent cell. The flow was routed step-wise until it ultimately drained into Enemy Swim Lake. By examining these flow paths it can be seen that small pockets of cells display runoff patterns that sometimes converge at a central point. These pockets of cells within a watershed are called “subwatersheds”.

The Enemy Swim watershed contains twelve subwatersheds varying in total drainage area from 520 acres to 4,440 acres. Information regarding each of the twelve delineated subwatersheds can be found in Table 4 below.

Table 4. Subwatershed Outlet Cell and Drainage Number.

SUBWATERSHED #	OUTLET CELL #	DRAINAGE AREA
1	130	1,280
2	154	1,400
3	189	2,280
4	218	640
5	224	1,880
6	250	1,120
7	295	4,440
8	363	800
9	367	1,080
10	394	1,120
11	622	520
12	920	920

Once the subwatersheds had been established, both the sediment and nutrient loadings from the subwatersheds were examined on a broader scale than if done on a cell by cell basis. Some factors pertaining to a subwatershed’s relevance toward loadings were the proximity to Enemy Swim Lake, volume of runoff draining from the subwatershed, and velocity of runoff from the subwatershed. Both the subwatershed and the critical individual cell analyses will concentrate on loadings of sediment, nitrogen and phosphorus.

Subwatershed delineation is shown in Figure 5. Waterbodies are displayed on the AGNPS model map as the dark cells with Enemy Swim Lake being on the left-hand side of the delineated watershed.

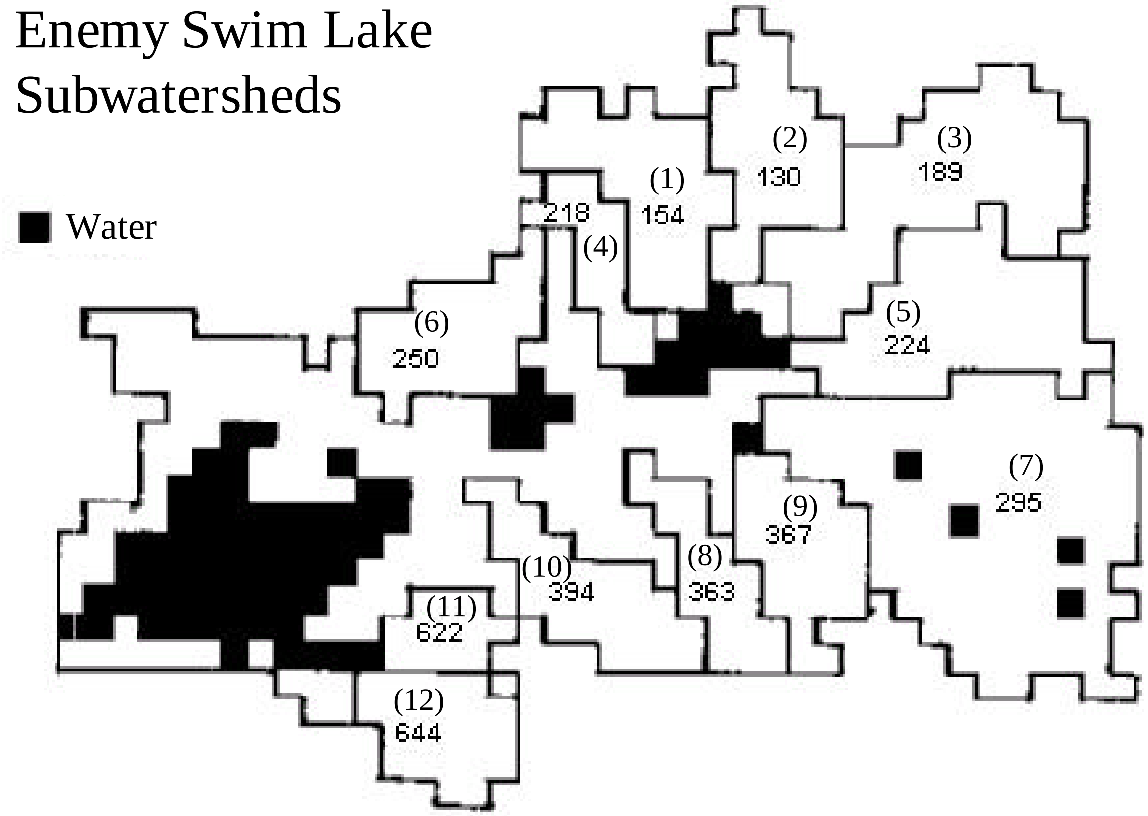


Figure 5. Enemy Swim Lake Subwatersheds

Subwatershed Sediment Analysis

The AGNPS model concluded that the overall sediment delivered to Enemy Swim Lake was low. Sediment delivered to the lake was calculated by totaling only those cells that drained directly to the lake (cells # 310, 311, 392, 621) and not what was delivered by the individual subwatersheds. The yearly sediment load into Enemy Swim Lake was approximately 138 tons. Compared to the watershed directly south of Enemy Swim, Blue Dog Lake received 1,465 tons of sediment. The difference was due primarily to the much larger amount of cropland within the Blue Dog Lake watershed.

The sediment load for each of the twelve subwatersheds located in the Enemy Swim watershed also appeared to be quite low when compared to other regional subwatersheds. The subwatersheds with markedly higher outputs of sediment were #4, #10, #11, and #12. The annual sediment outputs of both the subwatersheds as well as the cells that empty to Enemy Swim Lake can be found in Table 5 below.

Table 5. AGNPS Estimated Loads of Sediment, Nitrogen, and Phosphorus.

Sub-Watershed Number / Outlet Cell	Drainage Area / %	Sediment		Nitrogen		Phosphorus	
		Annual Load	Annual Load per Acre	Annual Load	Annual Load per Acre	Annual Load	Annual Load per Acre
#	Acre	Ton	lbs. / Acre	lbs.	Lbs. / Acre	lbs.	Lbs. / Acre
(1) 130	1280 / 4.8	12.2	19.06	256	0.20	64	0.05
(2) 154	1400 / 5.2	47.48	67.83	**3,500**	**2.50**	**910**	**0.65**
(3) 189	2280 / 8.5	25.42	22.30	1,049	0.46	205	0.09
(4) 218	640 / 2.4	**57.78**	**180.56**	646	1.01	282	0.44
(5) 224	1880 / 7	9.97	10.61	301	0.16	75	0.04
(6) 250	1120 / 4.2	37.44	66.86	1,075	0.96	336	0.30
(7) 295	4440 / 16.5	21.93	9.88	1,376	0.31	-	0.00
(8) 363	800 / 3	13.67	34.18	1,392	1.74	288	0.36
(9) 367	1080 / 4	9.38	17.37	1,285	1.19	324	0.30
(10) 394	1120 / 4.2	**95.52**	**170.57**	**4,917**	**4.39**	**1,232**	**1.10**
(11) 622	520 / 1.9	**59.32**	**228.15**	**2,720**	**5.23**	**660**	**1.27**
(12) 644	920 / 3.4	**136.03**	**295.72**	**6,734**	**7.32**	**1,711**	**1.86**
Weighted Average			**98.95**		**1.44**		**0.35**

Sub-Watershed Inlets to Enemy Swim	Drainage Area / %	Sediment		Nitrogen		Phosphorus	
		Annual Load	Annual Load per Acre	Annual Load	Annual Load per Acre	Annual Load	Annual Load per Acre
#	Acre	Ton	lbs. / Acre	lbs.	Lbs. / Acre	lbs.	Lbs. / Acre
310	600 / 2.2	9.09	30.30	264	0.44	60	0.10
311	560 / 2.1	9.95	35.54	874	1.56	168	0.30
392	19680 / 73.1	78.93	8.02	17,515	0.89	2,165	0.11
621	1480 / 5.5	40.45	54.66	8,510	5.75	1,717	1.16
Total Inputs	**22320 / 82.9**	**138.42**	**12.40**	**27,163**	**1.22**	**4,110**	**0.18**
Outlet	**26,920 / 100**	**68.8**	**5.11**	**36,880**	**1.37**	**3,769**	**0.14**

Using the AGNPS model to compare loadings to the location of the land uses in the watershed, the elevated sediment yields of the four subwatersheds were primarily from cropped lands that have an average land slope of 7% or greater. The practice factors of these cells indicate little or no contour farming or conservation tillage practices on these lands. The benefits of conservation tillage as well as the reductions in sediment loadings realized by implementing conservation farming practices will be discussed later in the section pertaining to individual priority cells.

Bearing in mind that AGNPS does not model sediment basins (wetlands, dugouts, or other lakes) within a watershed very well, it did not appear that Enemy Swim Lake had a severe sediment problem resulting from watershed drainage. In the few areas where BMPs should be installed, areas should be targeted in the four subwatersheds that have the highest loadings per acre; subwatersheds #4, #10, #11, and #12. (Figure 5 – Page 13). These subwatersheds do not have the benefit considerable acres of CRP or rangeland that can capture runoff sediments before they enter the lake.

Subwatershed Nitrogen Analysis

The AGNPS model computed that the Enemy Swim Lake watershed had a relatively low deliverability rate for total nitrogen of 1.22 lbs./acre/year. The Blue Dog Lake watershed, just south of Enemy Swim Lake receives approximately 5 lbs./acre/year. Compared with other data from eastern South Dakota, the average watershed had a mean nitrogen deliverance of 3.5 lbs./acre/year, Enemy Swim's nitrogen delivery rate again appeared low. The nitrogen data associated with each of Enemy Swim's subwatersheds can be found above in Table 5 (page 14).

As with the sediment loadings, Table 5 shows the largest per acre nitrogen losses were also from subwatersheds #10, #11, and #12. This again was a result of acres of cropland with little or no conservation tillage practices. Although both subwatersheds #10 and #12 contain a feedlot (often a source of elevated nitrogen runoff), the model suggested that a more probable source of nitrogen was field-applied fertilizers not incorporated or only minimally incorporated. A large number of cells in both subwatersheds had data inputs of 100% fertilizer availability. This means that the applied fertilizers were left in the top two inches of topsoil and were immediately available to runoff, pending a storm event. Subwatershed #2 was also highlighted as having a high loss of sediment per acre, however because this subwatershed drains through Oak Island Lake long before it reaches Enemy Swim Lake, the nutrient deliverability of this subwatershed was minimal. Efforts to improve management of nitrogen in the watershed should be concentrated on the cells closer to Enemy Swim Lake.

Subwatershed Phosphorus Analysis

The AGNPS model suggested that the Enemy Swim inlet cells delivered a cumulative load of 4,110 lbs. (or .0001 ton/acre/year) of phosphorus a year. When compared to sixteen other watersheds in the area, this loading was lower than the average of .0003 ton/acre/year. The Blue Dog Lake watershed annual phosphorus delivery rate was .0005 ton/acre/year. The percentage of CRP and rangeland acres in the Enemy Swim watershed was much higher than in the Blue Dog Lake watershed. The larger percentage of grassed areas usually corresponds to less sediment delivered, and thus, less phosphorus.

Table 5 shows that the same subwatersheds that delivered the highest nitrogen loads delivered the highest loadings of phosphorus to Enemy Swim Lake. The AGNPS data indicated that subwatersheds #10, #11, and #12, contained a large percentage of cells that have high levels of fertilizer availability and fertilizer application per acre. As with nitrogen, the phosphorust output from subwatershed #2 has little impact on Enemy Swim Lake. Any BMPs implemented on a subwatershed basis should be directed toward the three subwatersheds (#10, #11, and #12) adjacent to Enemy Swim Lake.

Critical Cell Sediment Analysis

An analysis of the entire Enemy Swim Lake watershed indicated that there were only eight cells with erosion rates greater than 5 tons/acre. Proportionately, this number was much lower than the Blue Dog Lake watershed, which had 55 cells with erosion rates --------higher than 5 tons/acre. The eight cells given a critical rating are listed below in Table 6.

Table 6. Critical Sediment Cells.

AGNPS Cell	Annual Cell Erosion	Annual Cell Erosion
#	(tons)	(ton/acre)
591	332.56	8.31
660	332.56	8.31
547	287.99	7.20
664	262.9	6.57
318	260.52	6.51
515	237.54	5.94
658	205.68	5.14
662	205.68	5.14

Four of the eight critical cells fell within subwatershed #12 (# 644). Subwatershed #12 had by far the highest sediment delivery of any subwatershed in the drainage. Most of the Enemy Swim Lake watershed has a land slope is 7% or greater. The common denominator of all eight critical cells was that the high land slope was coupled with small grain cropland with little or no conservation tillage. That combination produces cells with high levels of sediment erosion. The locations of the critical sediment cells are displayed in Figure 6.

The AGNPS model was run with the cover management factor (c-factor) for the eight targeted cells changed to represent a limited till or no till practice. The resulting data indicates that an 11% reduction in sediment delivered to the lake could be realized by implementing conservation tillage on the 320 acres (8-40 acre cells) comprising the critical erosion area. By manipulating the c-factor on a number of cells that were slightly below the critical level, a marginally larger percentage reduction in sediment could be realized. Although these cells had higher sediment output when compared to other cells in the watershed, the total sedimentation to Enemy Swim Lake was relatively low. Benefits from BMPs may be difficult to document because of the overall low sedimentation rate to Enemy Swim Lake.

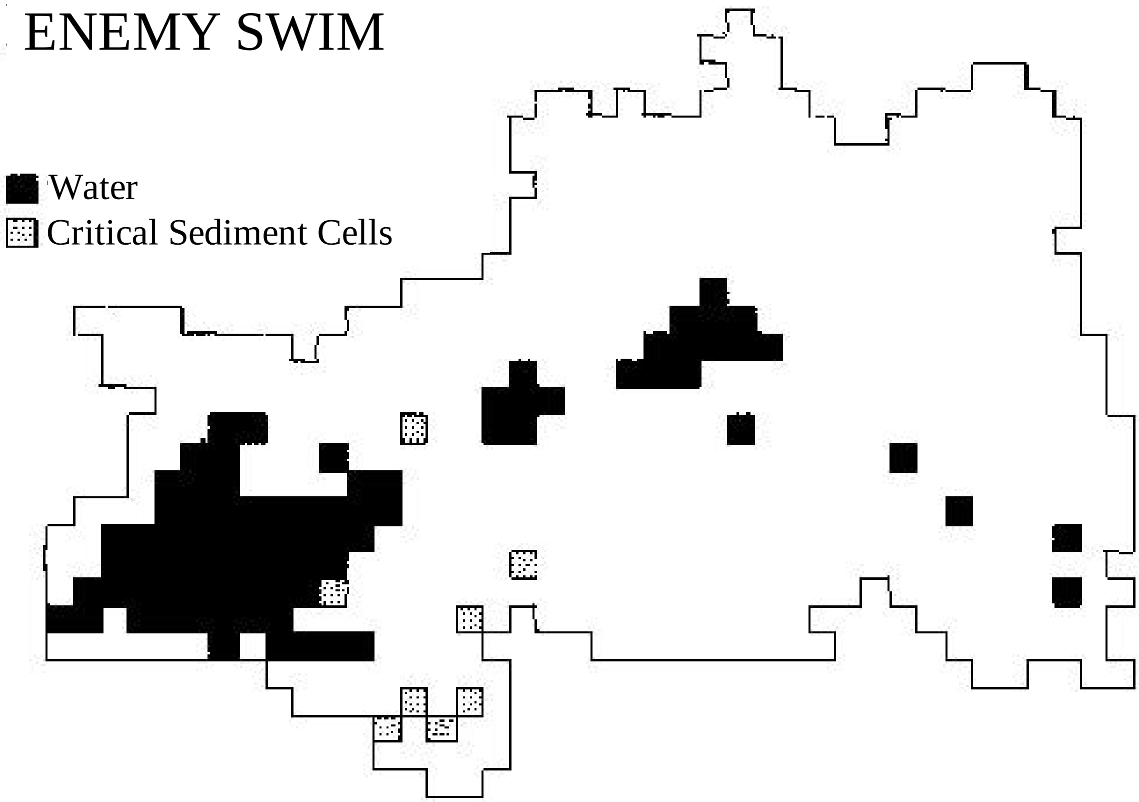


Figure 6. Location of Critical Sediment Cells

Critical Cell Nitrogen Analysis

The AGNPS model indicated that the Enemy Swim watershed contained 37 cells that had an annual nitrogen output of 10 lbs./acre or more. This number of critical cells was also quite small when compared to regional watersheds. Proportionately, the Blue Dog Lake watershed had about double the critical nitrogen cells. The critical nitrogen cells are listed in Table 7.

The commonality among most of the 37 critical cells was the fertilizer availability factor on croplands. Storm events affecting fields with 100% fertilizer availability made up the majority of the critical cells. Because the land slope ranged from 1% to 7%, the data indicated that land slope itself played a minor role in the total nitrogen load delivered from each cell. Among the top eight critical nitrogen cells, three have animal feeding areas (cells #364, #627, and #669). Animal feeding areas in cells #364 and #627 rated very high and were the most likely cause of the elevated nitrogen outputs. The animal feeding rating in cell # 669 was very low however; the remainder of the forty-acre cell is comprised of a bean field on a 4% slope with 100% fertilizer availability. Therefore, in cell #669, the cropland and not the animal feeding area was the most probable cause of the high nitrogen output.

Table 7. Critical Nitrogen Cells

AGNPS Cell #	Annual Nitrogen (lbs./a)
364	28.38
671	20.66
547	16.99
11	15.78
627	15.37
318	15.24
41	13.99
669	13.48
664	12.54
672	11.76
512	11.66
21	11.57
281	11.57
317	11.57
42	11.44
560	11.44
551	11.4
648	11.4
649	11.4
659	11.4
666	11.4
280	11.39
282	11.39
554	11.34
555	11.34
660	11.16
665	11.16
40	11.14
647	11.09
22	10.92
663	10.65
628	10.62
630	10.42
629	10.38
658	10.14
661	10.11
474	10.06

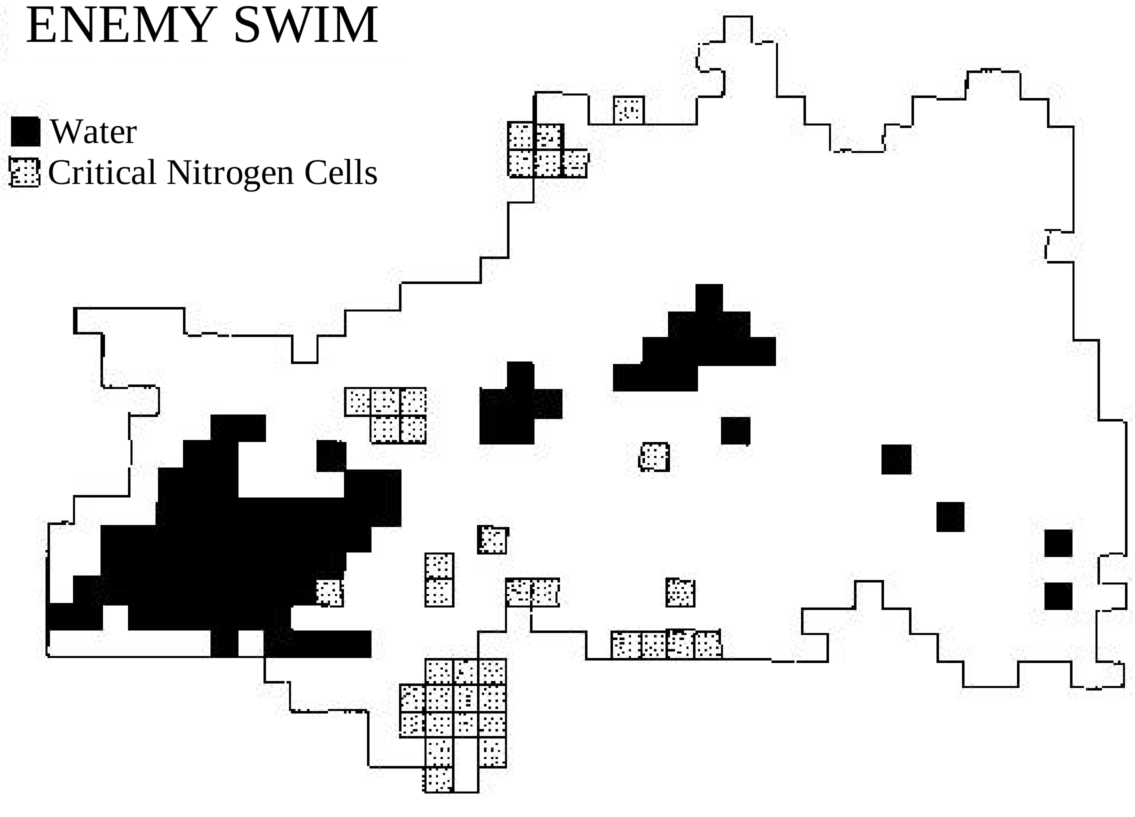


Figure 7. Location of Critical Nitrogen Cells

The locations of critical nitrogen cells within the Enemy Swim watershed are shown above in Figure 7. The critical cells in the northern portion of the watershed drain through Oak Island Lake where the high flow rate dilutes the nutrient concentration. The cells located within close proximity to Enemy Swim Lake were not effected by dilution and drain into the lake with very little loss in nitrogen concentration. To better represent incorporation of field applied fertilizers, the AGNPS model was re-run with the input data altered on 23 (62%) of the critical cells (920 acres of cropland) closest to the lake. The availability of the fertilizer to runoff from storm events was changed from 100% to 50% availability in these cells. A 50% availability factor is comparable to simply disking a field after surface-applied fertilizer has been spread. The result was a 20% reduction in total nitrogen delivered to Enemy Swim Lake.

Critical Cell Phosphorus Analysis

As stated in the subwatershed analysis earlier, the Enemy Swim watershed has a below average deliverability of phosphorus to the lake. This is a result of the large quantity of rangeland within the watershed. The AGNPS model indicated there were only eight priority cells above the 4 lbs./acre cutoff. This same cutoff point was used in the Blue Dog Lake analysis, which resulted in 78 cells with an output greater than 4 lbs./acre.

Enemy Swim Lake received approximately 0.0001 ton/acre/year of total phosphorus. In comparison with regional watersheds, the average total phosphorus delivered for eastern South Dakota was 0.0003 ton/acre/year. Below, Table 8 lists the critical cells along with their respective phosphorus loading.

Table 8. Critical Phosphorus Cells

AGNPS Cell #	Annual Phosphorus (lbs./a)
547	6.95
364	6.81
11	4.96
671	4.76
318	4.68
474	4.24
41	4.14
627	3.9

Of the eight critical phosphorus cells above, two contain animal feeding areas. These cells are #364 and #627. The balance of the critical cells was comprised of croplands of varying slopes. The croplands had 100% fertilizer availability, much the same as with the critical nitrogen cell analysis. Figure 8 below shows the locations of the critical phosphorus cells with respect to Enemy Swim Lake.

To estimate the reduction in phosphorus that may be obtained, the AGNPS model was run by simply converting these eight cells to 50% fertilizer availability. This would represent using a row cultivator to incorporate the fertilizer after it has been spread on the field. The response showed a 13% reduction in total phosphorus entering Enemy Swim Lake. A larger percentage reduction was obtained when the combination of cells from both the critical nitrogen and critical phosphorus cells were addressed in a combined effort. By introducing row cultivating, or some other method in the targeted areas to reduce fertilizer availability, a 24% reduction of phosphorus was realized (Figure 8).

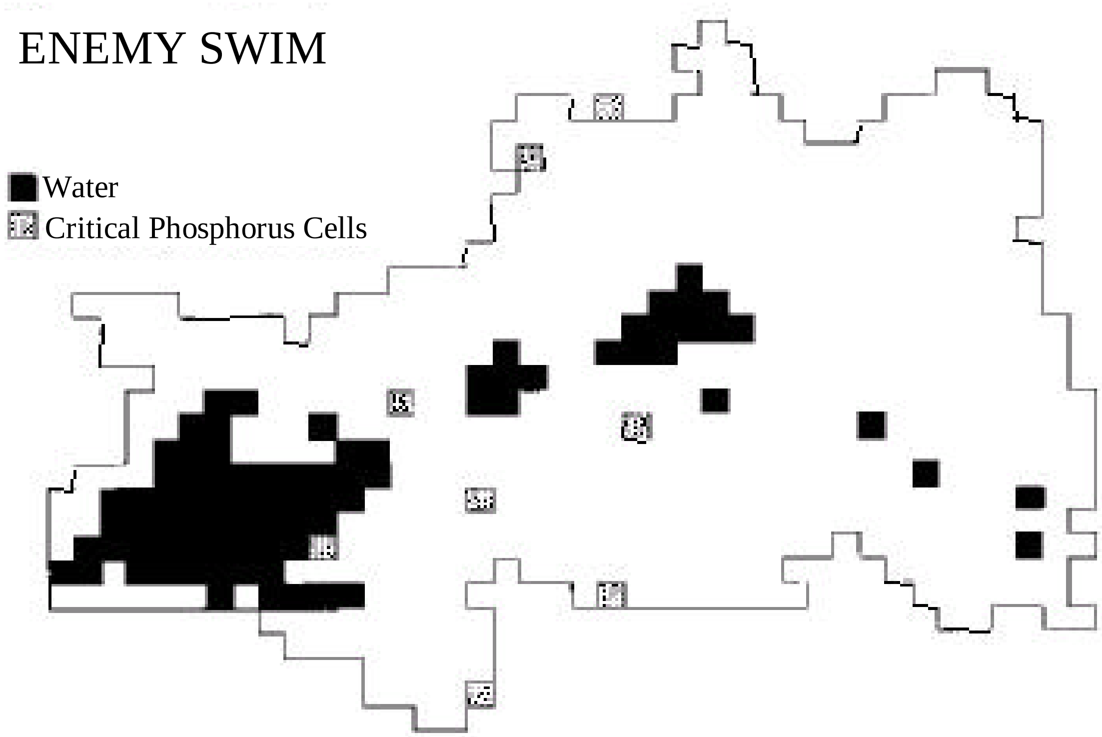


Figure 8. Location of Critical Phosphorus Cells.

Feedlot Analysis

Thirteen animal feeding areas were identified by AGNPS as being a potential source of non-point pollution in the Enemy Swim watershed. The AGNPS model recognizes feedlots as a point source of nutrients. Feedlots rank from 0 to 100 according to severity of nutrient outputs using a number of factors exclusive to feedlots. Some factors taken into account by the model were feeding area size in acres, number and type of animals, acres of land draining through the feedlot, and the specific data relating to the presence of a buffer (grassed) area between the feeding area and channelized flow. Below (Table 9) is a listing of the feedlots in the Enemy Swim watershed ranked by the AGNPS model. This data was the result of running the model with a single storm event of a 25-year intensity.

The delivered load of total nitrogen to Enemy Swim Lake dropped by 5% after removing those cells containing one or more feedlots, ranked 50 or greater, to simulate construction of animal waste containment systems. The reduction in phosphorus entering the lake dropped 7% according to the model.

Table 9. AGNPS Animal Feeding Area Data Output.

Cell #	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Rating
	ppm	ppm	lbs.	Lbs.	
483	15.0	3.6	66.2	15.9	32
334	54.0	13.0	74.6	18.0	32
669	10.2	2.1	59.7	12.1	35
459	104.0	23.9	194.9	44.9	45
359	23.6	5.6	187.2	44.5	48
209	45.0	10.8	211.8	51.0	48
346	**64.8**	**15.1**	**254.3**	**59.4**	**50**
214	**34.4**	**8.2**	**293.0**	**70.1**	**54**
244	**47.6**	**9.8**	**369.8**	**75.9**	**57**
627	**135.0**	**32.5**	**478.4**	**115.2**	**58**
189	**75.0**	**18.1**	**498.5**	**120.1**	**61**
602	**67.5**	**16.3**	**718.1**	**173.0**	**67**
364	**54.9**	**12.9**	**839.2**	**196.3**	**69**

The complete AGNPS report with more in-depth information is located in Appendix C.

Inlake Methods and Materials

Two inlake sample locations were chosen for collecting nutrient information for Enemy Swim Lake during the study. The locations of the inlake sampling sites are shown in Figure 9.

One sample set from each site consisted of a surface and a bottom sample collected each month. After the summer of 1997, Site ESL1 was no longer sampled. Statistical analysis found there was no significant difference between sites ESL1 and ESL2. Sites ESLC and ESLT were sampled to compare water quality from developed and non-developed areas.

Enemy Swim Lake Inlake Sites

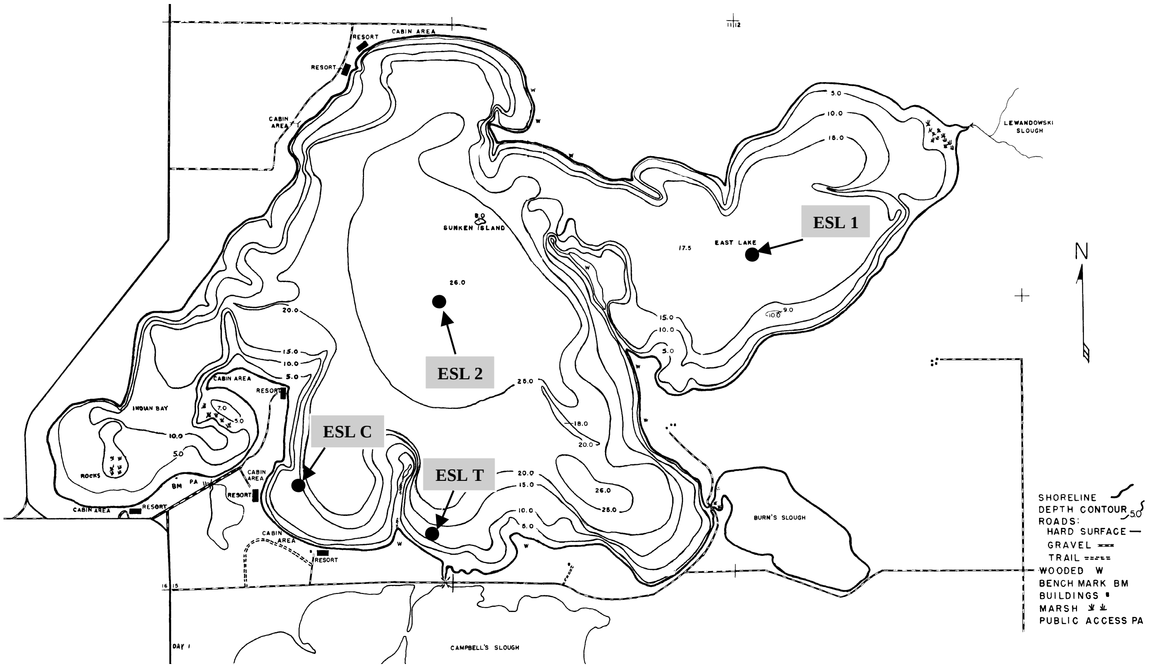


Figure 9. Inlake Site Locations.

Additional inlake data were collected in 1989, 1991, 1992, 1993, 1994, and 1995 for the state-sponsored Statewide Lake Assessment Project. These samples were used to analyze water quality trends over time. Samples collected for the Statewide Lake Assessment were collected by compositing three widely separated sample sites in each lake (Stueven, 1996). Individual surface and bottom samples were collected for the assessment. All samples were collected and analyzed according to the *South Dakota Standard Operating Procedures for Field Samplers.*

The water quality sample set analyzed by the State Health Laboratory consisted of the following parameters:

Total Alkalinity	Total Solids	Total Suspended Solids
Ammonia	Nitrate-Nitrite	Total Kjeldahl Nitrogen
Fecal Coliform	Total Phosphorus	Total Dissolved Phosphorus

Water quality parameters that were calculated from the parameters analyzed above were:

Unionized Ammonia	Organic Nitrogen	Total Nitrogen

In addition to the chemical water quality data above, inlake field parameters and biological data were also collected. The following are a list of field parameters collected:

Water Temperature	Air Temperature	Dissolved Oxygen Profiles
Field pH	Secchi Depth	Chlorophyll a
Algae counts and identification		

The chlorophyll a samples were used with the phosphorus and Secchi disk data to evaluate the eutrophic status and trends in Enemy Swim Lake. The AGNPS hydrologic and nutrient loads were used to find the inlake chlorophyll a response if phosphorus inputs were reduced. The model was taken from Vollenweider and Kerekes, 1980.

All samples collected at the inlake sites 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, SD, for analysis. Quality Assurance/Quality Control samples were collected in accordance with South Dakota's EPA-approved *Nonpoint Source Quality Assurance/Quality Control Plan*. These documents can be obtained by contacting the Department of Environment and Natural Resources at (605) 773-4254.

South Dakota Inlake Water Quality Standards

Enemy Swim Lake has been assigned the beneficial uses of:

- Warmwater permanent fish life propagation
- Immersion recreation
- Limited contact recreation
- Wildlife propagation and livestock watering

When the above uses have two or more standard limits for the same parameter, the most stringent standard is applied. Table 10 shows the most stringent standards for the parameters sampled in Enemy Swim Lake during the study.

Table 10. State Water Quality Standards.

Parameter	Limits
Unionized ammonia	< 0.04 mg/L
Dissolved Oxygen	> 5.0 mg/L
pH	> 6.5 and < 9.0 su
Suspended Solids	< 90 mg/L
Temperature	< 26.67 °C
Fecal Coliform	< 400 counts/100 ml (grab)
Alkalinity	<750 mg/L
Nitrates	< 10 mg/L

The only exceedence of the South Dakota water quality standards was recorded for a dissolved oxygen sample collected from the bottom of Site ESL2 on July 15, 1998 (4.40 mg/L). The surface sample at that site measured 7.10 mg/L with a water column average of 5.70 mg/L. Many factors may have led to the low oxygen levels in the bottom sample. The surface chlorophyll a for that site was the second largest during the entire study. The Secchi depth at the site was only 1.23 meters. The algae may have blocked the light and inhibited oxygen production by plants at lower depths. The warm summer water temperatures may have also increased aerobic decomposition in the sediments which uses oxygen. Since the sample was collected at 9:30am, the water may have still been rebounding from nighttime respiration activities of algae.

Inlake Water Quality

Water Temperature

Water temperature is important to the biology of a lake, as it affects many chemical and biological processes in the lake. Higher temperatures increase the potential for raising the unionized fraction of ammonia. Concentrations of unionized ammonia above 0.04 mg/L can be toxic to fish. Algae have optimal temperature ranges for growth. Blue-green algae are more prevalent in warm waters. Green algae and diatoms are often more dominant in cooler waters. Fish life and propagation are also dependent on water temperature.

The overall mean temperature for the project period was 15.5 ^{o}C. Figure 10 shows all the average temperatures throughout the project period. The maximum temperature sampled during the project period was 26 ^{o}C. That sample was collected from the surface in mid July 1998. There was very little thermal stratification in the water column of Enemy Swim Lake. However, on calm days during the heat of summer, the growth of algae occasionally blocked the penetration of light thus creating a thermocline at the lower depths (6 meters). This only happened once or twice when the local sampler was actually sampling; however, it may occur anytime when conditions are suitable. Most times, however, the wind and wave action keeps Enemy Swim Lake waters mixed throughout the water column. Temperature profiles for the entire sampling season are shown in Appendix D.

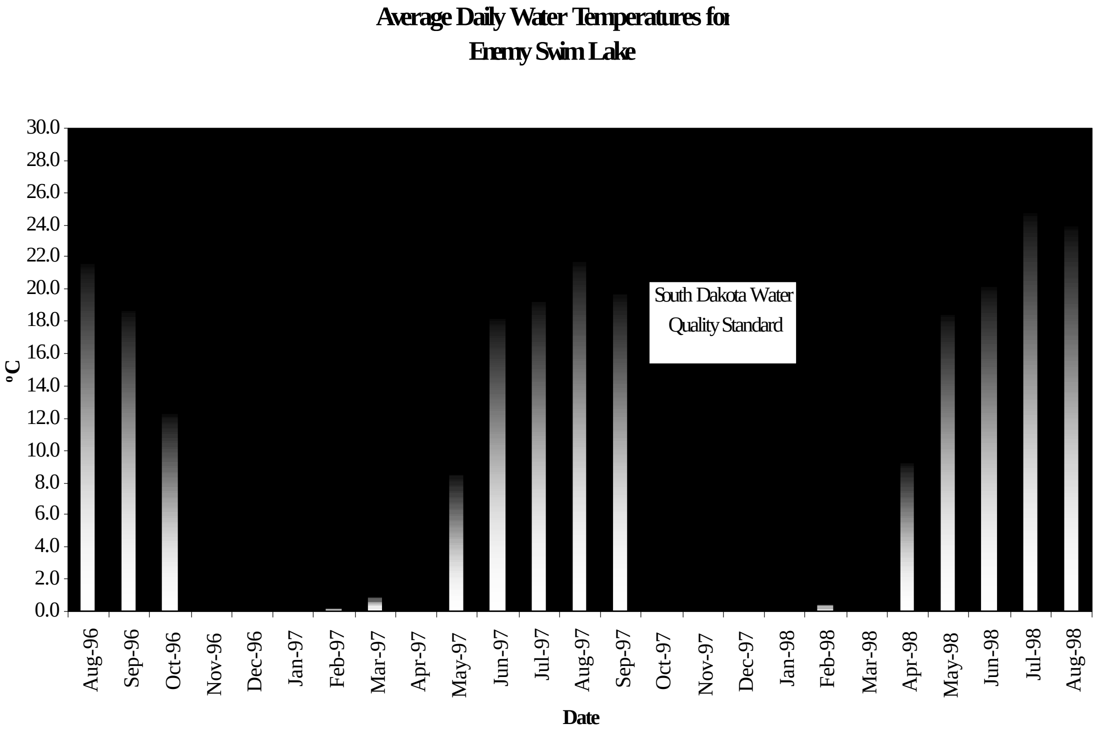


Figure 10. Average Daily Water Temperatures for Enemy Swim Lake.

Dissolved Oxygen

The dissolved oxygen concentrations change with the growth and decomposition of living organisms in a lake system. As algae and plants grow and photosynthesize, they release oxygen into the water. When living organisms decompose, bacteria can use oxygen from the system and replace it with carbon dioxide (CO_2). This process (aerobic decomposition) usually takes place near the sediment. Dissolved oxygen concentrations also change at the surface air-water interface. Wave action and other turbulence can increase the oxygen level of a lake. Dissolved oxygen averaged 8.89 mg/L (median 8.55 mg/L) over the entire duration of the study. There was a significant difference ($p < 0.05$) between surface and bottom dissolved oxygen concentrations. The difference was most likely caused by stratification of temperature and oxygen levels between the epilimnion and the hypolimnion. The major stratifications happened during the winter and the summer seasons. Winter stratification was due to heavy snowfall blocking light and inhibiting the production of oxygen by algae in the deeper depths of the lake. The summer stratification was due to the heavy production of surface floating algae, blocking light and inhibiting algae production/oxygen production in the hypolimnion. Summer stratification usually takes place on hot days with little wind. The use of oxygen for decomposition of organic matter may have also lowered the oxygen concentrations in the bottom samples. There were summer days when wind and wave action appeared to mix the surface and bottom waters of the lake and/or break up the algae mats so light could penetrate to greater depths, allowing photosynthesis to occur. There were oxygen concentrations measured in bottom samples during the project below the South Dakota water quality standard. Although low oxygen levels may be present at greater depths, fish will migrate to areas of the lake with optimum temperature and oxygen levels so they are not stressed.

The maximum oxygen concentration in Enemy Swim Lake was 15.0+ mg/L (the maximum concentration for the Model 51B YSI DO meter is 15 mg/L). That sample was collected at Site ESL2 on March 18, 1998. Since the sample was collected through the ice, the higher oxygen levels may have been due to the ability of water to hold more oxygen at colder temperatures. Other sources of increased oxygen may have been water agitated by an ice auger increasing the oxygen content. Algae production under the ice with limited snow cover may also have increased oxygen production.

The minimum dissolved oxygen concentration was 4.4 mg/L at Site ESL2 on July 15, 1998. As the sample was collected in the morning, the lake may have been recovering from low nighttime oxygen levels due to respiration. Nighttime dissolved oxygen samples were not collected during this project. Typically, as much oxygen as is produced by photosynthesis during the day is used in respiration. During respiration, algae take up oxygen and release CO_2 into the water column. The maximum oxygen concentration usually occurs in the afternoon on clear days, and the minimum occurs in the early morning hours (Reid, 1961).

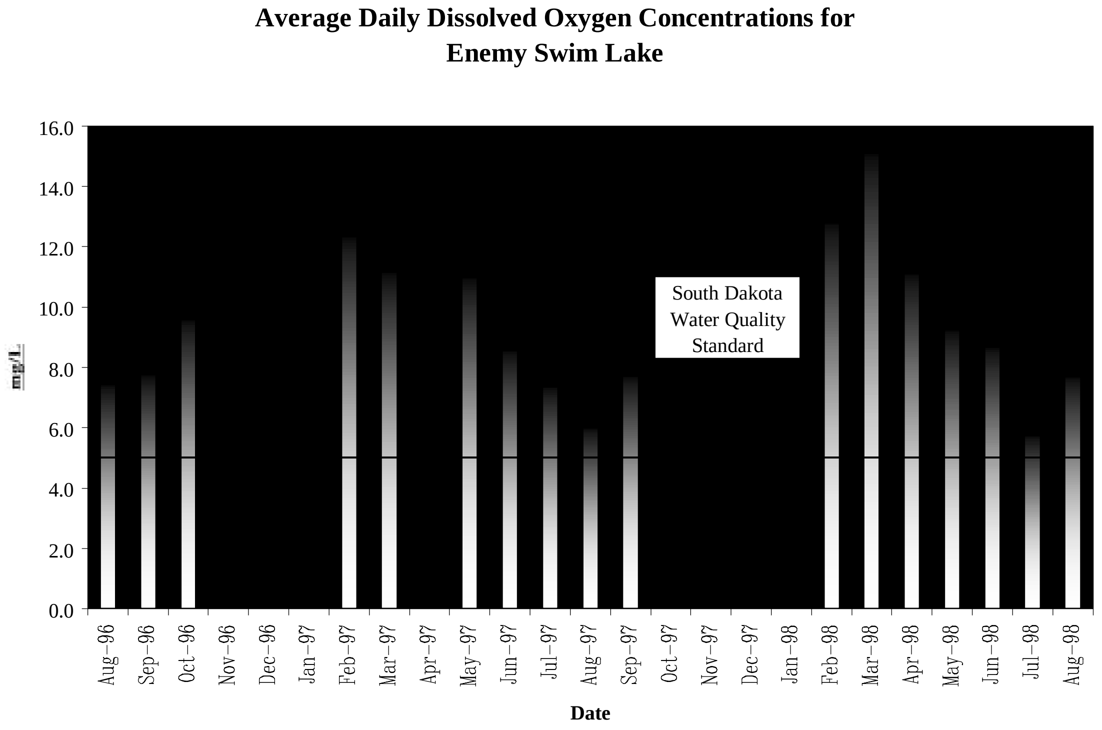


Figure 11. Average Daily Dissolved Oxygen Concentrations.

Seasonally, the four highest oxygen concentrations were found in the winter surface samples. Eight of the lowest ten oxygen concentrations were measured during the summer. Seven of the ten lowest dissolved oxygen measurements were from the bottom samples. The dissolved oxygen profiles for all of the sample dates are presented in Appendix D. The average daily dissolved oxygen concentrations are shown in Figure 11.

PH

pH is the measure of the hydrogen ion. More free hydrogen ions lower the pH in water. During decomposition, carbon dioxide is released from the sediments. The carbon dioxide (CO_2) reacts with water to create carbonic acid. The carbonic acid creates hydrogen ions. Bicarbonate can be converted to carbonate and an additional hydrogen ion. The extra hydrogen ions created from decomposition will tend to lower the pH in the hypolimnion (bottom of the lake). Increases in the different species of carbon come at the expense of oxygen. Decomposers will use oxygen to break down the material into different carbon species. In addition, the lack of light in the hypolimnion prevents plant growth, so no oxygen can be created through photosynthesis. Typically, the higher the decomposition and respiration rates, the lower the oxygen concentrations and the lower the pH in the hypolimnion.

The inverse occurs when photosynthesizing plants increase pH. Plants use carbon dioxide for photosynthesis and release oxygen to the system. Photosynthesis can reverse the process explained above, increasing pH.

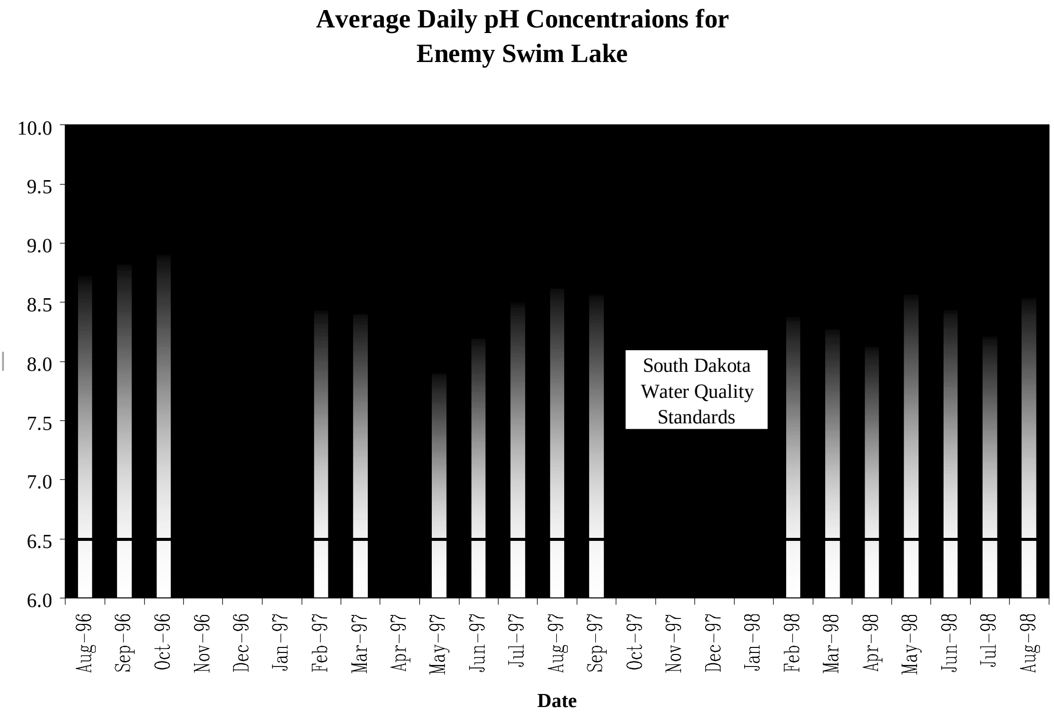


Figure 12. Average Daily pH.

As shown in Figure 12, Enemy Swim Lake experienced the typical pH scenario explained above to a small degree. The pH during the winter in Enemy Swim Lake was slightly lower than the pH concentrations found in the summer samples. The higher algae production in the summer months most likely increased the pH concentration. The relatively sharp drops in the spring are most likely due to the large amount of runoff from the watershed. Precipitation and runoff typically have lower alkalinity, which does not buffer changes in pH as well as ground water. There was a large inflow of water to Enemy Swim Lake and, as of the spring of 1997, it was the wettest in recent history. The pH concentrations in Enemy Swim Lake were not extreme in any samples. Other than spring, the relatively high alkalinity concentrations in Enemy Swim Lake work to buffer dramatic pH changes.

Secchi Depth

Secchi depth is a measure of lake clarity or turbidity. The Secchi disk is 20 cm in diameter and usually painted with opposing black and white quarters (Lind, 1985) (Figure 13). The Secchi disk is used worldwide for comparison of water clarity. Secchi disk readings can also be used in Carlson's Trophic State Index (TSI). Carlson's TSI is a measure of trophic condition, or the overall health of a lake. One limitation of the Secchi disk is that it cannot differentiate if organic or inorganic matter is limiting the depths at which the disk can be seen. A low Secchi depth reading may indicate hyper-eutrophy due to suspended sediments or algal (chlorophyll *a*) production.

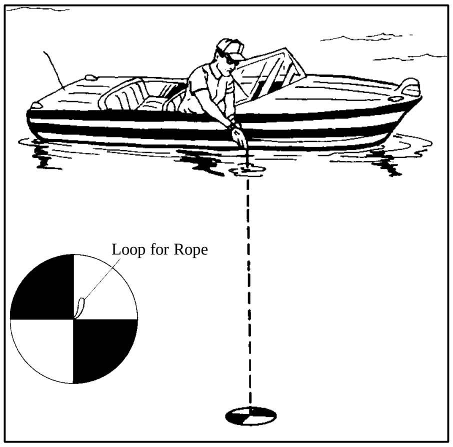


Figure 13. Secchi Disk.

Figure 14 shows lower Secchi depth readings in the summer when Enemy Swim Lake had higher algal production. The deepest Secchi disk reading (4.27 meters) was collected on June 11, 1997. Blue Dog Lake, located just south of Enemy Swim Lake measured its deepest reading just one week before. It appears that flushing of the large amount of water from the watershed cleared the water for a short time. The hydraulic residence time during the spring run off was too short for algae to assimilate nutrients and grow. The spring average was one meter deeper than any other season. As the growing season progressed, the algae had an opportunity to grow. The summer and early fall Secchi depths were the lowest. The increased turbidity in Enemy Swim Lake appeared to be caused by algae and not suspended sediment (inorganic). Because of the depth and shape of Enemy Swim Lake, wind and wave action does not impact Secchi readings with regard to suspended bottom sediments as much as algae. Compared to other lakes in its region Enemy Swim typically has deeper Secchi depth readings, however, there are times when algae blooms reduce Secchi depths to those of other lakes in the area.

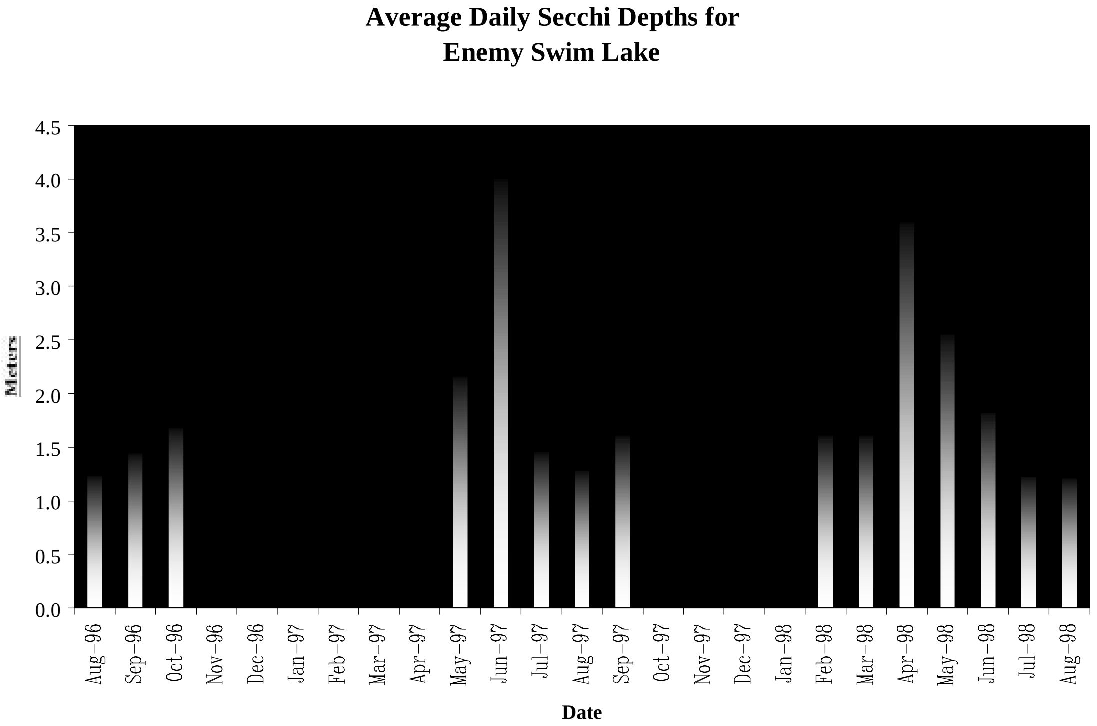


Figure 14. Average Daily Secchi Depths.

<u>Alkalinity</u>

Alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7). Alkalinity is usually dependent on geology. Alkalinity in natural environments usually ranges from 20 to 200 mg/L (Lind, 1985). The average alkalinity in Enemy Swim Lake was 196.8 mg/L with a median of 195 mg/L (Figure 15). The minimum alkalinity concentration was 187 mg/L and the maximum concentration was 221 mg/L. The standard deviation was only 7.1 mg/L. Such a low deviation from the mean shows Enemy Swim to be a quite stable water source. The high alkalinity should limit drastic changes in water chemistry in the lake.

Winter alkalinity concentrations were slightly higher than other seasons. As water freezes, salts are excluded from the ice, which results in increases in dissolved solids and hardness. During spring, summer and fall, there was no significant change in alkalinity concentrations. However, the spring concentrations are slightly less than the summer and fall concentrations. The slight decrease in alkalinity is most likely due to dilution from the spring runoff and storm events.

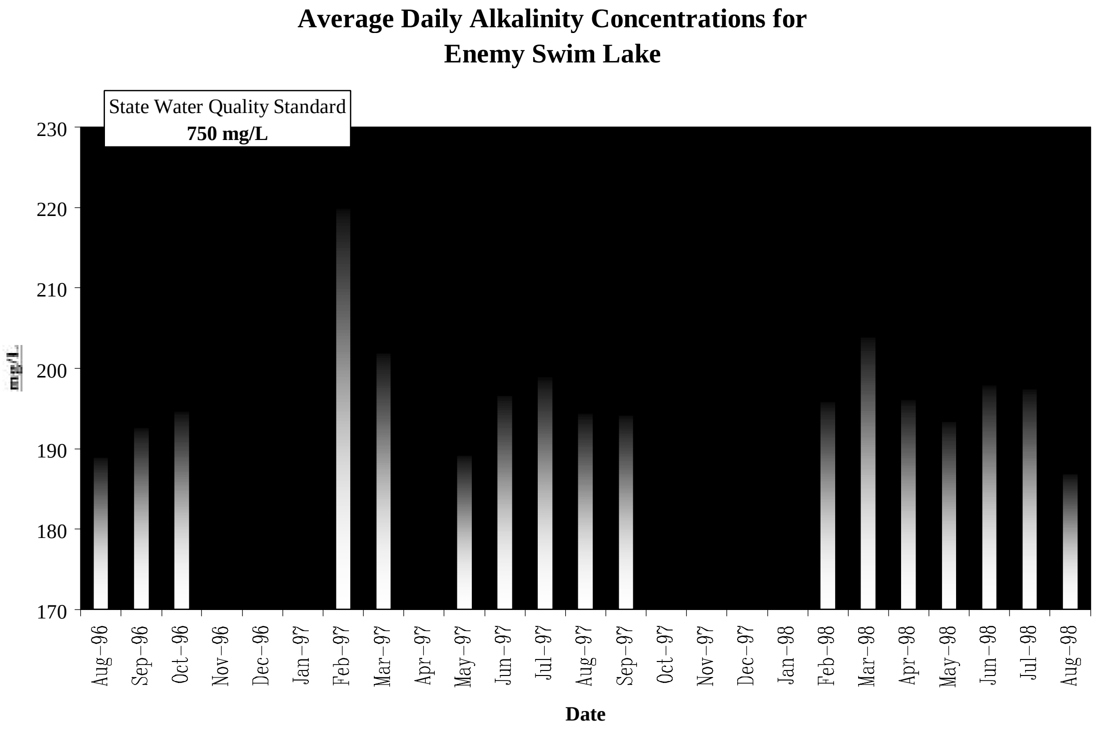


Figure 15. Average Daily Alkalinity Concentrations.

Solids

Total solids are the materials, suspended or dissolved, present in water. Dissolved solids include materials that pass through a water filter. Suspended solids are the materials that do not pass through a filter, e.g. sediment and algae. Total dissolved solids are calculated by subtracting the suspended solids from the total solids. The total solids concentrations in Enemy Swim Lake averaged 263 mg/L. The lowest concentrations were found in the spring and summer. The lower solids concentrations were from snow melt and spring runoff diluting the concentrations in the lake. Snowmelt and rain generally have lower concentrations of dissolved solids. Dissolved solids are typically made up of salts and compounds that keep the alkalinity high. As the total dissolved solids concentration drops, typically so does the alkalinity. The daily average total solids concentrations can be found in Figure 16.

Many factors can increase inlake total suspended solids concentrations. Regionally however, the source is usually inputs from watershed tributaries, suspended bottom sediments, or algae. Average daily total suspended solids are graphed in Figure 17. Total suspended solids in Enemy Swim Lake averaged 6.32 mg/L. The average concentration was 13 mg/L less than Blue Dog Lake. Blue Dog is shallow and has more suspended bottom sediments. The largest concentrations of suspended solids were collected at the surface on April 22, 1998 (19 mg/L). The higher suspended solids concentration were most likely due to spring runoff or a storm event. The April sample was the first after the ice melted off the lake.

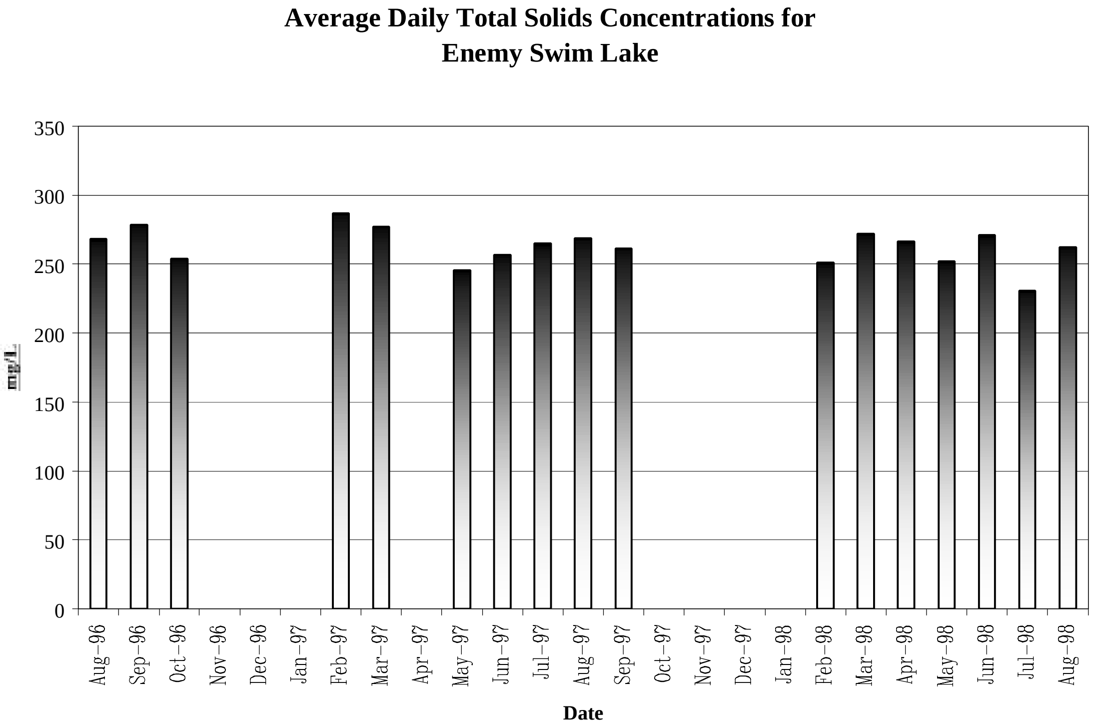


Figure 16. Average Daily Total Solids Concentration.

Suspended volatile solids (organic matter that burns in a 500°C furnace) were also analyzed for a few sampling dates. For surface samples, the percentage of suspended solids that were volatile was approximately 50%. Since the tributaries entering Enemy Swim Lake are all buffered by wetlands, the suspended solids coming from the watershed were very low. The volatile organic matter found in Enemy Swim Lake was most likely algal. Overall, the concentrations of suspended solids in the lake were low due to the depth of the lake and the low input from the watershed.

Average Daily Total Suspended Solids Concentrations for Enemy Swim Lake

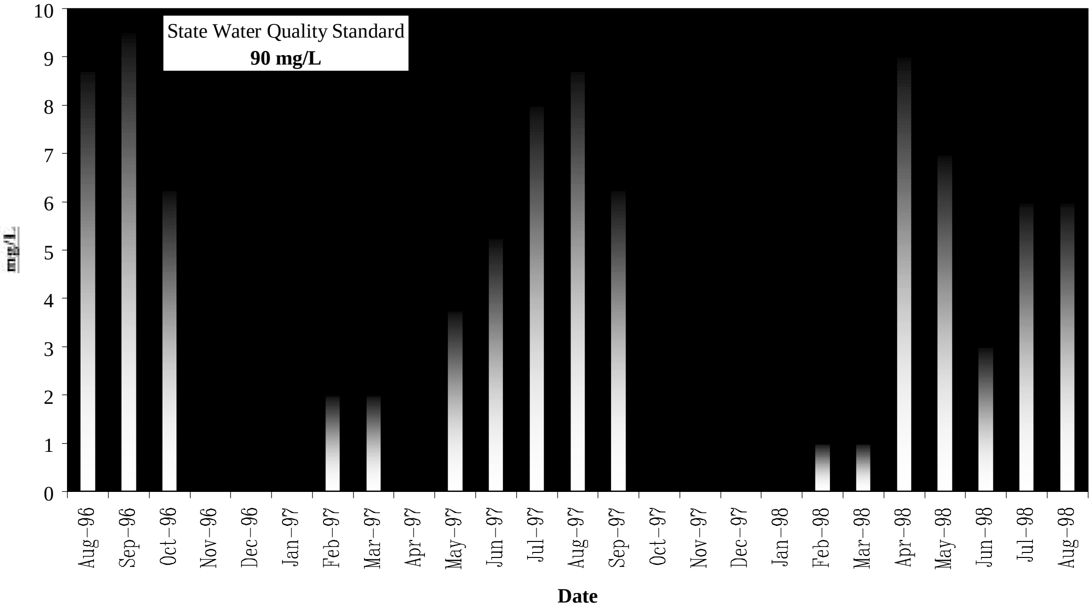


Figure 17. Average Daily Total Suspended Solids.

Ammonia

Ammonia is the nitrogen product from bacterial decomposition of organic matter and is the form of nitrogen most readily available to plants for uptake and growth. Sources of ammonia in the watershed may come from animal feeding areas, anhydrous from fertilizer, decaying organic matter, or bacterial conversion of other nitrogen compounds. Decomposing bacteria in the sediments and blue-green algae in the water column can convert free nitrogen (N_2) to ammonia. Blue-green algae can then use the ammonia for growth. Although algae assimilate many forms of nitrogen, highest growth rates are found when ammonia is available (Wetzel, 1983). Since nitrogen is water soluble, and blue-green algae can convert many forms of nitrogen for their own use, it is more difficult to remove nitrogen than phosphorus from a lake system.

Only five samples of ammonia were above the South Dakota Health Department detection limit. Since the detection limit was 0.02 mg/L, a value of half the detection limit was used to calculate the mean. The mean concentration of ammonia for the project period was 0.017 mg/L. The standard deviation was 0.03 mg/L which shows a small variation in the samples. Three of the five detections were winter surface samples in 1997. The most likely source of the increased ammonia concentrations was decomposition of organic matter under the ice. The other two samples that were higher than the detection limit were bottom samples collected on June 11, 1997. Decomposition was again the most likely source. Overall, the ammonia concentrations for Enemy Swim Lake were low. The daily average for the project period can be found in Figure 18.

No inlake unionized ammonia concentration came close to approaching the State Water Quality Standard (0.04 mg/L). The maximum unionized ammonia concentration for the project period was 0.005 mg/L. The average unionized ammonia concentration was 0.0011 mg/L. Because unionized ammonia is a calculated value, high ammonia concentrations do not necessarily mean unionized ammonia concentrations will also be high. Unionized ammonia is dependent on temperature and pH. As these two parameters increase, the percent of ammonia that is toxic to fish (unionized ammonia) increases.

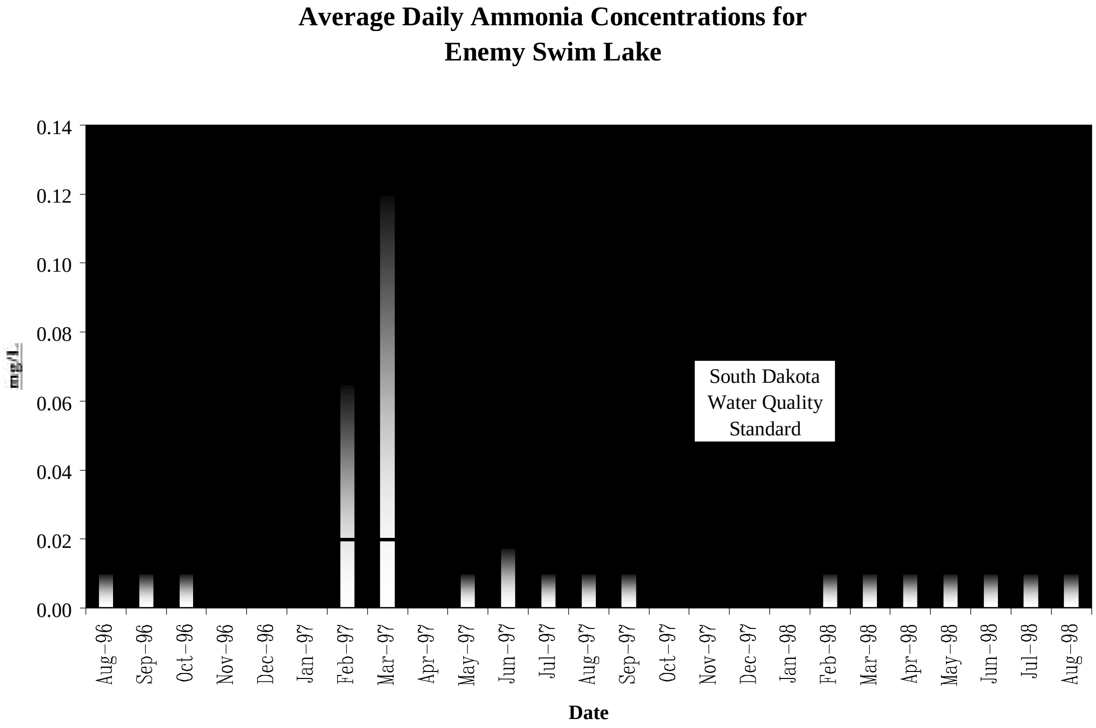


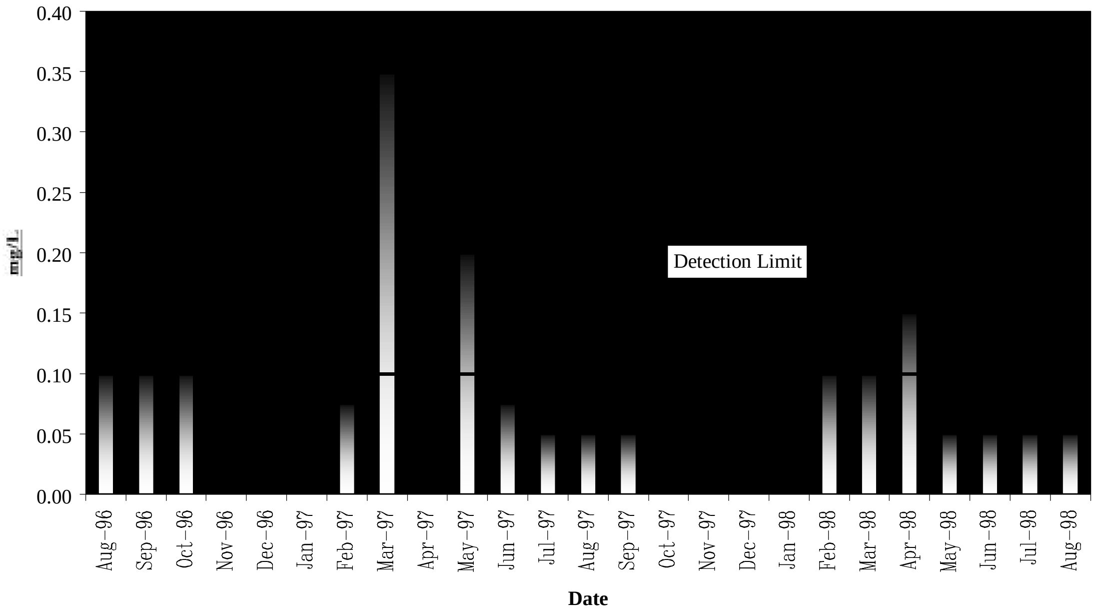
Figure 18. Average Daily Ammonia Concentration.

Nitrate-Nitrite

Nitrate and nitrite are inorganic forms of nitrogen easily assimilated by algae and other macrophytes. Sources of nitrate and nitrite can be agricultural practices and direct input from septic tanks, precipitation, ground water, and decaying organic matter. Nitrate-nitrite can also be converted from ammonia through denitrification by bacteria. The process increases with increasing temperature and decreasing pH.

The average nitrate-nitrite concentration for Enemy Swim Lake was 0.099 mg/L (median 0.10 mg/L) for the entire project. As with ammonia, the standard deviation for nitrate was very low (0.086 mg/L). Seasonally, the winter and spring months had the highest averages. The production of chlorophyll a in the summer and fall most likely assimilated all of the available nitrogen in the lake system. The low algae production in the winter leaves more available nitrogen in the water column. Figure 19 shows the average daily nitrogen concentrations for the project period.

Nitrogen and phosphorus concentrations in eutrophic lakes are frequently higher after ice out due to accumulation over the winter through decay, low algal numbers and ground water input. It was difficult to tell what effect the potentially high nitrate concentrations found in the ground water in the area were having on inlake concentrations. Being connected to an alluvial outwash, Enemy Swim Lake has a good ground water connection with the surrounding sand and gravel aquifers. The extremely soluble nitrate-nitrite quickly leaches out of soils into ground water. High nitrate concentrations seeping into Enemy Swim Lake could increase inlake nitrate concentrations.



Average Daily Nitrate-Nitrite Concentrations for Enemy Swim Lake

Figure 19. Average Daily Nitrate-Nitrite Concentration.

<u>Total Kjeldahl Nitrogen/Organic Nitrogen</u>

Total Kjeldahl Nitrogen (TKN) is used to calculate organic and total nitrogen. TKN minus ammonia equals organic nitrogen. TKN plus nitrate-nitrite equals total nitrogen. Total nitrogen is used to determine if the lake is nitrogen or phosphorus-limited. The limiting factor in Enemy Swim Lake will be discussed later. Sources of organic nitrogen can include release from dead or decaying organic matter, lake septic systems, or agricultural waste. Organic nitrogen is broken down through decomposition to more usable forms of nitrogen, such as, ammonia, nitrate, and nitrite. Ordinarily, as organic nitrogen concentrations increase, so does eutrophication.

The mean and median organic nitrogen concentrations were 0.82 mg/L and 0.74 mg/L respectively. The maximum concentration was from a surface sample collected at Site ESL2 on March 27, 1997 (5.96 mg/L). The sample at Site ESL1 on the sample date had an organic nitrogen concentration of 0.83 mg/L. Such high readings during the winter at the deepest sites in the lake may have been a sample anomaly. No other sample collected during the two-year project period was close to this elevated sample concentration. Very little chlorophyll _a_ was found that day at the sampling site. If nutrient levels in the lake were actually as high as recorded, some chlorophyll _a_ production should have been present even though algal populations were low on that date. Another possible explanation is that there may have been an influx of water from the watershed although ice still covered the lake. A combination of low oxygen levels near the bottom of the lake and the influx of nitrogen from ground water may have caused the increased nutrient concentrations. Figure 20 shows the high concentration (3.40 mg/L) in March 1997, compared to the relatively stable nitrogen levels throughout the year.

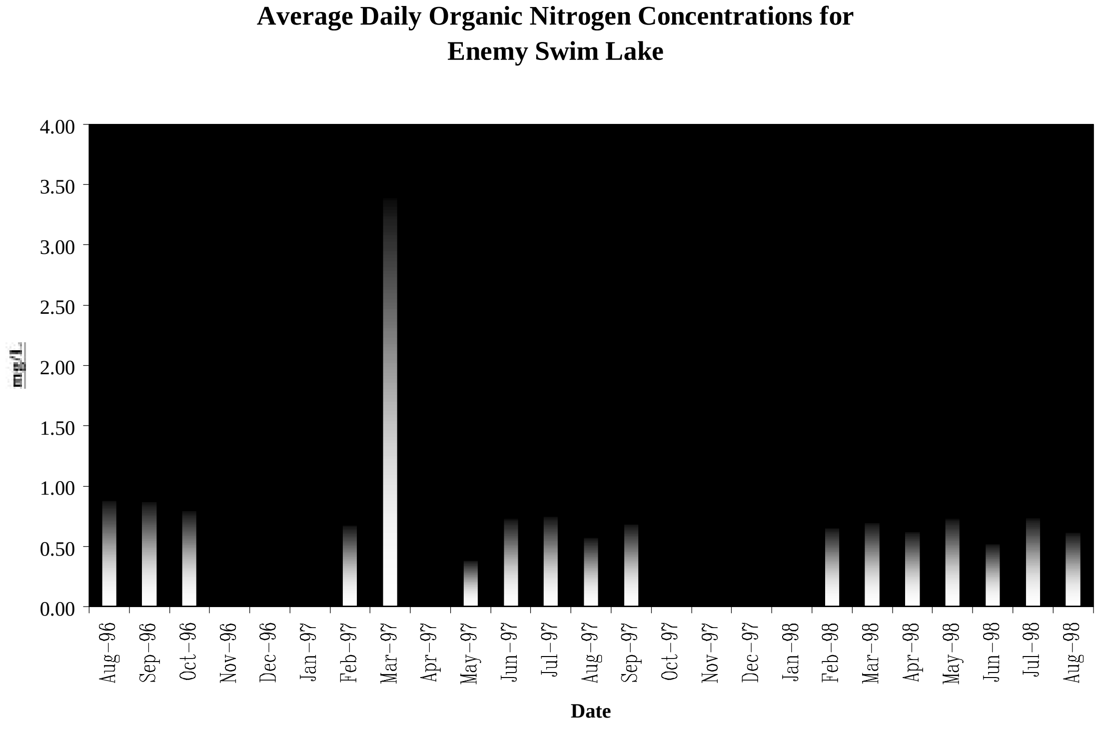


Figure 20. Average Daily Organic Nitrogen Concentration.

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used mostly in determining the limiting nutrient discussed later in the report.

Of the total nitrogen concentration, the percent that was organic ranged from 61% to 94%. The average percentage of organic was 87%. The lowest organic percentages were found during the spring months. With no algae production due to low hydraulic residence time and cooler temperatures, the nitrogen fractions remained in inorganic form.

The maximum concentration of total nitrogen (6.79 mg/L) was collected at the same time and place as the maximum TKN sample mentioned above (Figure 21). Again, sampling anomaly or influx of nutrient-rich waters were the most likely causes of the elevated concentrations. The mean concentration for the entire sampling season was 1.07 mg/L. The standard deviation for total nitrogen was only 0.59 mg/L throughout the sampling season.

Besides the one large increase in the spring of 1997, there were no marked seasonal patterns in Enemy Swim Lake. Due to its small watershed and the buffering effect of the wetlands “guarding” Enemy Swim Lakes inlets, there was very little change throughout the year. Figure 21 shows the daily average concentrations for the entire project period.

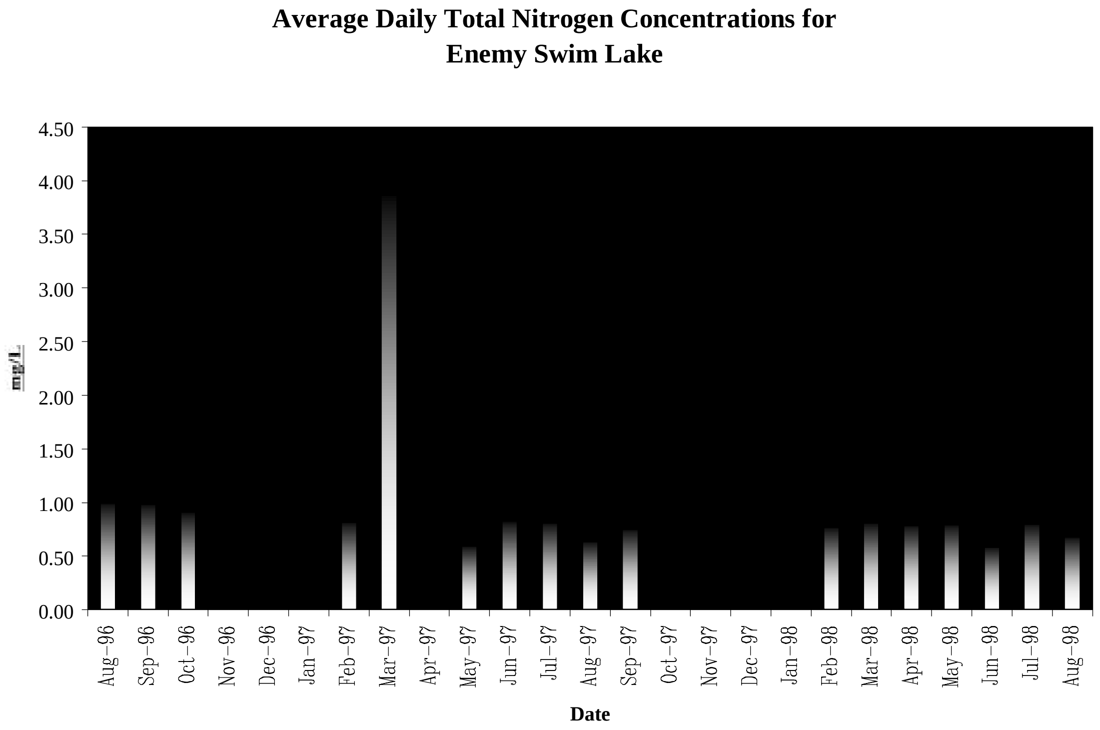


Figure 21. Average Daily Total Nitrogen Concentration.

Total Phosphorus

Typically, phosphorus is the single best chemical indicator of the condition of a nutrient-rich lake. Algae need as little as 0.020 mg/L of phosphorus to cause a nuisance algal bloom (Wetzel, 1983). Phosphorus differs from nitrogen in that it is not as water-soluble and will sorb on to sediments and other substrates. Once phosphorus sorbs on to any substrate, it is not readily available for uptake by algae. Phosphorus sources can be natural from the geology, soil, wildlife, and decaying organic matter. Human-induced sources of phosphorus include leachate from septic tank waste, lawn fertilizer or agricultural runoff. Once phosphorus enters a lake it may be used by the biota or stored in the lake sediments. Phosphorus will remain in the sediments unless released by wind and wave action suspending phosphorus into the water column, or by the loss of oxygen and the reduction of the redox potential in the microzone. The microzone is located at the sediment-water interface. As the dissolved oxygen levels are reduced, the ability of the microzone to hold phosphorus in the sediments is also reduced. Phosphorus released into a lake from the sediments is called internal loading and can be a large contributor of phosphorus when compared to other sources affecting the lake (Zicker, 1956).

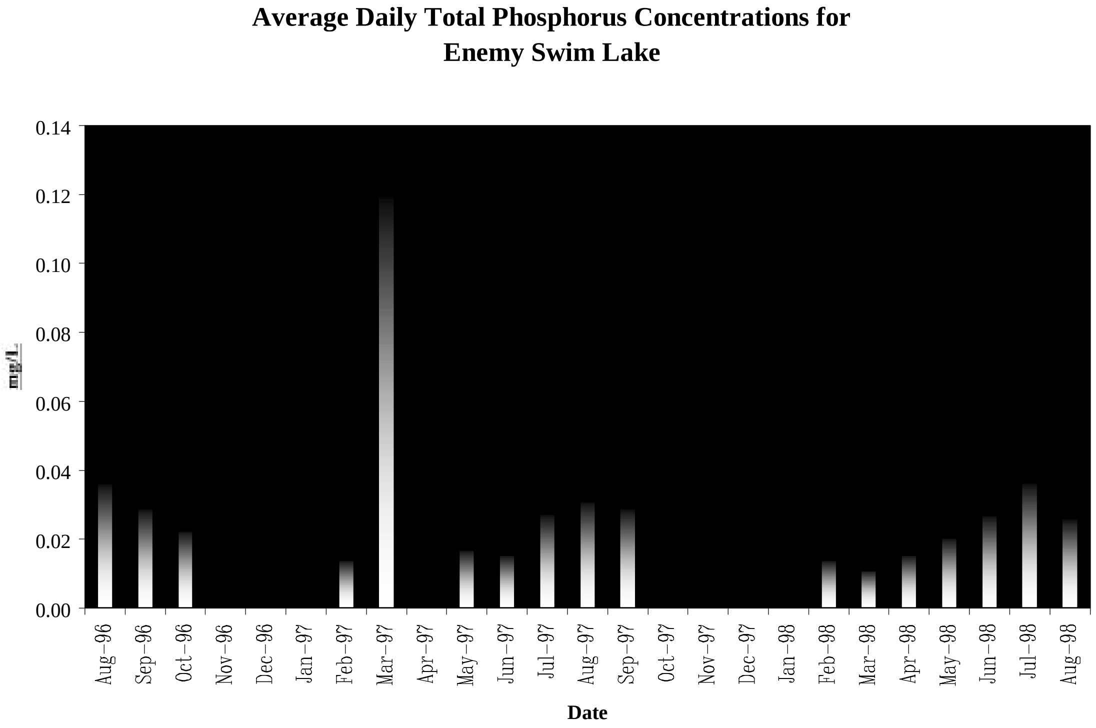

Average Daily Total Phosphorus Concentrations for Enemy Swim Lake

Figure 22. Average Daily Total Phosphorus Concentration.

The average concentration of total phosphorus throughout the study period was 0.037 mg/L (median 0.025 mg/L). The minimum value was 0.011 mg/L and the maximum value was 0.476 mg/L was measured over the entire project period. The maximum value, collected on May 16, 1997 was most likely an outlier. The reason the maximum sample was suspected as an outlier was that no other parameter in the sample had increased concentrations, including suspended solids. The sample was also almost twice as large as the next highest sample (0.225 mg/L) collected on March 17, 1997. If the outlier was removed from the data set, the average value for the project period was 0.028 mg/L. Figure 22 shows the phosphorus results of the average daily concentration after the outlier was removed.

The March sample was most likely the result of watershed inputs by the thawing of the winter snow. The next closest sample to the March 17 sample was 0.044 mg/L. The mean after removing the two highest samples was 0.024 mg/L with a standard deviation of only 0.009 mg/L. Such a low standard deviation again shows the relatively stable phosphorus concentrations within Enemy Swim Lake.

As can be seen Figure 22, there were seasonal differences in phosphorus concentrations. There is a steady rise of phosphorus from spring to mid summer and then a decline in the fall. The summer increases were from sources in the watershed, decomposition of organic matter, or from septic systems leaching phosphorus to Enemy Swim Lake. Whatever the source, the increase in phosphorus concentrations in Enemy Swim Lake coupled with the warmer summer temperatures meant an increase in the productivity of the lake. Since phosphorus is usually the cause of algal blooms, by removing the phosphorus sources coming into the lake, in time, Enemy Swim Lake should see a decline in algal bloom density and duration.

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae. Dissolved phosphorus will sorb onto suspended materials, especially sediment, if it is present in the water column and not already saturated with phosphorus. Figure 23 shows that there was not the expected inverse relationship between total suspended solids and total dissolved phosphorus ($R^2 = 0.045$). Usually, a percent drop in dissolved phosphorus means an increase in suspended sediment. The low R^2 value again shows Enemy Swim Lake does not have a suspended sediment problem. The average dissolved phosphorus concentration in Enemy Swim Lake was 0.012 mg/L (median 0.007 mg/L).

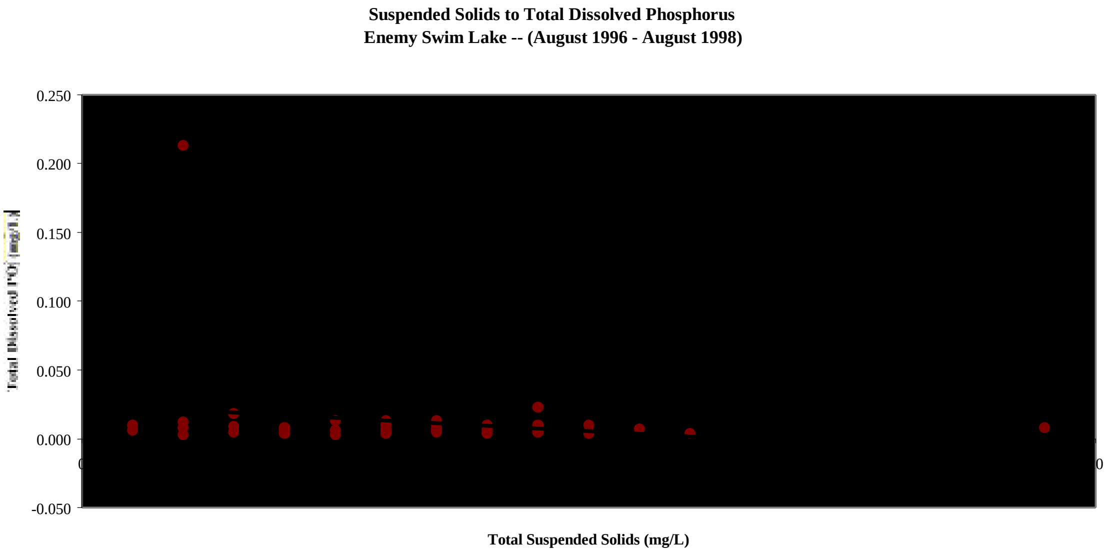


Figure 23. Total Suspended Solids Compared to Total Dissolved Phosphorus.

** R^2 = is a value given for a group of points with a statistically calculated line running through them. The higher the R^2 value the better the relationship, with a perfect relationship reached when R^2 = 1.0.*

The average percent of phosphorus that was dissolved during the project was 37.6%. The percent dissolved phosphorus ranged from approximately 34% for spring, summer, and fall to 77% during the winter months. The seasonal changes are most likely due to the production of algae. As algae reproduce, they readily take up the dissolved fractions of phosphorus. During the growing seasons, there was much less dissolved phosphorus available in the water column than in the winter and, to some extent, the spring months. Algae only need 0.02 mg/L (20µg/L) of phosphorus to produce an algal bloom (Wetzel, 1983). As can be seen in Figure 24, the daily average dissolved phosphorus concentrations in Enemy Swim Lake rarely reach that level. This is not to say Enemy Swim doesn't have nuisance algal blooms, however the duration and intensity were diminished due to the relatively low phosphorus concentrations.

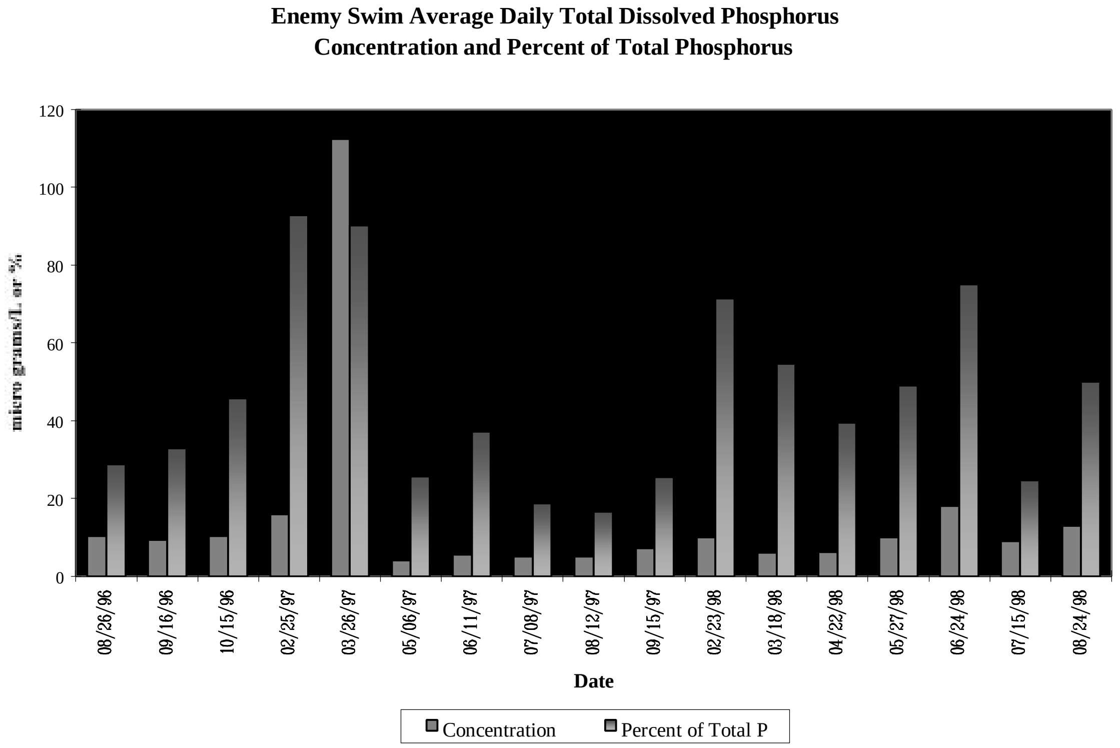


Figure 23. Average Daily Total Dissolved Solids Concentration. The second bar is the percent of the total phosphorus fraction that is dissolved.

The dissolved phosphorus concentrations in Enemy Swim Lake were directly affected by algae production. Because algae use dissolved phosphorus, the concentrations were reduced during the growing season. Generally, higher dissolved phosphorus can be found during winter when cold water temperatures and snow cover inhibit algae growth.

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals. Fecal coliform bacteria are used as indicators of waste and potential presence of pathogens in a waterbody. Many outside factors can influence the concentration of fecal coliform. Sunlight and time seem to lessen fecal concentrations although the nutrient concentrations may remain high. As a rule, just because fecal bacteria concentrations are low or non-detectable, does not mean animal waste is not present in a waterbody.

Only one inlake sample had a concentration above the detection limit (10 counts/100 mL). That sample was collected near the surface of Site ESL1 on September 16, 1996. Sources for the detection could have been from septic systems, the watershed or wildlife found in, or migrating through, the area. Inlake concentrations are typically low because of exposure to sunlight and dilution of the bacteria in a larger body of water. Figure 25 shows the daily average sample concentration for the duration of the project.

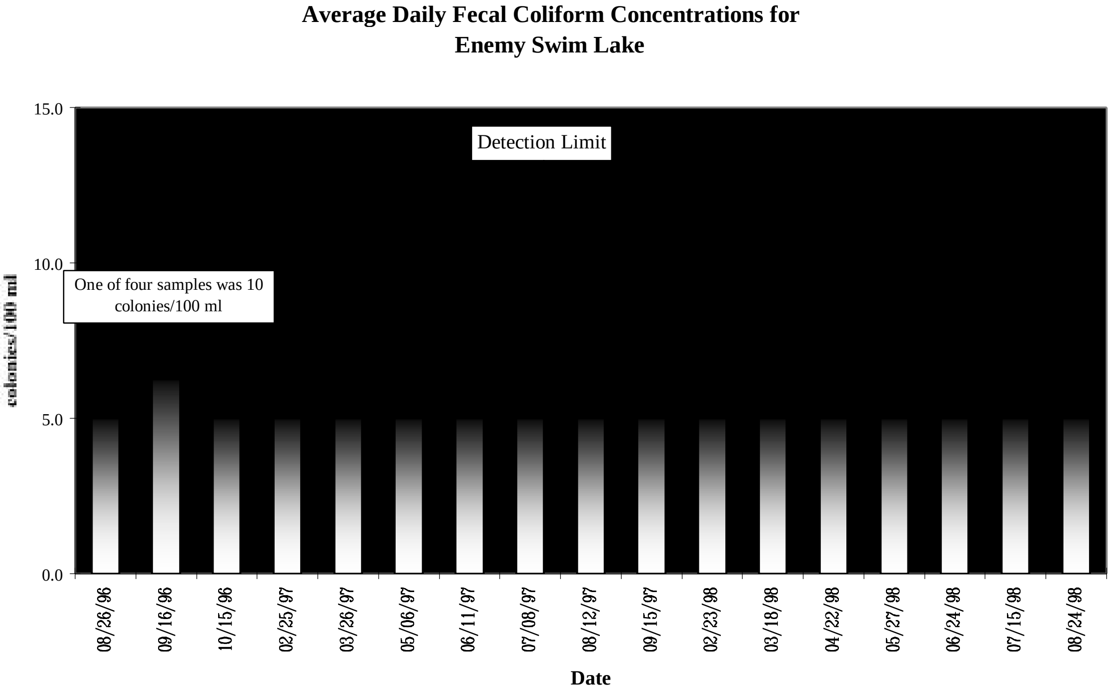


Figure 24. Average Daily Fecal Coliform Concentration.

Chlorophyll *a*

Chlorophyll *a* is a pigment in plants that may be used to estimate the biomass of algae (Brower, 1984). Chlorophyll *a* samples were collected with all inlake samples during the project. Overall, the chlorophyll *a* concentrations in Enemy Swim Lake were relatively low (Figure 26). Figure 26 shows the average of site ESL1 and site ESL2 on the date a sample was collected.

The date with the highest inlake chlorophyll *a* sample (26.13 mg/m^3) was July 15, 1998. Figure 26 shows that the high readings found in July 1998 were almost twice as high as the next closest concentration and almost 4 times higher than the project average (7.09 mg/m^3). The median concentration for the project was 6.87 mg/m^3.

As can be see in Figure 26, there is a definite seasonal progression of chlorophyll *a* concentration from winter into the growing season. The average concentration of chlorophyll *a* for each season can be found in Table 11.

Table 11. Seasonal Differences in Chlorophyll a.

	Winter	Spring	Summer	Fall	Project Average Total
Average Concentration	1.46	3.42	10.74	9.10	7.09

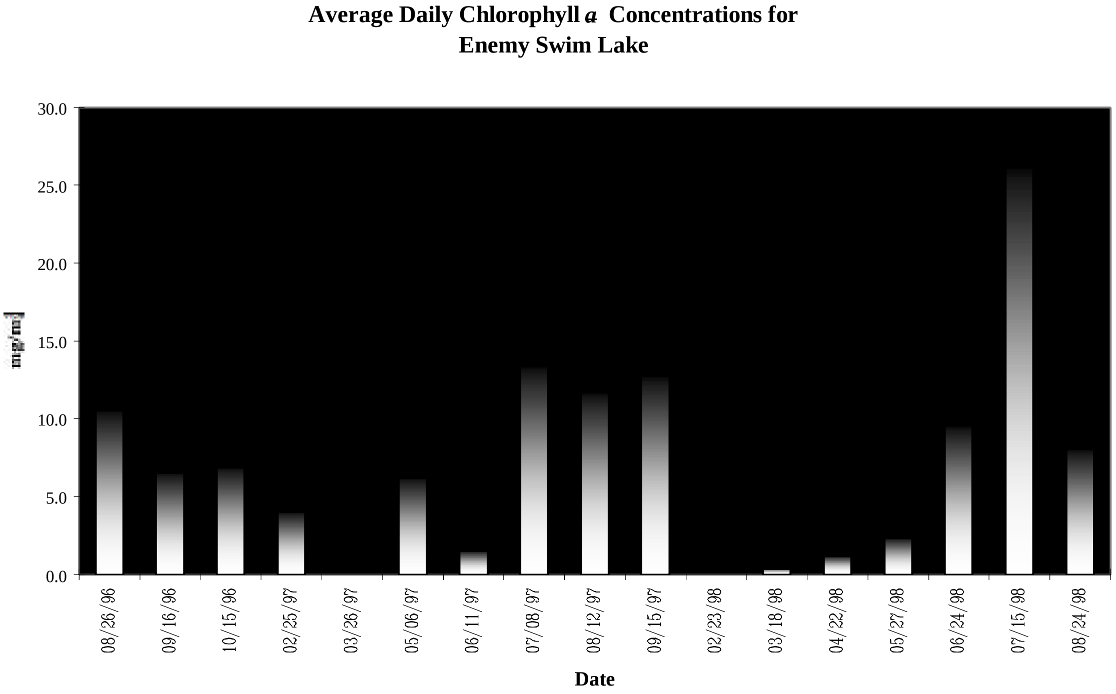


Figure 25. Average Daily Chlorophyll a Concentrations.

As can be seen in Table 11, winter samples were 7 times less than the summer samples. Spring samples also have relatively low chlorophyll a concentrations mostly due to the low hydraulic residence time during the project period and the cooler water temperatures. By summer and fall, the hydraulic retention time has diminished and algae can produce sufficient amounts of chlorophyll a.

Typically, chlorophyll a and total phosphorus have a relationship in regards to increasing concentrations. As total phosphorus increases, so do chlorophyll a concentrations. Each lake usually shows a different relationship because of factors including but not limited to; nutrient ratios, temperature, light, suspended sediment, and hydraulic residence time. Such a relationship was attempted using all of the data from the project. As can be seen from Figure 27, Enemy Swim has a close relationship between total phosphorus and chlorophyll a ($R^2 = 0.55$). Enemy Swim Lake is one of the few lakes where the total phosphorus to chlorophyll a were directly proportional from year to year and season to season.

The relationship between phosphorus and chlorophyll a can be used to estimate a reduction in chlorophyll a by reducing inlake phosphorus concentrations. The better the relationship, the more confident lake managers can be in the expected results. The data will be used in the reduction response model later in the report. The equation of the line in Figure 27 will be used to predict chlorophyll a levels by using inlake phosphorus concentrations. The equation for the line is shown below.

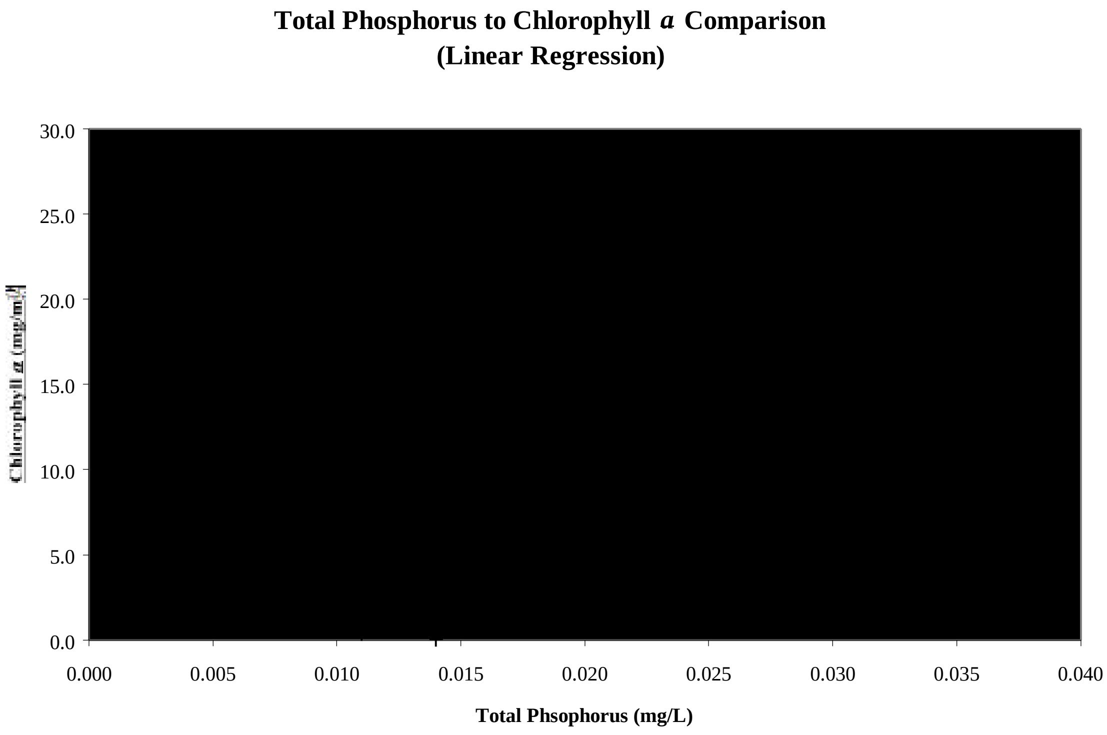


Figure 26. Total Phosphorus to Chlorophyll a Relationship.

Equation 1.

$$y = 553.96x - 4.7737$$

$$y = \text{predicted chlorophyll } \underline{a} \text{ concentration}$$

$$x = \text{phosphorus concentration}$$

Phytoplankton

Planktonic algae collected at four sites in Enemy Swim Lake during 1997 and 1998 consisted of 127 taxa which represented 63 genera within seven algal divisions (Appendix E, Table 1). Green algae (Chlorophyta) and blue-green algae (Cyanophyta) were the most diverse groups with 37 and 32 taxa, respectively, followed by diatoms (Bacillariophyta) with 27 taxa. The remaining 31 taxa were variously distributed among four phyla of motile (flagellated) algae including cryptomonads (Cryptophyta), yellow-brown algae (Chrysophyta), euglenoids (Euglenophyta), and dinoflagellates (Pyrrophyta).

Flagellated algae, mainly chrysophytes, were important components of the lake plankton in spring while blue-green algae were most abundant in the summer. Pronounced blooms of diatoms were not observed in Enemy Swim Lake during this survey but this algal group was most common in spring and mid-summer at lake sites ESL1 and ESL2. Green algae represented the least abundant group and also became more common in summer (Appendix E, Tables 1-4).

The algal communities of eutrophic lakes in the Midwest are frequently dominated by blue-greens and diatoms with green algae comprising a relatively small percentage of the total population (Prescott, 1962). Most of the foregoing scenario appears to fit the algal grouping in Enemy Swim Lake although the diatoms were not found to be particularly abundant during this 2-year study. The only blue-green algae consistently abundant were those of the *Aphanocapsa*/*Aphanothece* group. These very small colonial taxa appear to be common to a wide range of lakes from oligotrophic to highly eutrophic waters and do not necessarily reflect poor water quality unless extremely abundant. For example, *Aphanocapsa/Aphanothece* are equally common in Lake Cochrane, one of the better quality lakes in eastern SD. The most recent DENR assessment classifies Enemy Swim Lake as mesotrophic (Stueven and Stewart, 1996). The present survey recorded low to moderate densities of several algae species in Enemy Swim Lake that are known to be characteristic of oligotrophic/mesotrophic waters, including the diatoms *Cyclotella ocellata, Cyclotella comta,* and *Tabellaria fenestrata* (Appendix E, Tables 1-4). The disappearance of these taxa in future years may signal a significant decline in lake water quality marked by the establishment of eutrophic conditions.

The initial algae samples of this survey were collected in late February and March 1997 at inlake sites ESL1 and ESL2. Sample analysis indicated small algae populations were present in Enemy Swim Lake during late winter and early spring (Appendix E, Table 1). Total algal densities at the two sites ranged mostly below 1000 cells/ml for those months. As expected, the algal numbers were the lowest recorded for the 2-year study. The samples contained primarily small cryptomonad flagellates (mostly *Chroomonas* sp.), small-sized unidentified flagellates, and small numbers of green algae. In most major respects (size and general composition) this community resembled that of Blue Dog Lake for the same time period (March 1997) even though the latter is classified as a eutrophic lake. Diatoms were not found in February and March samples while greens and blue-greens were present in trace densities.

The next algae samples taken on May 6, 1997, indicated a pronounced bloom of the small (5-7µ) chrysophyte flagellate *Chrysochromulina parva* at an average density of 10,305 cells/mL, which represented nearly 38% of the total algae on this date. Other common constituents were miscellaneous unidentified small flagellates and small algal cells, *Dinobryon sertularia,* and *Chroomonas* sp. In addition, moderate numbers of diatoms were recorded in early May at an average density of 809 cells/mL and trace numbers of green and blue-green algae (Appendix E, Table 1). Total algae densities increased significantly to a mean of 27,306 cells/mL in May.

The following samples collected on June 11, 1997, indicated a nearly 60% decline in mean algal densities to 16,162 cells/mL which was mainly the result of a sharp decline in *Chrysochromulina* numbers. Densities of blue-green algae increased from a trace in May to a mean of 11,755 cells/mL. *Aphanocapsa* and *Aphanothece* spp. Made up 96% of this increase. Diatoms maintained moderate numbers in June (599 cells/mL) and green algae increased over trace densities in May but total numbers remained low (330 cells/mL).

Summer algae samples collected on the next sampling of July 8, 1997, disclosed a further decline in total algae densities (mean 5485 cells/mL) due primarily to a decline in *Aphanocapsa/Aphanothece* numbers (Appendix E, Table 2). *Aphanizomenon flos–aquae* was first collected on this July date at a rather low mean density of 1275 cells/mL (approx. 42 filaments/mL). It was not collected in August and on the last sampling date of the year in mid-September *Aphanizomenon* occurred as only 200 cells/mL. Other common nuisance blue-greens also were present in low numbers in Enemy Swim Lake (sites ESL1 and ESL2) during 1997. *Microcystis* spp. Recorded a maximum annual density of 182 cells/mL in June and *Anabaena* spp.- 210 cells/mL in September.

There was only a moderate increase in total algal densities noted on August 12, 1997, above July values (mean 6615 cells/mL). Moderate increases in diatoms and green algae offset a decline in blue-green algae, primarily *Aphanizomenon* and *Oscillatoria* (Appendix E, Table 2). Diatoms attained their maximum annual abundance (mean 1840 cells/mL) in August due to larger numbers of *Fragilaria crotonensis* and *Melosira granulata.* Peak annual densities for non-motile green algae were also recorded (mean 675 cells/mL) as well as for the green flagellate *Chlamydomonas* spp.(mean 1440 cells/mL).

The final samples of 1997 were taken at sites ESL1 and ESL2 on September 15. Sample analysis indicated a 20% decrease in total algae numbers from August levels (mean: 5325 cells/ml). Primary reasons for this decline were smaller numbers of green algae, diatoms, and flagellated algae present in September (Appendix E, Table 2). Blue–green algae showed a slight increase in numbers for the same time period, due mainly to larger numbers of *Lyngbya birgei* (mean 365 cells/ml).

The first samples of 1998 were collected on April 22 at inlake sites ESL1 and ESL2. After April, site ESL1 was taken off the sampling schedule because no consistent differences in algal abundance or composition could be demonstrated between sites. April samples contained considerably fewer algae than those of the comparable period in 1997 (6 May) due to the absence of a *Chrysochromulina* bloom in spring of 1998 (Appendix E, Table 4). However, more diatoms and, particularly, more blue-green algae were present in April 1998. Green algae were present at consistently low (trace) densities in both years (Appendix E, Tables 1 and 4). The above differences can be partly ascribed to natural year-to-year variability in plankton populations commonly reported in the literature. Total algae densities on May 6, 1997 averaged 27,306 cells/mL compared to 11,178 cells/mL on April 22, 1998. Then, too, algal populations tend to increase rapidly in spring due to increases in light and water temperature, and a time difference of one week or less can make a considerable difference in the size of the sampled plankton population.

Algae populations more than doubled in size on May 27, 1998 to 28,034 cells/mL due to a nearly 17 fold increase in blue-green algae, mainly *Aphanocapsa/Aphanothece* spp.. Blue-greens, as a group, tend to favor warmer water temperatures and frequently start developing large populations in late spring or early summer (Appendix E, Table 4). Numerically, *Aphanocapsa/Aphanothece* comprised 85% of the total algae and 94% of the blue-green algae on this date. Flagellated algae, diatoms, and green algae ranged in density from 558 to 952 cells/mL. Diatoms represented the least abundant group. During the comparable time span in 1997 (11 June), *Aphanocapsa/Aphanothece* were similarly dominant but were only able to build up a population half the size of that in 1998.

The trend of blue-green algal dominance established in late May was maintained to the end of this survey through August 1998. From June 24 to August 24, 1998, *Aphanocapsa/Aphanothece* spp. Made up from 81% to 92% of the summer blue-green algae and from 70% to nearly 91% of total algae and ranged in density from 31,080 to 410,600 cells/mL (Appendix E, Table 4). Other blue-greens occurred in moderate to low densities. *Aphanizomenon* reached a maximum annual density of 468 cells/mL in August as did *Microcystis* spp. With a density of 8120 cells/mL. *Anabaena flos-aquae* attained maximum annual abundance in late June (5180 cells/mL). *Lyngbya subtilis*, a small filamentous species, attained a moderately high density of 22,920 cells/ml, also in August. During summer, flagellated algae maintained densities of 3244 and 3504 cells/mL in June and July before declining to 1281cells/mL, perhaps in response to large populations of blue-greens in August (Appendix E, Table 4). The most common identified flagellates in summer were *Chrysochromulina* sp. And *Chroomonas* sp. Diatoms were found in relatively low densities from 393 to 702 cells/mL. Common species were *Cyclotella ocellata* and *Fragilaria crotonensis*. Densities of green algae ranged from 247 to 362 cells/ml before increasing to an annual maximum of 1134 cells/mL in August. *Scenedesmus quadricauda* and *Oocystis* spp. Represented common summer green algae in Enemy Swim Lake at site ESL2 during 1998.

Twenty-one metrics were calculated for Enemy Swim Lake algae, using recent data as well as data collected in 1979 and 1989, to chart any long term trends in algal populations that may reflect historical changes in lake water quality. No consistent or interpretable trends were evident in most of the results obtained. Four metrics did show an increasing trend (higher values) from 1979 to 1998. Those included the Shannon and Simpson diversity indices, the Palmer eutrophication index, and the algal Biovolume TSI(B) Index based on Carlson's (1977) Trophic State Indices (Sweet, 1986). The four indices suggested significant nutrient enrichment (eutrophication) has taken place in Enemy Swim Lake over the past 20 years. The TSI(B) index, in particular, seemed to indicate a considerable increase in lake algal biomass during the last two decades (Appendix E, Tables 5, 6).

Cabin Leachate Study

In order to detect any major effects of leachate from lakeshore cabin septic tank absorption fields on local algae populations, two special sampling sites were established near the south shore of Enemy Swim Lake. Site ESLC was located in close proximity to the most developed length of shoreline, and site ESLT was situated at the far edge of the developed area to serve as a control. The two sites were sampled on the same date of each month from June through September 1997 and in July 1998 (Appendix E, Tables 1 and 3).

Of the five comparisons made, only one sample was noteworthy. This took the form of a bloom of *Lyngbya birgei* (14,980 cells/mL) in the area monitored by site ESLC on August 12, 1997 (Appendix E, Table 3). No *L. birgei* was recorded from the control site ESLT at the same time. Another noteable event, although of lesser magnitude, occurred in the previous month when 2400 cells/mL of *L. birgei* were counted from site ESLC while none was recorded for site ESLT. This alga is a large blue-green filamentous species which is not a common nuisance species in eastern South Dakota waters, but, paradoxically, seems to occur mostly in a few of the ‘cleaner’ state lakes. It has been reported as a localized nuisance species in Lake Okeechobee, Florida, where it bloomed in response to high phosphate loads from local cane fields (USGS, 1987). Other apparent differences between the two sites were slight or inconsistent and could not be identified with any confidence. In conclusion, it must be noted that both of the above sites appeared to have consistently higher total algae densities than mid-lake sites ESL1 and ESL2 (Appendix E, Tables 1-4). Average algae populations were three times larger at sites ESLC and ESLT (Figure 28). The reason(s) for these apparent differences is not clear at present, unless it represents evidence of a more wide-spread effect of south shore development.

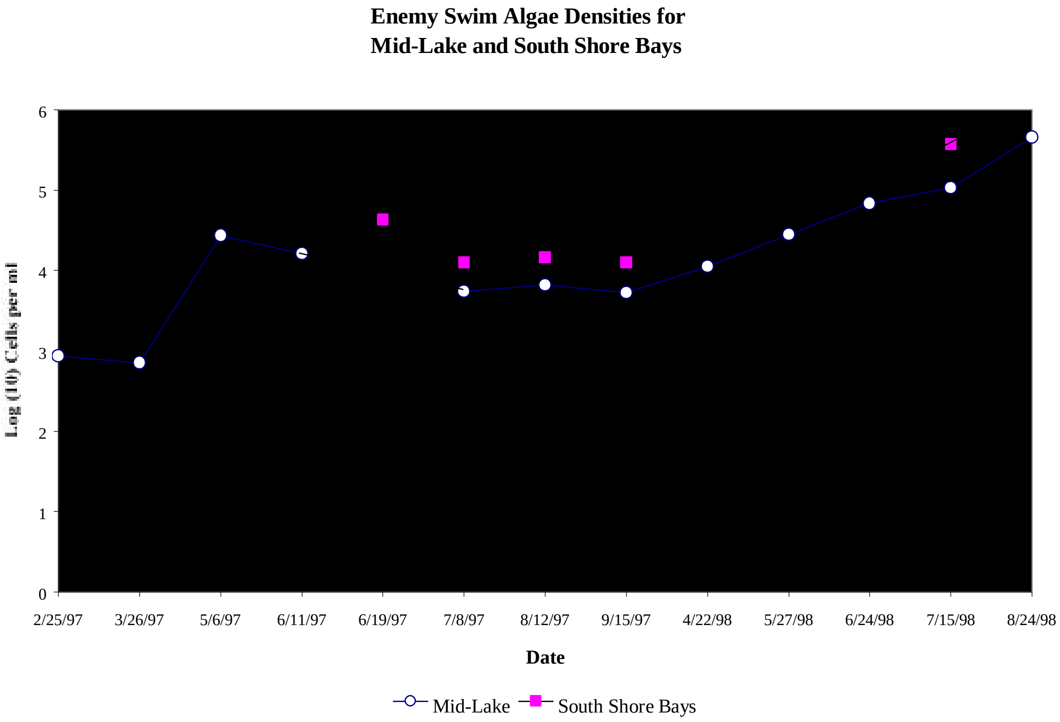


Figure 27. Algal Differences Between Mid-Lake and South Shore Bays.

Trophic State Index

Carlson's (1977) Trophic State Index (TSI) is an index that can be used to measure the relative nutrient enrichment of a waterbody. The trophic state is tied to algal production in the waterbody. The lower the nutrient concentrations in a waterbody, the lower the trophic level, and the larger the nutrient concentrations, the more eutrophic the waterbody. Oligotrophic is the term used to describe the least productive lakes and hyper-eutrophic is the term used to describe lakes with excessive nutrients and production. Table 12 describes the different numeric limits applied to various levels of the Carlson Index.

Three different parameters can be used to compare the trophic index of a lake; 1) chlorophyll a, 2) total phosphorus, and 3) Secchi depth. The average TSI levels are shown in Table 13 and a graph showing all of the TSI readings is shown in Figure 29.

Table 12. Trophic State Index Ranges

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

Table 13. Enemy Swim Lake TSI Values.

Parameter → Calculation ↓	Chlorophyll *a*	Total Phosphorus	Secchi	Parameters Combined
Mean TSI	50.88	48.92	51.49	50.37
Median TSI	58.48	49.39	53.08	51.74
Standard Deviation	18.26	8.49	5.74	12.22

The mean and median for chlorophyll *a* and Secchi TSI were slightly to moderately eutrophic. The mean phosphorus TSI was just below the eutrophic level into the mesotrophic level. The overall TSI mean of Enemy Swim Lake during the project period was slightly eutrophic. One unusual aspect of the TSI index numbers was that the phosphorus TSI was actually lower than the TSIs for chlorophyll *a* and Secchi depth.

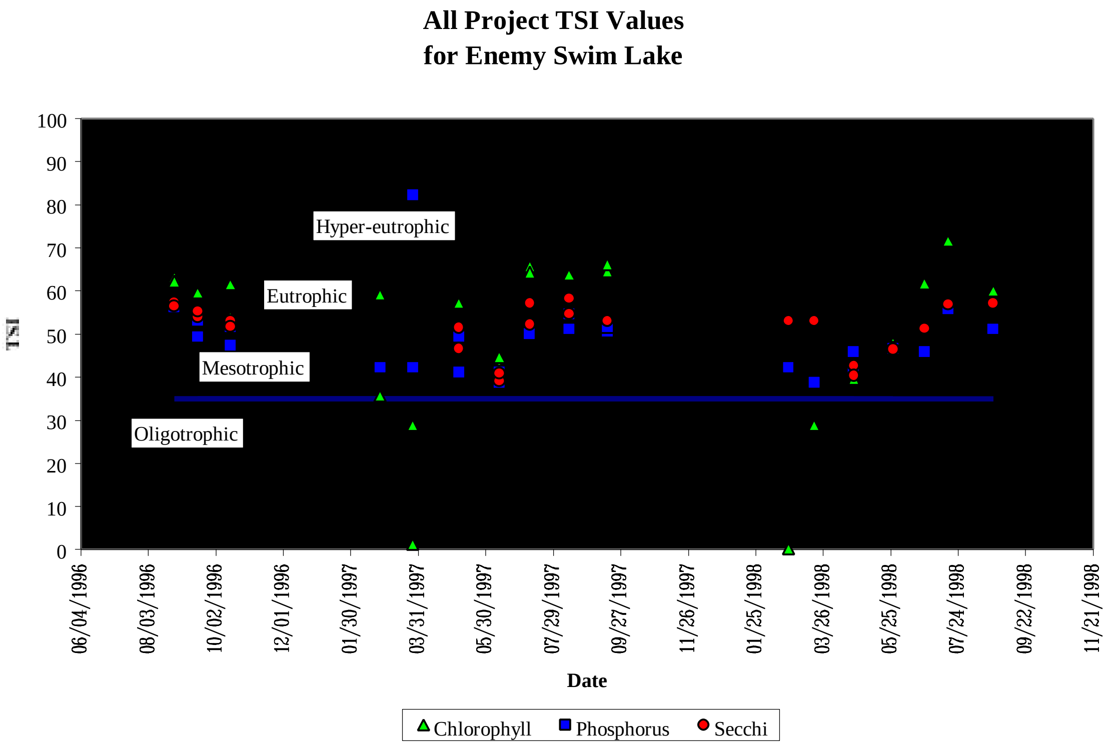


Figure 28. All Project TSI Values.

The analysis of the seasonal differences shows the summer and fall months were more eutrophic than the winter and spring months (Table 14). Of all the parameters, chlorophyll a had the largest seasonal changes, ranging from a TSI of 25.67 in the winter to the low 60s in the summer and fall. Spring phosphorus TSI values were lowest due most likely to dilution from heavy spring runoff. Secchi TSI values followed the chlorophyll a concentrations in the summer and fall, however, the winter Secchi TSI values were high considering that very little chlorophyll a was found under the ice. Two factors were most likely the reason for these higher numbers.

Table 14. Seasonal TSI Values.

	TSI Parameters			
Season	Chlorophyll	Phosphorus	Secchi	Average TSI
Winter	25.67	48.32	53.08	39.29
Spring	49.01	44.83	45.53	46.46
Summer	60.32	50.14	52.86	54.44
Fall	60.35	50.66	53.39	54.80
Average TSI	50.88	48.92	51.49	50.37

First was lack of measurements. Secchi readings were only collected on two of the four winter sampling dates. Second, turbulence either from fish or the ice auger may have caused cloudy water under the ice decreasing Secchi depth and increasing TSI values. Figure 30 is a graph of the seasonal average daily TSI values.

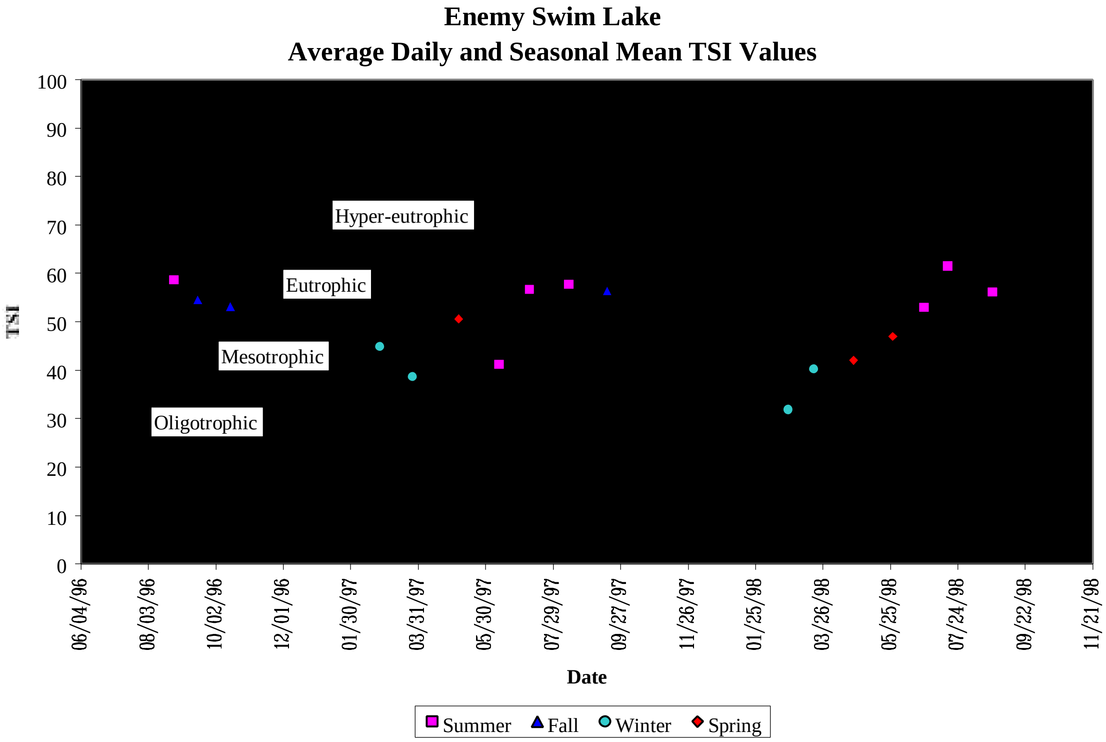


Figure 29. Daily and Seasonal TSI Values.

Long-Term Trends

Due to the length of this project, this is only a “snapshot in time” of the lake’s water quality, it is useful to look at changes in water quality over a longer period. Comparable water quality samples were collected for the Statewide Lake Assessment in the summers of 1979 and 1989-1995 (Stueven and Stewart, 1996). Since the samples taken for the Statewide Lakes Assessment were collected in the summer, only summer samples collected during this project will be used in the trend analysis (Figure 31). Carlson’s TSI will be used for the comparison.

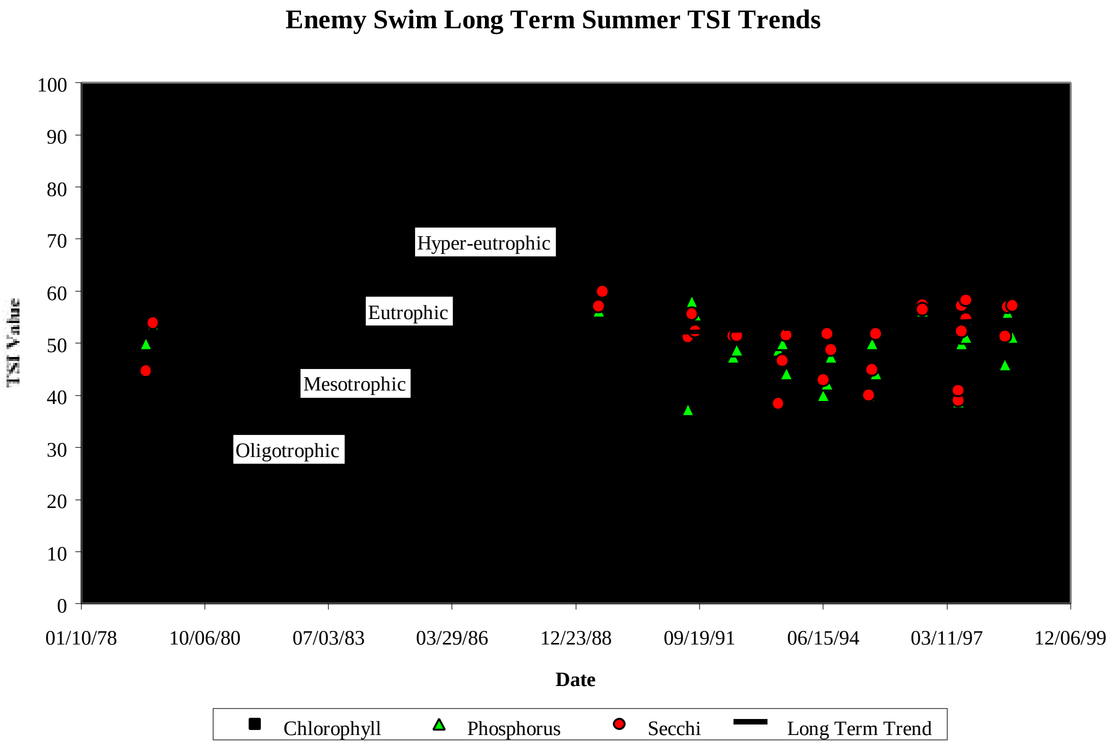


Figure 30. Long Term TSI Trends.

Effect

Since 1979, there has been no considerable change in the long-term trend for phosphorus and Secchi depth. Chlorophyll, however, has increased from mesotrophic levels to well into the eutrophic category. Although the phosphorus had not changed dramatically, there has been sufficient concentrations for algal blooms. One reason for the increasing chlorophyll a concentrations may be the volume of water that passed through the lake in the spring of 1997 and continuing into 1998. The increased volume may have raised ground water levels, cause septic drainfields to be flooded and thereby negatively impact the lake.

The most effective way to slow the trend of increasing chlorophyll a concentrations is to reduce nutrient levels in the lake. Installing best management practices in the watershed and stopping leachate from septic systems entering the lake are the best ways to reduce the trend of increasing eutrophication.

Limiting Factor for Chlorophyll Production

For an organism, such as algae, to survive in a given environment, it must have the necessary nutrients and environment to maintain life and to be able to reproduce. If an essential component approaches a critical minimum, this component will become the limiting factor (Odum, 1959). Nutrients such as phosphorus and nitrogen are most often the limiting factor in eutrophic lakes. Typically, phosphorus is the limiting nutrient for algal growth. However, in many highly eutrophic lakes with an overabundance of phosphorus, nitrogen can become the limiting factor.

In order to determine which nutrient will be the limiting factor, EPA (1990) has suggested a total nitrogen to total phosphorus ratio of 10:1. If the total nitrogen concentration divided by the total phosphorus concentration on a given sample date is greater than 10, the lake is said to be phosphorus-limited. If the ratio is less than than 10, the waterbody is said to be nitrogen-limited.

During the project period, Enemy Swim was a phosphorus-limited lake (Figure 32). The average daily total nitrogen to total phosphorus ratio in Figure 32 was 36.7 with a standard deviation of 15.5. Seasonally, Enemy Swim is more phosphorus-limited in the winter.

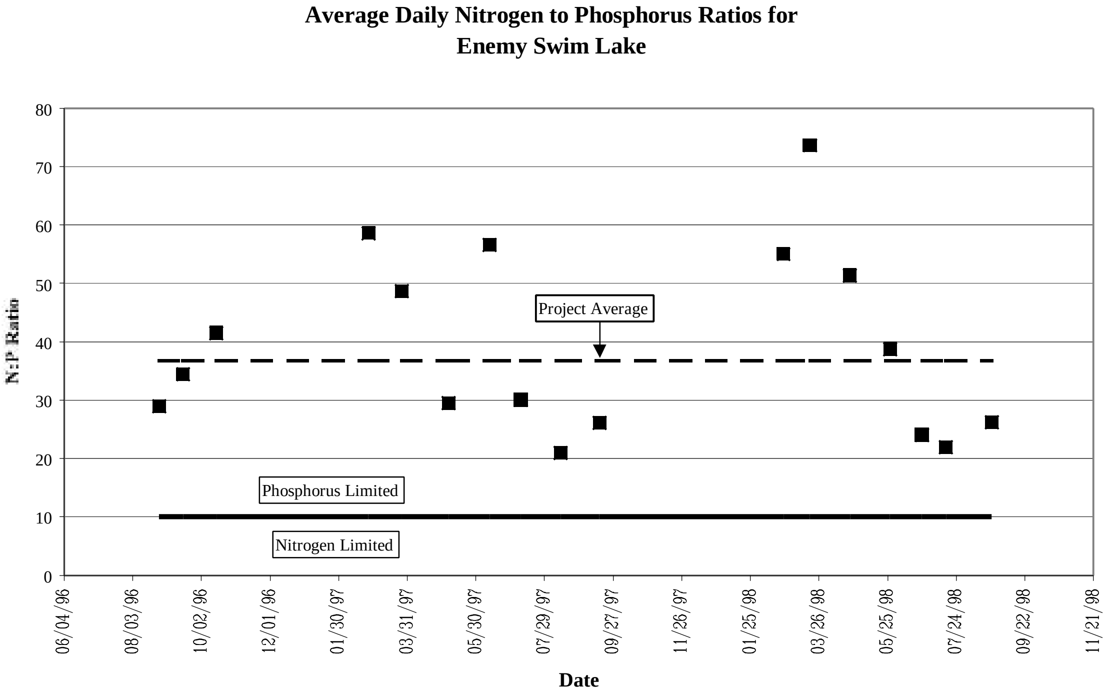


Figure 31. Nitrogen to Phosphorus Ratios.

The growing season is when Enemy Swim comes closest to becoming nitrogen limited. If Enemy Swim becomes more eutrophic and the nitrogen to phosphorus ratio decreases, it will be more difficult to remove enough phosphorus to limit algae growth in the lake.

Unlike many other lakes in eastern South Dakota, sedimentation in Enemy Swim Lake does not affect reductions in the nitrogen to phosphorus ratio. In many lakes, light-blocking sediments can be more limiting than nutrient concentrations. In Enemy Swim however, the algae seem to be the major light inhibitor in the lake. If phosphorus concentrations were to decrease, one should expect a similar response by both chlorophyll *a* concentrations and Secchi depth measurements.

Developed vs. Undeveloped Bays

Before the septic leachate survey was conducted by ECOSCIENCE Inc., an attempt was made to sample two different bays for differences in nutrient levels caused by septic leachate. Site ESLC was located east of the developed peninsula area, and the other sample site (ESLT) was located east of a small bay surrounded by tribal land approximately 0.25 miles east of site ESLC (Figure 33). The purpose of the sampling was to see if there was any difference in nutrient and chlorophyll *a* concentration between the developed site (ESLC) and the undeveloped site (ESLT).

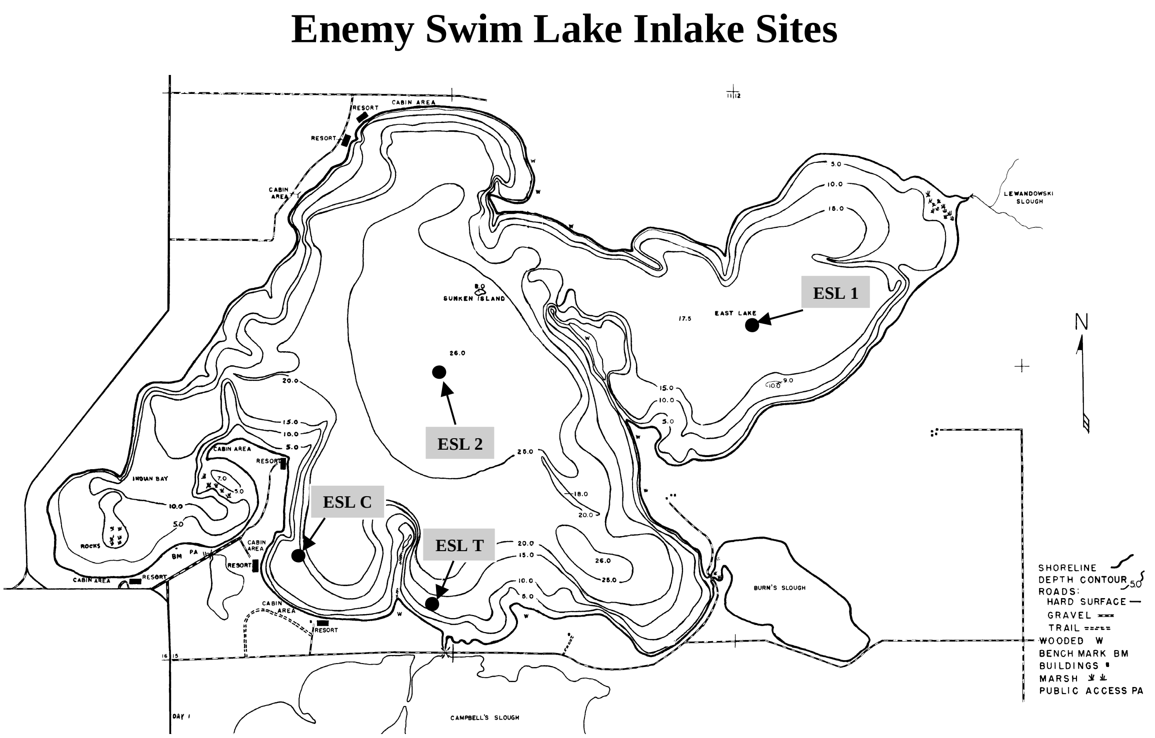


Figure 32. Location of Sites ESLC and ESLT.

As stated in the phytoplankton discussion, in two of the four samples, blue-green algae were present at site ESLC and not at site ESLT. On one of those occasions, the volume of algae at site ESLC was 2.5 times greater than at site ESLT.

According to statistical analysis, there was no significant difference in the water quality at the two sites. This may have been due to the fact that sites were not far enough apart to be considered different. The ground water gradient also appears to flow from site ESLC to site ESLT, which may have also decreased the independence of each site. Other evidence that the two sites were not as independent as expected was that the phytoplankton found that both sites ESL-C and ESLT were consistently higher in algal density than inlake sites ESL1 and ESL2. The effect of septic leachate from the developed areas may be more widespread than expected.

Discrete Animal Feeding Area Samples

Discrete grab samples were taken after the local coordinator received a call from cabin owners about their concern regarding an animal feeding area adjacent to their property. More specifically, they were concerned that the animal waste was running over their lawns and into the lake. Two samples were collected during the project period. The first sample was collected in April of 1997, and the second sample was collected in February of 1998. Because runoff did not channel, collection of the samples was difficult. Water depths were shallow and flow rates could not be measured. Samples were collected as close to the lake as possible. Results of the samples showed extremely high nutrient and suspended solids concentrations.

All of the chemical parameters analyzed were higher than any other sample collected during the project. Many parameters were more than 100 times greater than the mean concentration of the inlake samples (Appendix F). Although the total volume of water is unknown, such high concentrations entering the lake will have a negative impact by increasing eutrophication. The concentration of fecal coliform bacteria over the lawns of the cabin owners may be an indicator of human health issues. With the well-drained soils sloping toward the lake, ground water inputs of nitrogen and phosphorus from the feeding area may have a more long-term effect on the lake.

Reduction Response Model

Inlake total phosphorus concentrations are a function of the total phosphorus load delivered to the lake by the watershed. Vollenweider and Kerekes (1980) developed a mathematical relationship for inflow of total phosphorus and the inlake total phosphorus concentration. They assumed that if the inflow of total phosphorus changed, inlake phosphorus concentrations would change by a corresponding but steady amount. The variables used in the relationship are:

1) $[\overline{P}]\,l$ = Average inlake total phosphorus concentration
2) $[\overline{P}]i$ = Average concentration of total phosphorus that flows into the lake

3) $\overline{T}p$ = Average residence time of inlake total phosphorus

4) $\overline{T}w$ = Average residence time of lake water

Since no tributary data was available for the Enemy Swim Watershed, the components for the equation were gathered from AGNPS data in conjunction with samples and information collected for the Blue Dog Lake study. . Data from both projects model provided enough information to estimate $[\overline{P}]l$, $[\overline{P}]i$, and $\overline{T}w$. In order to estimate the residence time of total phosphorus ($\overline{T}p$) it was necessary to back calculate Equation 2 below, and solve for $\overline{T}p$ by forming Equation 3 (Wittmuss, 1996):

Equation 2. Reduction Response Equation.

$$[\overline{P}]l = \left[\frac{\overline{T}p}{\overline{T}w}\right][\overline{P}]i$$

Equation 3. Phosphorus Retention Time Equation.

$$(\overline{T}p) = \frac{[\overline{P}]l}{[\overline{P}]i}(\overline{T}w)$$

Values for $[\overline{P}]l$, $[\overline{P}]i$, and $\overline{T}w$ were determined in the following manner:

$[\overline{P}]l$ was determined by averaging all of the surface total phosphorus samples for the entire project.

$[\overline{P}]i$ was determined by averaging the three sample that were collected at the inlet (Appendix F). However, since no discharge measurements were collected there will be no weighted average given to these samples.

$\overline{T}w$ (Equation 4) was determined by information data gathered for the Blue Dog Lake watershed study. Data from the Blue Dog sampling indicated that approximately 50% of the water from site BDL4 was from the outlet of Enemy Swim Lake. The total volume of Enemy Swim Lake (33,792 acre-feet) was divided by the estimated outputs of water from the lake (10,00 acre-feet/year).

Equation 4. Hydraulic Residence Time.

$$\overline{T}w = {}^{33{,}792/acre/\ feet}\big/_{10{,}000/acre/\ feet} = 3.38\ years$$

The final values for $[\overline{P}]l$ and $[\overline{P}]i$ were:

$[\overline{P}]l$ = 0.028 mg/L $[\overline{P}]i$ = 0.025

By inserting the numbers in the proper places as discussed in Equation 5, $\overline{T}p$ would be:

Equation 5.

$$\left(\overline{T}p\right)=\left[\frac{0.028}{0.025}\right](3.38)=3.79\ years$$

Once all factors for the four variables are calculated, certain variables can be changed to show a response of another variable. For our reduction model, the phosphorus residence time ($\overline{T}p$) divided by the hydraulic residence time ($\overline{T}w$) is a standard coefficient and will not change (1.12). With the limited tributary sampling data, there is no way to estimate the reduction in the retention time of total phosphorus. This leaves two factors; average phosphorus inputs ($[\overline{P}]i$) and average inlake phosphorus concentration ($[\overline{P}]l$). By inserting a reduced value for $[\overline{P}]i$ in Equation 2, a reduction in inlake phosphorus ($[\overline{P}]l$) can be calculated. This is assuming constant inputs of water. Theoretically, the phosphorus retention time should also be reduced. Table 15 shows that a reduction in phosphorus inputs to Enemy Swim Lake by 20% will reduce the inlake phosphorus to 0.022 mg/L (mesotrophic).

As discussed in the chlorophyll a section of the report, there is a good relationship (R^2=0.546) between chlorophyll a and total phosphorus (Figure 27). Using the equation for the regression line in Figure 27, a chlorophyll a reduction can also be predicted.

Table 15. Effects of Reducing Phosphorus Inputs on TSI.

Percent Reduction	Average Tributary Reduction (mg/L)	Inlake Phosphorus Response (mg/L)	Predicted Chlorophyll a Reduction (mg/m^3)	Predicted Phosphorus TSI	Predicted Chlorophyll TSI
0	0.025	0.028	10.74	52.22	62.89
10%	0.023	0.025	9.19	50.70	61.36
20%	0.020	0.022	7.64	49.00	59.54
30%	0.018	0.020	6.08	47.08	57.32
40%	0.015	0.017	4.53	44.85	54.43
50%	0.013	0.014	2.98	42.22	50.32
60%	0.010	0.011	1.92	39.00	46.00
70%	0.008	0.008	1.04	34.85	40.00
80%	0.005	0.006	0.46	29.00	32.00
90%	0.003	0.003	0.118	19.00	22.50

Recommended Targeted Reduction

The average phosphorus concentrations in Enemy Swim Lake (0.028 mg/L) were 29% greater than the amount needed for an algal bloom (0.020 mg/L). Because reduced algae production and greater lake clarity are usually the desired results of restoration activities; targets for nutrient reduction are linked to chlorophyll a TSI levels. The current chlorophyll a TSI value, based on the line equation in Figure 34, is 62.89. To get the predicted chlorophyll a concentrations to a mesotrophic level, a 50% reduction of inlake phosphorus is required. After implementing the BMPs needed to reduce phosphorus loads, long-term monitoring should be conducted to see if the target has been reached.

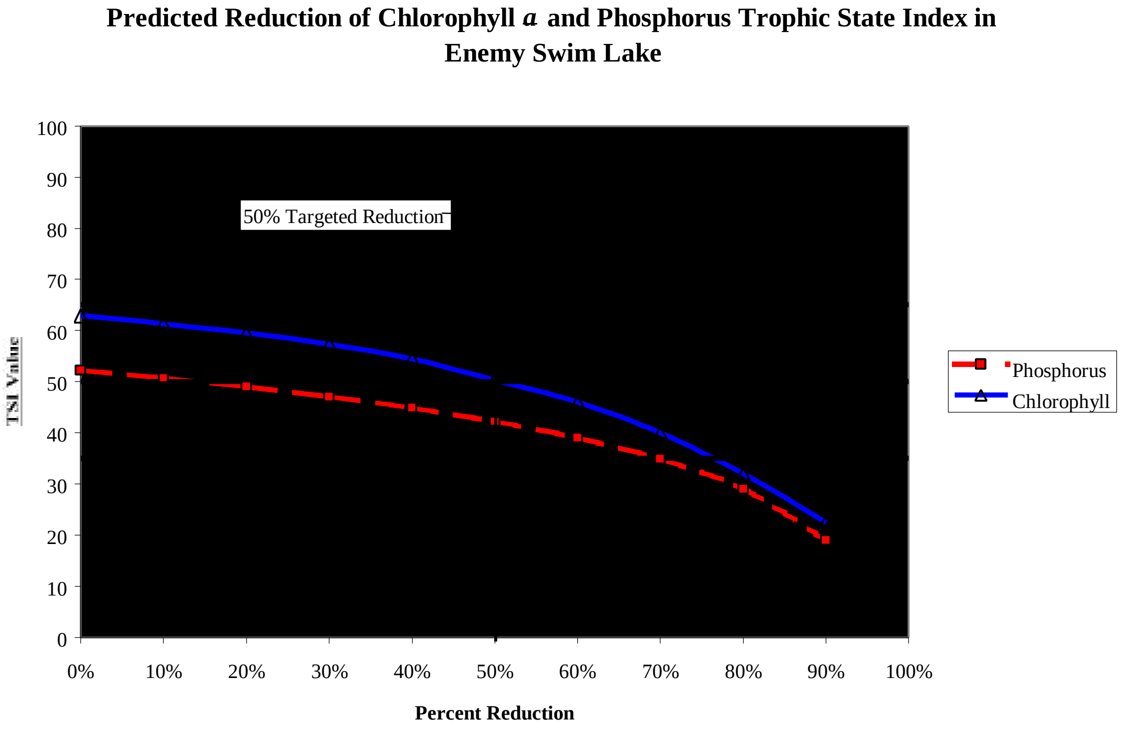


Figure 33. Predicted Phosphorus and Chlorophyll a Reduction.

This target was established because the AGNPS model estimated a 20% - 30% reduction of phosphorus in the watershed by eliminating discharge from selected feeding areas and improving manure and crop management in targeted cropping areas. It is also recommended that a wastewater sewer collection system be installed to serve the homes and cabins around Enemy Swim Lake. Although there is no actual target for reduction of phosphorus by removal, the sandy soils around Enemy Swim Lake and the shallow ground water combine to make septic systems ineffective. The Enemy Swim Lake septic leachate survey found 40 suspected areas of septic plumes around the lake shoreline. A minimum reduction of 20% of the total phosphorus input is expected from the construction of a centralized wastewater collection system.

Conclusions

Shoreline

Generally, the shoreline around Enemy Swim Lake was in good condition. Most areas had vegetation and rocks protecting the shoreline in the undeveloped areas. A few over grazed pastures on the north end of the lake have eliminated the riparian vegetation. These banks are showing signs of erosion. Developed areas have been “landscaped” and are subject to erosion by high water. Plans should be made to implement BMPs on both the overgrazed and the developed shorelines to stop further erosion to Enemy Swim Lake.

Fishery

The structure and depth of Enemy Swim Lake make it difficult to alter the fishery. Despite that fact, Enemy Swim has an exemplary fishery. A large diversity of desirable fish species in many different size classes makes catching fish anytime of the year highly probable. The large diversity, coupled with low rough fish numbers, should make the Enemy Swim fishery good for many years to come.

Septic Leachate Survey

A septic leachate survey was conducted by ECOSCIENCE Inc. from Moscow, Pennsylvania to see if leachate from shoreline septic systems was reaching Enemy Swim Lake. The survey found over 40 potential septic plumes in front of shoreline cabins. Samples were collected on 23 of the cabin sites as well as two background samples and one sample from the major inlet into Enemy Swim Lake. The conclusion of the study found the soils and the high ground water level not conducive for proper operation of septic systems. The consultant recommended constructing a centralized sewer system for the lake cabins and also implementing an information and education program for detergent and water use.

AGNPS

The complete AGNPS model can be found in Appendix C.

Sediment Analysis

The AGNPS data indicated that the Enemy Swim Lake watershed had a low sediment deliverability rate at both the inlets and the outlet of Enemy Swim Lake. The AGNPS model estimated the sediment deliverability to the lake was 12 lbs./acre/year. This corresponds to 68.8 tons of sediment entering Enemy Swim Lake resulting from one year’s average rainfall events. The estimated load was quite low when compared to other watersheds in northeast South Dakota.

An analysis of the Enemy Swim Lake watershed indicated that there were four subwatersheds with sediment rates far above the average. Three of these subwatersheds (#10, #11, and #12) had sediment inputs almost directly to Enemy Swim Lake. Subwatershed #4 had a relatively high loss per acre; however, the subwatershed drained to Oak Island Lake which most likely settled out most of the eroding sediments. The AGNPS model flagged only eight cells with sediment erosion rates greater than five tons/acre. Since most of the Enemy Swim watershed had slopes of 4% to 7%, the common factor in the higher erosion rates was the greater slopes coupled with cropland with little to no conservation tillage. The AGNPS model was run with the eight cells (320 acres) having the c-factors changed to represent a limited tillage or no-till practice. The model showed an 11% reduction in sediment delivered to Enemy Swim Lake.

To reduce sediment loads to Enemy Swim Lake, it is recommended those areas having land slopes greater than 7% with limited or non-existent conservation tillage practices be modified to no-till or limited-till practices. Cells should be field verified before any BMPs are implemented.

Nutrient Analysis

The AGNPS model estimated the nitrogen delivered to the lake was 1.2 lbs./acre/year. This corresponded to 13.6 tons of nitrogen entering Enemy Swim Lake resulting from one year's average rainfall events. The estimated load was quite low when compared to other watersheds in northeast South Dakota. Blue Dog Lake located just south of Enemy Swim Lake had a nitrogen load of 12 lbs./acre/year. AGNPS estimated approximately 0.18 lbs./acre/year of total phosphorus corresponding to 2.05 tons annually entering Enemy Swim Lake.

Like the sediment analysis, AGNPS highlighted four subwatersheds with higher nutrient rates. The same subwatersheds in both the nitrogen analysis and the phosphorus analysis were responsible for the higher nutrient loads to Enemy Swim Lake. Three of these subwatersheds (10, 11, and 12) drain almost directly to the lake. Subwatershed #2 drains to Oak Island Lake, which significantly changes the deliverability rates of that subwatershed.

During the cell by cell comparison of Enemy Swim Lake, AGNPS found 37 nitrogen cells and eight phosphorus cells that had unusually high nutrient deliverability. Most of these cells had 100% fertilizer availability on cropped fields with land slopes greater than 7%. By simply reducing the availability to 50% through disking or row cultivating after a fertilizer application, nitrogen loads were reduced by 20% and phosphorus loads were reduced by 24%, according to the AGNPS model.

Feedlot Analysis

Thirteen feeding areas were identified by AGNPS as being potential sources of nonpoint pollution. The AGNPS model ranked the animal feeding areas utilizing data collected specifically for animal feeding area analysis of the model. Of the thirteen animal feeding areas defined, seven had an AGNPS rating of 50 or greater when modeled using a 25-year frequency storm event. Three of these seven feeding areas had ratings of 60 or greater.

To analyze the impacts of these animal feeding areas on the watershed, the model was run after removing the feedlots that ranked 50 or greater. The results were then compared to the output data from the model run with the original data. Reductions in nutrients delivered to the watershed were then calculated. The results of this action on the model indicated that when those cells that rated 50 or greater were removed, a 7% reduction in phosphorus could be realized as well as a 5% reduction in nitrogen delivered to the lake.

Inlake

Water Quality

Enemy Swim Lake is a well-mixed lake with very little difference in surface and bottom chemical composition. Oxygen levels were sufficient throughout the water column most of the year, however, at times the lake stratified lowering oxygen levels in the hypolimnion. Suspended solids concentrations in Enemy Swim Lake, as a whole, were not excessive. Suspended sediment not does appear to be one of the factors limiting algal blooms.

The average ammonia concentration in Enemy Swim Lake was 0.02 mg/L with the highest concentrations found in the winter. The average concentration of nitrate-nitrite was 0.10 mg/L. The average total phosphorus concentration in Enemy Swim Lake was 0.028 mg/L. The phosphorus concentration is high enough to produce large algal blooms if favorable conditions exist.

Fecal coliform bacteria counts were below detection limits in all but one inlake sample during the project period. Only 10 colonies per 100 ml of water were counted for the one sample.

Chlorophyll *a* concentrations were relatively high with respect to the nutrient concentrations found in Enemy Swim Lake. Summer chlorophyll *a* concentrations were as high during the project, as ever recorded.

The phytoplankton community of Enemy Swim Lake was dominated by blue-green agae with diatoms more common than green algae during this project. The dominant blue-green species found in Enemy Swim Lake were not indicative of highly eutrophic lakes. The algae taxa are very diverse in this lake, populations are relatively low for eastern South Dakota. Enemy Swim Lake does have nuisance species present, however, no intense algal blooms occurred during the project period.

Trophic State Index

The average TSI in Enemy Swim Lake was 50.37 ranking Enemy Swim Lake as slightly eutrophic. The total phosphorus TSI (48.92) was slightly lower than the chlorophyll a or the Secchi TSI (50.88 and 51.49 respectively). It appears that the Secchi TSI was dependent on the chlorophyll a TSI. Summer and fall TSI values were much higher than the winter and spring TSI values. This was due mostly to the production of algae during the growing season.

Long-Term Trends

The long-term trend in Enemy Swim Lake from 1979 to 1998 appeared to show slight movement toward a higher eutrophic condition. The data showed, that during the last decade or two, the chlorophyll a TSI values have increased more so than the Secchi or phosphorus TSI values.

Developed vs. Non-Developed Bay

In the attempt to document the affect of septic systems around the lake, no significant water quality difference was found between the two sites (ESLC and ESLT). There was a difference in the algae populations; the sites closer to the developed cabins had significantly more of one blue-green algae species than the site farther from the development. Both sites (ESLC and ESLT) had consistently more algae than sites ESL1 and ESL2. The effect of septic systems may have been more widespread than expected.

Animal Feeding Area Samples

Samples collected between an animal feeding area and the lake found extremely high nutrient concentrations, although the shallow depth of the runoff made sampling difficult. Many parameters were 100 times greater in concentration than any inlake sample collected. The animal waste passing over the adjacent cabin owner's lawn may present human health concerns.

Reduction Response Model

To accurately calculate a reduction response model there needs to be a good relationship between phosphorus and chlorophyll a concentrations. The R^2 value for the chlorophyll a to total phosphorus ratio was 0.546 (zero being the worst and 1.0 being the best). Reduction of phosphorus should result in a reduction in chlorophyll a concentrations.

Limiting Factor for Chlorophyll a Production

Enemy Swim Lake is phosphorus limited; meaning a reduction of phosphorus should reduce chlorophyll a production. There were no instances during the project when algae production was nitrogen limited. The average N:P ration for the project was 36.7.

Recommended Targeted Reduction

It is recommended that a target reduction of 50% in phosphorus inputs to Enemy Swim Lake should be reached. The 50% reduction will most likely move the average chlorophyll *a* TSI from the eutrophic to the mesotrophic level. After implementing best management practices in the watershed, long-term monitoring should be conducted to see if the target has been reached. According to the AGNPS model, a 30% reduction in phosphorus could be reached by implementing BMPs on targeted agricultural lands and animal feeding areas that ranked over 50. An additional 20% reduction could be reached by removing septic leachate from failing or non-existent private waste collection systems around the lake.

Recommendations

Enemy Swim currently has some of the best water quality of all natural lakes in South Dakota. Steps should be taken to preserve and even improve its condition as it is much easier to preserve and protect a lake than it is to restore it from a highly eutrophic condition. According to the AGNPS model and the water quality monitoring data, grain fields on steep slopes with 100% fertilizer availability, animal feeding areas and private septic systems were the most likely sources of nutrients to Enemy Swim Lake. To reach the targeted reduction goal, all cells shown with excessive delivered nitrogen and phosphorus loads should be implemented with BMPs to incorporate applied fertilizer. To eliminate additional nutrient and sediment runoff, it is recommended that animal waste management systems be constructed on all animal feeding areas with rankings over 50. These livestock concerns should also implement NRCS-approved nutrient management plans. Although not quantified, evidence from the septic leach survey showed septic systems were not functioning properly on Enemy Swim Lake. A central sewer collection system or individual containment systems should be installed to reduce the eutrophication caused by septic leachate. If the preceding recommendations are followed, post implementation and long-term sampling should be conducted to monitor improvements and check effectiveness of BMPs.

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APPENDIX A

Septic Leachate Survey

SEPTIC LEACHATE SURVEY
Enemy Swim Lake
Day County, South Dakota

August 30, 1999

Prepared for Day County Conservation District
Webster, South Dakota

ECOSCIENCE
Ecological Restoration & Management Services

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PREFACE

The following report discusses the findings of the Septic Leachate Surveys performed at Enemy Swim Lake (ESL). All Field work was performed by experienced biologists and survey crews familiar with septic leachate detection equipment and methodology. All laboratory analyses were performed by a South Dakota State certified laboratory. Discussion, conclusions, and recommendations of the study are presented in the following report.

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EXECUTIVE SUMMARY

The following study was conducted for the Day Conservation District to locate and qualitatively characterize septic leachate plumes emanating from malfunctioning on-site sanitary systems, i.e. septic tanks. The developed portions of the shoreline of ENEMY SWIM LAKE were intensively scanned using ECOSCIENCE's patented Septic Leachate Detection System during the week of, August 24 – 27, 1999.

Leachate from poorly treated wastewater will adversely impact lake water quality by contributing growth-limiting nutrients, typically phosphorus or nitrogen. The input of bacteria laden wastewater may also pose a health hazard to those pursuing body contact recreation. Improperly treated wastewater often contains potentially pathogenic viruses and bacteria. Elevated concentrations of nutrients promote the growth of nuisance forms of aquatic vegetation and accelerate the eutrophication, or "aging process" of the lake.

Over 40 suspected leachate plumes were identified on ENEMY SWIM LAKE during the present investigation. The survey also identified several shoreline areas of extended plume readings. For budgetary reasons, only 20 suspected septic leachate sites were sampled. Laboratory analyses of 26 sample stations, which included 4 background, one inlet, and discharge from a wetland revealed elevated total phosphorus (TP) and nitrogen (TKN) concentrations. Fecal contamination was also identified at over 30% of the selected sample stations.

In view of the study findings. We recommend the Day County Conservation District consider the following recommendations:

1. Seek immediate assistance from Local, State and Federal Agencies to develop a comprehensive wastewater collection and treatment system for Enemy Swim Lake. Basin topography, soil types, and a number of other factors limit the effectiveness of on-site sanitary systems as a wastewater disposal method for ENEMY SWIM LAKE.

2. Seek assistance from the South Dakota Department of Environment and Natural Resources, Sisseton-Wahpeton Sioux Tribe, and Enemy Swim Sanitary Sewer District in enforcing violated sanitary codes.

3. Encourage the use of low or no phosphate containing detergents and household cleaners. A listing of the phosphate contents of some detergents is provided in Appendix B.

4. Encourage the use of water conservation devices in all households. A list of such items with percent water usage reductions is presented in Appendix C.

5. Prohibit the use of phosphorus-containing lawn fertilizer.

6. Continue to monitor selected water quality and bacteriological parameters on a routine basis. As a minimum, we recommend re-sampling the identified sites. The background stations should also be sampled. Water samples should be collected during peak wastewater loading conditions and analyzed for wastewater indicator parameters. The use of groundwater tracers and well point samplers should also be employed at the identified locations to further quantify wastewater discharges.

7. A comprehensive in-lake water quality and watershed assessment of ENEMY SWIM LAKE has been completed and will be published by spring 2000. The nutrient budget calculated for ENEMY SWIM LAKE will be useful for determining the significance of phosphorus and nitrogen contributions from on-site systems.

INTRODUCTION

In recent years the residents of ENEMY SWIM LAKE have become increasingly concerned about the accelerated rate of eutrophication, or ‘aging” of their Lake. Increasingly, nuisance growths of submergent aquatic macrophytes occupy many littoral zone regions of the lake, and both planktonic and filamentous algal populations appear to “bloom” more frequently than in the past. The trend toward more eutrophic conditions will continue until a sound lake / watershed management program is developed and implemented at ENEMY SWIM LAKE. The local economy will also suffer if sportfishing declines with the diminishing lake water quality.

All lakes age. The process of aging is defined as eutrophication and, in actuality, represents a series of stages whereby the lake becomes increasingly productive. The aging may proceed slowly over hundreds of years. However, human influence can dramatically accelerate the eutrophication process. Land development within the watershed results in the increased influx of both displaced sediment and nutrients. Stormwater is the primary vehicle for introducing pollutants into a lake. Thus, during every storm event, deleterious substances and organic materials are discharged to the lake. The loading of nutrients and sediments contributes to increased productivity and loss of water depth and volume, which further accelerates the aging.

Improperly operating septic systems will also significantly accelerate the eutrophication process. Nitrates and phosphates are prime constituents of domestic wastewater. Septic systems of improper design, and those set too close to the lake, lead to the contamination of groundwater. This groundwater eventually reaches the lake, where it adds to the reserves of available nutrients. The nutrient contribution of septic systems at ENEMY SWIM LAKE may be significant due to their density and proximity to the water’s edge. In addition, the drainage basin topography and geology may limit the efficacy of on-site sanitary systems for wastewater treatment. According to the Soil Survey of Day County, South Dakota, the majority of the immediate shoreline is composed of Sioux (SbB) gravelly loam sand with 2 – 6 % slopes. SbB soils are excessively drained gravelly sand units, which possess *severe limitations for septic tank absorption fields*, and also offer poor filtering capabilities. Other soils including RsB –

Renshaw-Sioux complex with 2 to 9 % slopes, and MnA – Minnewasta sandy loam with 0 to 2 % slopes that are excessively drained or possess high seasonal water tables (1.0 – 3.5 feet). Likewise, there is little or no area for the sitting of adequate absorption fields for most of the residential dwellings occupying the perimeter of ENEMY SWIM LAKE.

In 1997, the Day Conservation District conducted a septic system survey. Only fifty-five percent of the surveys mailed to lake property owners were completed and returned. Previous investigations have demonstrated that a significant number of non-respondents typically do not provide proper on-site system maintenance, or utilize wastewater facilities with less than acceptable treatment. Respondents provided the following information.

Type System	**Number**
Septic tank with Drywell	8
Septic Tank with Drainfield	88
Holding Tank	10
Open Bottom	3
Outhouse (Open Bottom)	11

In 1997, the NE-SO-DAK Bible Camp constructed a gray water system for all camp facilities that has been designed to allow for the additional hookup of all lake cabins/homes along the Dakota and Sandy Beach developments.

In order to provide additional information on this important component of ENEMY SWIM LAKE, a Septic Leachate Survey was conducted. The purpose of the survey was to locate and qualitatively characterize suspected septic leachate plumes emanating from malfunctioning on-site sanitary systems. The ECOSCIENCE Type 2100 Septic Leachate Detection System was utilized for this work. Fieldwork was performed from August 24 through August 27, 1988. Approximately 3.7 miles of shoreline was examined during this investigation. *Dennis Skadsen*, an aquatic biologist with the Day County Conservation District accompanied ECOSCIENCE during all aspects of this work.

BACKGROUND

On-site sanitary systems usually rely on three components to adequately treat domestic wastewater. The septic tank serves primarily as a settling basin and, although partial purification is accomplished, the effluent contains large quantities of nitrogen, phosphorus, bacteria, and other decomposition products (Figure 1).

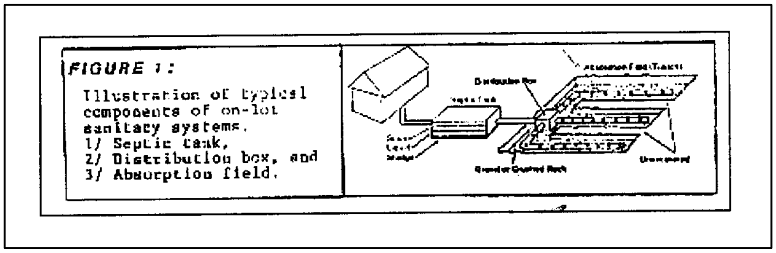


FIGURE 1:
Illustration of typical
components of on-lot
sanitary systems.
1/ Septic tank,
2/ Distribution box, and
3/ Absorption field.

Figure 1 Typical On-Site Sanitary System

In a properly operating anaerobic septic tank, organic nitrogen is hydrolyzed to ammonia-nitrogen (NH3-N) and passively released into the aerobic absorption field. Here, the ammonia-nitrogen, and any organic-nitrogen which may be present are quickly converted to nitrite-nitrogen (N02-N) by Nitrosomonas, then to the final oxidative product nitrate (N03-N) by Nitrobacter. Organic phosphorus is hydrolyzed in the tank to the orthophosphate ion (P04) and also passively released to the absorption field along with some organic forms. As the effluent percolates through the absorption field, phosphate removal is accomplished by a number of mechanisms, including absorption on soil particles and precipitation with calcium, aluminum, iron, and other metals. Biological immobilization by plant uptake also occurs in some areas. Properly designed and maintained on-site sanitary systems may achieve a phosphorus removal efficiency of over 90%.

The problem in a lake setting is that the groundwater depth is usually quite shallow along the shoreline. As a result, the soil is often saturated and anaerobic. Under these conditions, poorly treated wastewater is introduced into the lake with the ground water (Figure 2).

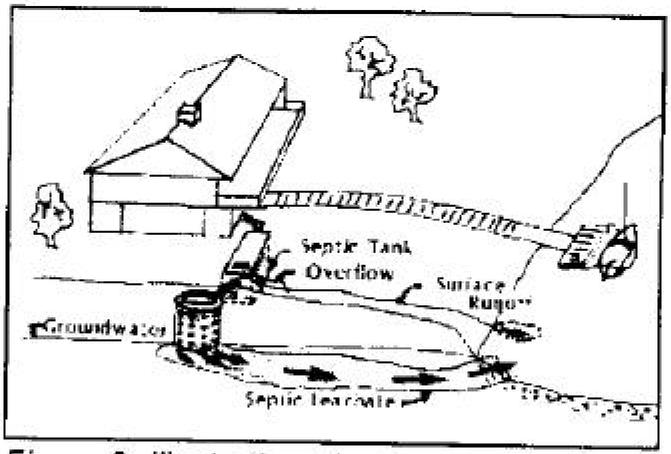


Figure 2. Illustration of typical septic tank performance at lake setting.

METHODOLOGY AND SURVEY PROCEDURE

The Septic Leachate Detection system utilized by ECOSCIENCE is a sophisticated, portable field unit capable of scanning extensive shoreline areas in a relatively short period of time. The system consists of a subsurface probe, water intake pump, analysis control unit, and graphic recorder. The Detector is designed to continuously monitor and document relative increases in fluorescence and conductivity. Both parameters are normal constituents of septic leachate.

Calibration of the unit is conducted before the Survey begins with a 2% solution of secondarily treated effluent water. The unit is re-calibrated and checked for accuracy several times a day. For calibration purposes at ENEMY SWIM LAKE, five liters of representative lake water and 100 milliliters of STP effluent from the nearby Pickerel Lake Sanitary District Lagoon were utilized. Secondarily treated wastewater effluent is used for calibration purposes because its conductive and fluorescence properties are similar to that of typical septic tank effluent. The survey at ENEMY SWIM LAKE was started at Cottage #368 on north ENEMY SWIM LAKE, and continued in a counter-clockwise direction. As the survey team moved forward (at a very slow walking pace), lake water was continuously drawn from just above the sediment-water interface and passed through the analyzer unit.

As the water flowed through the detector, separate conductivity (inorganic) and fluorescence (organic) signals were generated, depending on the relative increases in each parameter. The joint signals were then sent to the analog computer, which compared them against the background signals to which the instrument was originally calibrated (Figure 3).

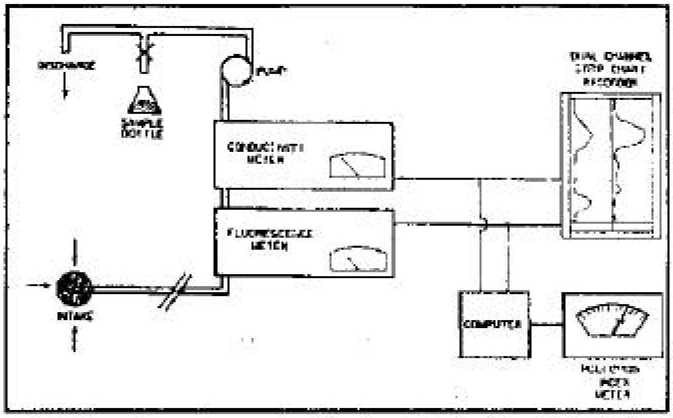


Figure 3. Diagram of ECOSCIENCE's Septic Leachate Detector

In addition, signal increases were evident to the survey team by an LED meter and audible beeper calibrated to instrument response intensity. Whenever significantly elevated readings were recorded, Dennis Skadsen would compile detailed notes on the plume's location, and a digital photograph was taken for future reference (Appendix A).

In order to maintain quality assurance, all water samples collected each day were transported on ice to Waubay, SD for shipment to the State Health Laboratory located in Pierre, South Dakota. All samples were analyzed for the following parameters:

Fecal Coliform – MF
Alkalinity – P
Alkalinity – M
Solids, Total
Solids (Suspended)
Ammonia

Nitrate
TKN
Phosphorus, Total
Phosphorus, Total Dissolved
Chloride
MBAS (Detergents)

All water analyses were performed according to Standard Methods for the Examination of Water and Wastewater, 19th Edition. Field measurements of pH, Dissolved Oxygen, and Secchi Disk Visibility were also performed in situ.

RESULTS

Over forty (40) suspected septic leachate plumes were identified during this investigation. However, only 20 of the identified sites were selected for further laboratory analyses due to budgetary reasons. The sites selected for lab analysis were chosen on the basis of instrument readings generated during the actual fieldwork. Water samples were collected from those stations with the highest organic or inorganic readings, or combinations of both. In addition, four (4) background stations, one (1) inlet stream, and one (1) discharge from a wetland area were also analyzed for comparative purposes. The stations selected for analyses are described in Table 1 and further identified by digital photographs in Appendix A.

Results of the laboratory analyses for all 26 selected stations are provided in Table 1. Instrument readings for all 26 sites have also been provided for review in Figure 4.

Phosphorus

The mean background total phosphorus (TP) concentration in ENEMY SWIM LAKE (0.026 mg/1) was exceeded in 74% of the sample stations. The highest TP encountered was 0.084 mg/l at sample station number 20. Other stations with exceptionally high TP values were numbers 9 and 19. The relationship between dissolved and Total Phosphorus concentrations is provided in Figure 5. Note: The TP value for SLD 11 was not included in the mean computation. There are a number of factors involved in the response of a lake to nutrient loading. However, in order to minimize the growth of problem aquatic vegetation, TP concentrations should not exceed 0.02 mg/1. Waters with concentrations above 0.02 mg /l often have problems with algae or weeds. Values in excess of this threshold limit were found at most sample stations, including all background stations and the inlet and wetland discharge stations Table 1 and Figure 5.

Nitrogen

Most of the nitrogen in ENEMY SWIM LAKE at the time of sampling was in the organic form. TKN values ranged from to 0.54 to 1.41 mg/l. Using a mean TKN background concentration of 0.82 mg/l, 74% of the suspected septic leachate sites possessed values exceeding background conditions. The amount of ammonia-nitrogen (NH3-N) present in lake waters will vary both seasonally and spatially within the lake. In typical aerobic surface waters, NH3-N is usually found only near trace levels. All stations including background and apparent contaminated locations including the inlet creek were below detection limits. It is possible laboratory results were not representative. The same comments apply for nitrate determinations, which provided little information.

Table 1. Enemy Swim Lake Septic Leachate Survey. Laboratory analyses of selected water quality samples.

August , 1998																		
Station	**Organic**	**Inorganic**	**F.C.**	**Alk - P**	**Alk - M**	**Solids,T**	**Solids, S**	**NH3**	**NO3**	**TKN**	**TP**	**TP - Dis**	**Chloride**	**MBAS**	**pH**	**D.O**	**Secchi**	**Comments**
	% Scale	% Scale	Count/100 ml	mg/L as CACO3	mg/L as CACO3	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Units	mg/L	feet	
SLD 1	**26**	**17**	**< 10**	**8**	**189**	**261**	**5**	**< 0.02**	**< 0.1**	**0.56**	**0.026**	**0.013**			**8.58**	**7.8**	**4.0**	**Background - Center Lake - ESL 2**
SLD 2	38	20	< 10	8	189	264	7	< 0.02	< 0.1	0.65	0.038	0.012	4	< 0.01				Lot # 8 - Extended organic to SLD 3
SLD 3	33	25	< 10	7	191	269	7	< 0.02	< 0.1	0.96	0.026	0.016	3					Lot # 10 - West Shepards Bay
SLD 4	30	18	50	4	201	415	143	< 0.02	< 0.1	0.96	0.309	0.011	4	< 0.01		8.0		4 Trailers East of A Block
SLD 5	34	31	10	10	188	265	7	< 0.02	< 0.1	0.60	0.038	0.01	4	< 0.01		8.0		5 Trailers East of A Blocks
SLD 6	36	42	10	8	188	262	8	< 0.02	< 0.1	0.54	0.026	0.008	4	< 0.01		8.0		Gray cabin one east of Hagens
SLD 7	22	14	< 10	7	188	270	14	< 0.02	< 0.1	0.61	0.039	0.011	4	< 0.01		8.0		Cabin one East of Erdsman
SLD 8	73	57	< 10	7	188	265	9	< 0.02	< 0.1	0.55	0.025	0.01	4	< 0.01				Pleasure Park 2 Sotry Cedar Cabin
SLD 9	42	19	< 10	11	188	290	40	< 0.02	< 0.1	1.01	0.078	0.008	4		8.57		4.0	Yellow cabin Second West
SLD 10	73	20	< 10	11	186	276	17	< 0.02	< 0.1	1.13	0.029	0.012	4	< 0.01	8.57	9.4	4.0	5G Destad Trailer House
SLD 11	**30**	**17**	**< 10**	**5**	**189**	**262**	**7**	**< 0.02**	**< 0.1**	**0.81**	**0.092**	**0.01**	**4**		**8.82**	**6.4**	**4.6**	**Background - Center South Bay**
SLD 12	40	12	< 10	7	191	277	14	< 0.02	< 0.1	1.16	0.031	0.011	4		8.70	6.4	4.0	South Bay 2 Story Cedar
SLD 13	62	12	< 10	7	189	270	9	< 0.02	< 0.1	1.17	0.034	0.008	4		8.70	6.4	4.6	South Bay Gray Cabin
SLD 14	22	20	< 10	7	188	262	10	< 0.02	< 0.1	1.15	0.027	0.01	4		8.66	7.4	4.6	South Bay Yellow Cabin Red Porch
SLD 15	53	14	< 10	7	192	267	20	< 0.02	< 0.1	1.02	0.026	0.01	4		8.58	7.6	4.6	South Bay 2 Cabins East of Kadings
SLD 16	44	24	< 10	9	188	265	14	< 0.02	< 0.1	0.84	0.03	0.009	4		8.53	8.9	4.6	Sandy Beach Resort - near gas pump, heavy filamentous algae
SLD 17	58	18	< 10	10	189	272	14	< 0.02	< 0.1	0.82	0.031	0.008	4		8.58	9.0	4.6	Dakota Beach East 3 South of Grace
SLD 18	**22**	**20**	**< 10**	**12**	**179**	**255**	**8**	**< 0.02**	**< 0.1**	**0.85**	**0.023**	**0.008**	**4**		**8.65**	**10.2**	**4.6**	**Background - Church bay**
SLD 19	15	12	< 10	12	186	274	22	< 0.02	< 0.1	1.32	0.066	0.01			8.68	10.2	4.6	Church Bay - Old cabin
SLD 20	24	12	< 10	10	185	299	50	< 0.02	< 0.1	1.41	0.084	0.01	3		8.73	8.1		Dakota Beach West Yellow cabin
SLD 21	34	12	10	9	182	291	50	< 0.02	< 0.1	1.67	0.038	0.012	3		8.69	8.1	4.1	Dakota Beach West No. Red Cabin
SLD 22	25	26	30	9	186	258	7	< 0.02	< 0.1	1.11	0.012	0.008	4			8.4	4.1	Dakota Beach East SE Corner Point
SLD 23	**30**	**28**	< 10	**7**	**190**	**273**	**8**	< 0.02	< 0.1	**1.06**	**0.029**	**0.009**	**4**		**8.60**	**7.9**	**4.1**	**Background - East Lake**
SLD 24	248	48	170	0	206	266	5	< 0.02	< 0.1	1.36	0.083	0.046	2		7.65	2.2		East Lake wetland discharge to lake, between 2 trailers
SLD 25	304	22	70	10	192	296	43	< 0.02	< 0.1	1.2	0.105	0.01	4			7.9	4.1	East Lake Old Blue Trailer
SLD 26	364	230	230	0	318	413	3	< 0.02	< 0.1	1.17	0.028	0.02	3		7.65	4.5		Inlet Creek

Bold indicate Background Sample Stations.

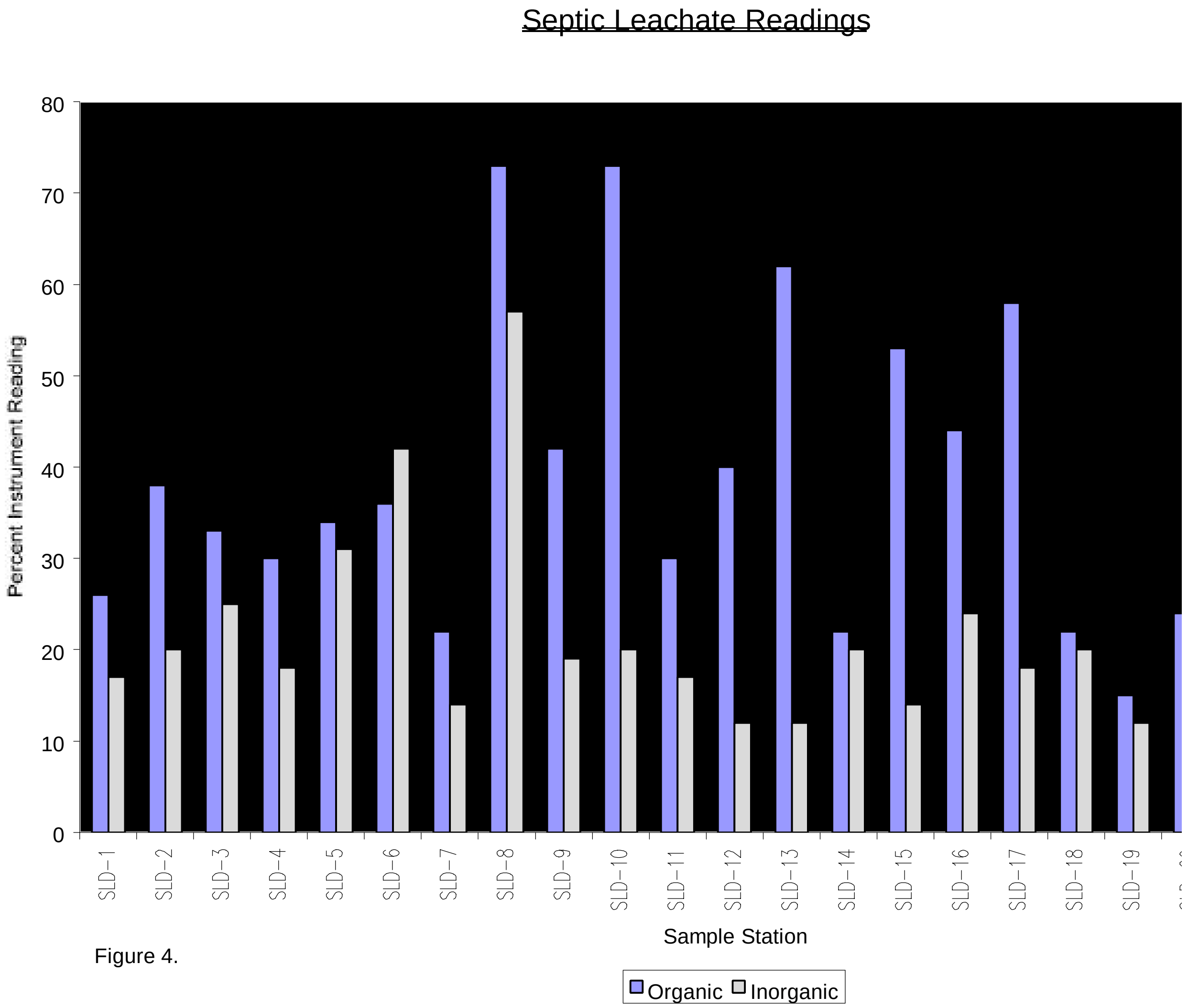

Septic Leachate Readings
Percent Instrument Reading
80
70
60
50
40
30
20
10
0
SLD-1
SLD-2
SLD-3
SLD-4
SLD-5
SLD-6
SLD-7
SLD-8
SLD-9
SLD-10
SLD-11
SLD-12
SLD-13
SLD-14
SLD-15
SLD-16
SLD-17
SLD-18
SLD-19
Sample Station
Organic
Inorganic

Figure 4.

Total Phosphorus/Total Diss. Phosphorus Relationship Per Sample

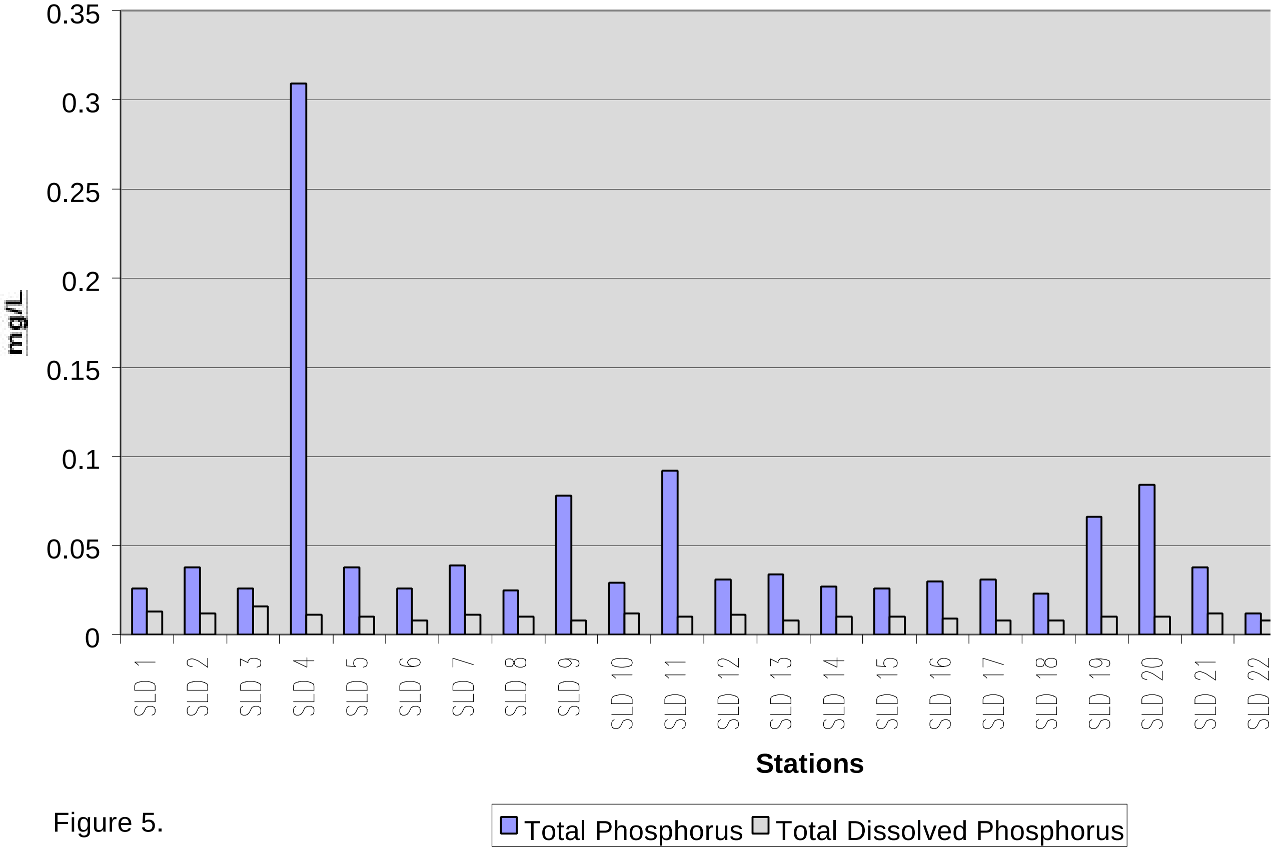


Figure 5.

Chlorides

Unlike phosphates and nitrogen, chlorides are not growth limiting factors for freshwater plants. However, large concentrations of chlorides are present in wastewater. Chlorides are also very soluble and mobile, and large quantities are continually being introduced into septic systems. For these reasons, chlorides are often useful as indicators of sewage input. At Enemy Swim Lake, chloride concentrations were low and do not appear to be a good indicator of septic leachate.

Fecal Coliform Bacteria

Fecal Coliform bacteria (FC) are a harmless group of organisms normally found in the intestines of warm-blooded animals, including man. They are not normal inhabitants of water, although they may survive for a few days to weeks if introduced. Their presence in lake water is therefore indicative of recent contamination. Most state agencies do not allow body contact in waters where fecal coliform density is equal to or greater than 200 colonies per 100-milliliter sample. Studies have shown that pathogenic (disease-producing) viruses or bacteria may be present when FC densities reach this level. Of the sampled waters, only the inlet creek possessed values in excess of 200 with 230 colonies per 100-ml sample. It is likely that non-point pollution including cattle or wildlife may be the contributing source for this station. However, while detected at low densities, fecal contamination was identified at sample stations 4, 5, 6, 21, 22, 24, and 25. Bacteriological sampling is highly variable and dependent on many factors. Additional sampling should be performed at the identified sites under various meteorological conditions to further document the bacteriological quality of ENEMY SWIM LAKE.

DISCUSSION

The efficacy of on-site sanitary systems is governed by a number of factors, including those discussed earlier in this report. The performance of individual systems will also vary seasonally according to the prevailing hydrologic regime, wastewater input, and other variables. Under the conditions of the present survey, over 40 suspected leachate plumes were identified at ENEMY SWIM LAKE. Laboratory analyses of 26 sites provided evidence that some of these systems, and possibly others, were releasing poorly treated wastewater to the Lake.

Nutrient input from malfunctioning systems will influence water quality and encourage the growth of nuisance aquatic vegetation on a localized basis. The cumulative impact of discrete nutrient discharges must also be considered since internal recycling is occurring in ENEMY SWIM LAKE. In addition to the role septic tank discharges may play in the eutrophication process, it is also important to consider the health hazards which may be created by poorly operating units. Pathogenic viruses and bacteria may be introduced into the waters during periods of hydraulic overloading.

Finally, since a nutrient budget of ENEMY SWIM LAKE has not yet been completed, it is unclear whether the amount of phosphorus contributed by the identified septic systems is significant when viewed on a lake wide basis. A nutrient budget will be part of the complete watershed and lake assessment report to be published, Spring 2000.

SUMMARY AND RECOMMENDATIONS

A septic leachate survey of ENEMY SWIM LAKE was conducted during a period of peak wastewater loading during the summer of 1998. The entire developed shoreline of the lake was examined using the ECOSCIENCE Septic Leachate Detector System. The purpose of the survey was to locate and qualitatively characterize septic plumes emanating from malfunctioning on-site sanitary systems.

Over forty – (40) potential septic leachate plumes were identified. In addition, four (4) stations were chosen to reflect background conditions, and one (1) inlet stream and a wetland discharge area were sampled. In total, water samples from twenty-six (26) stations were analyzed. The laboratory analyses of water samples collected from plume locations demonstrated the existence of a significant number of malfunctioning systems at ENEMY SWIM LAKE. The presence of elevated nutrients and fecal contamination indicated that many systems are releasing poorly treated wastewater effluent. It is likely that rapid dilution / flushing of septic leachate plumes occurs from the combination of the excessively drained and poor filtering capacity of theSbB soils, and wind generated wave action present throughout much of the survey. In view of the results of the survey and the need to protect ENEMY SWIM LAKE from further lake water quality degradation, we recommend that South Dakota DNR and other regulatory agencies complete a nutrient budget for ENEMY SWIM LAKE. Further, the following recommendations are also offered for consideration:

1. Seek immediate assistance from Local, State and Federal agencies to develop a comprehensive sewage collection and treatment facility for ENEMY SWIM LAKE. In the interim period, establish a comprehensive inventory and maintenance program for septic systems located within the watershed. The lots, adjacent to the identified plume locations should receive priority treatment. A sample survey form is also provided in Appendix B.

2. Seek assistance from the South Dakota Department of Environmental and Natural Resources, Sisseton-Wahpeton Sioux Tribe, and Enemy Swim Sanitary Sewer District in enforcing violated sanitary codes.

3. Encourage the use of low or no phosphate containing detergents and household cleaners. A listing of the phosphate content of some detergents is provided in Appendix C.

4. Encourage the use of the water conservation devices in all households. A list of much items with percent water usage reductions is presented in Appendix D.

5. Prohibit the use of phosphorus-containing lawn fertilizer. Information on no phosphorus lawn fertilizers is provided in Appendix E.

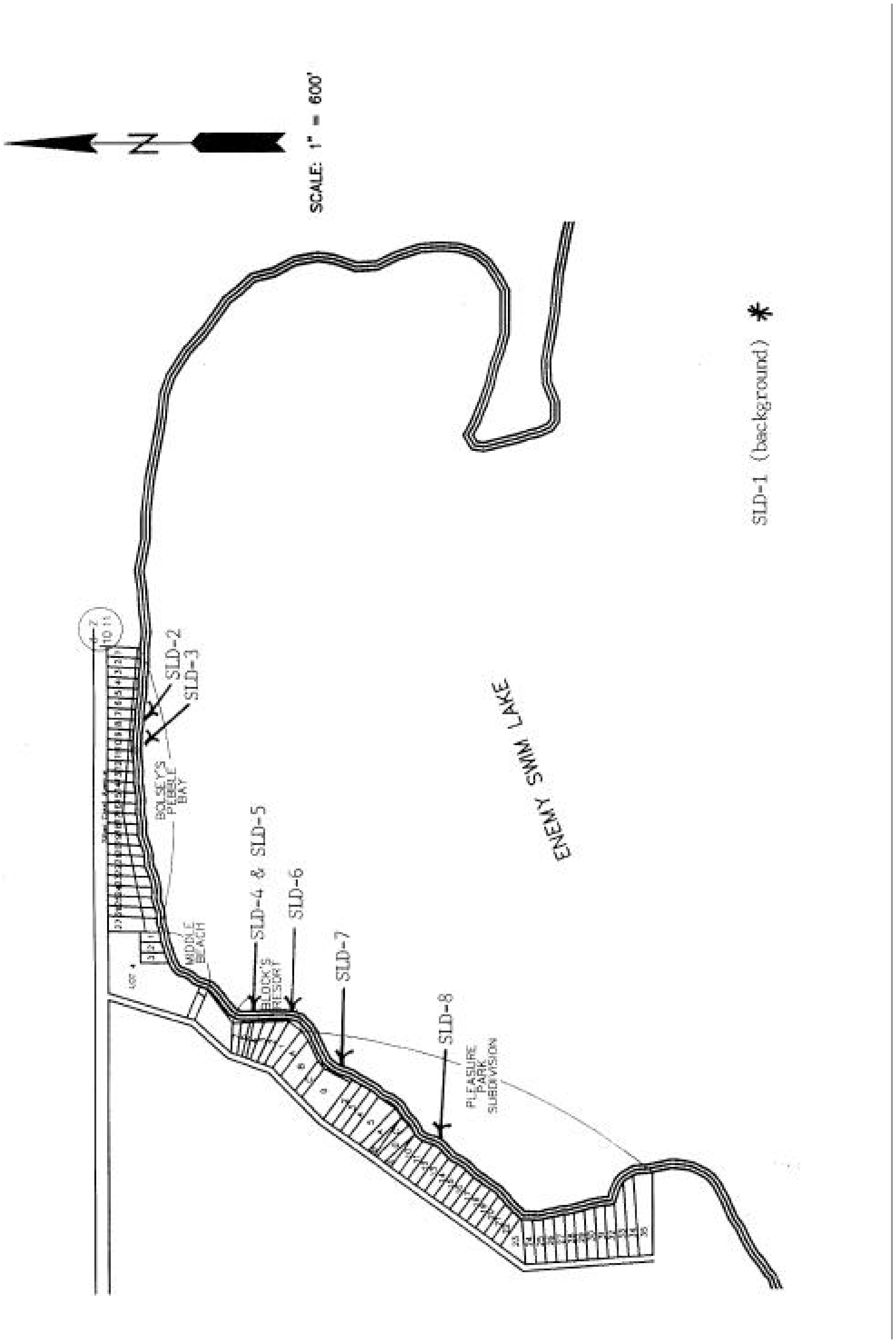
6. Continue to monitor selected water quality and bacteriological parameters on a routine basis. As a minimum, we recommend re-sampling the identified sites. The background stations should also be sampled. Water samples should be collected during peak wastewater loading conditions and analyzed for wastewater indicator parameters. The use of groundwater tracers and well point samplers should also be employed at the identified locations to further quantify wastewater discharges.

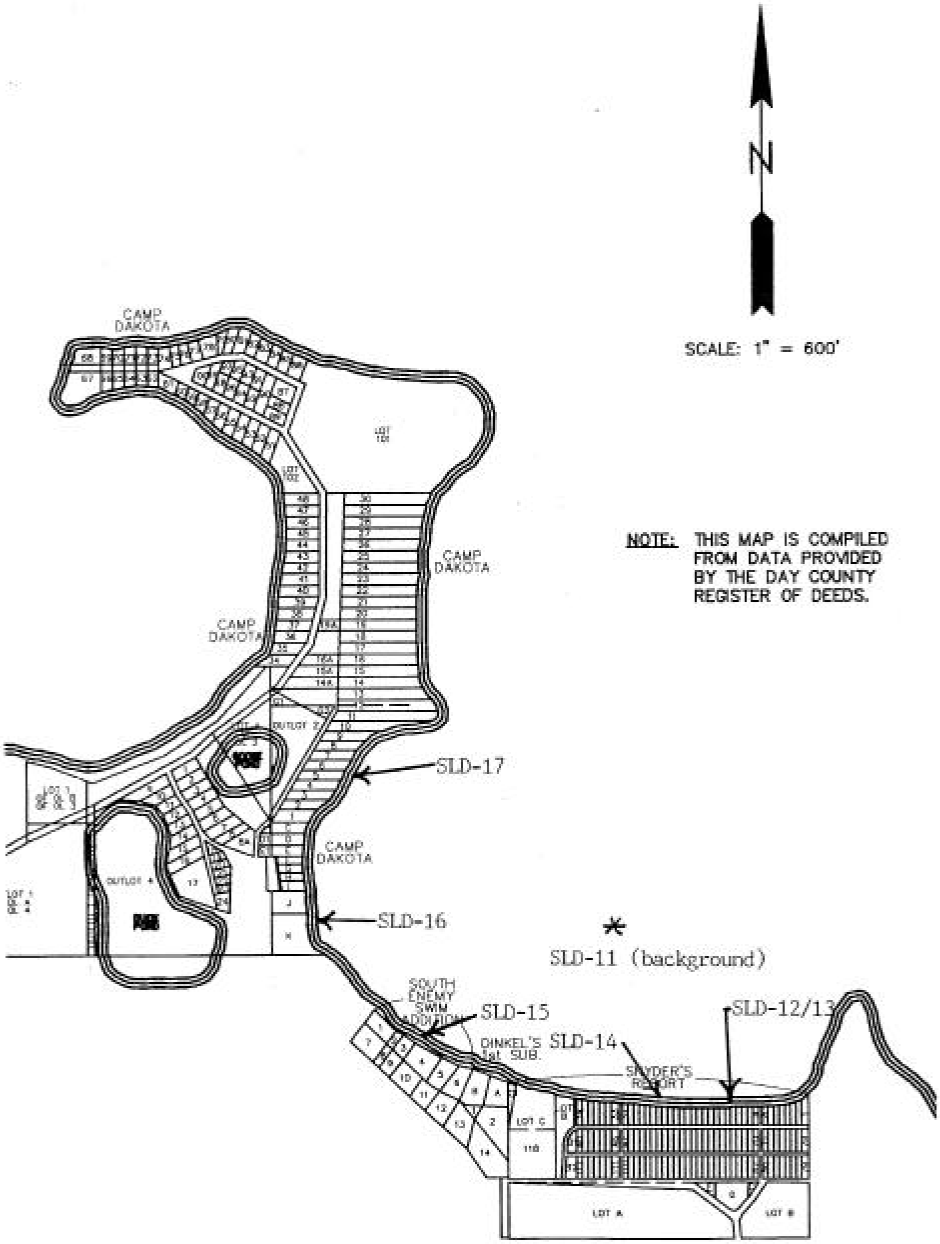
7. A comprehensive in-lake water quality and watershed assessment of ENEMY SWIM LAKE has been completed and will be published, by spring 2000. The nutrient budget for ENEMY SWIM LAKE will determine the significance of phosphorus and nitrogen contributions from on-site systems.

Appendix A

Photographs of Locations of Suspected Septic Leachate Plume Locations
Enemy Swim Lake: August 24-27, 1998

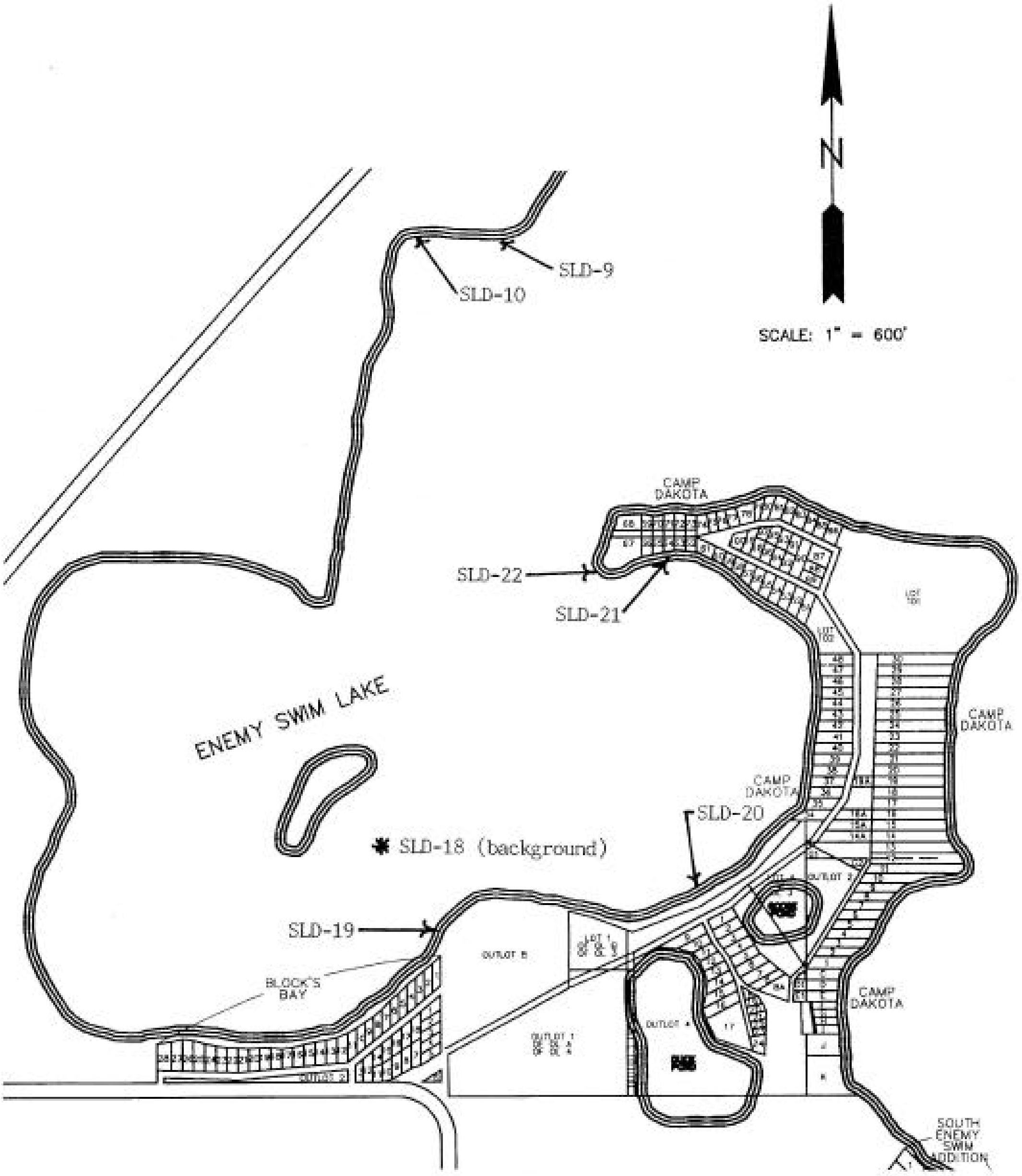
Photos can be found in the original ECOSCIENCE report.

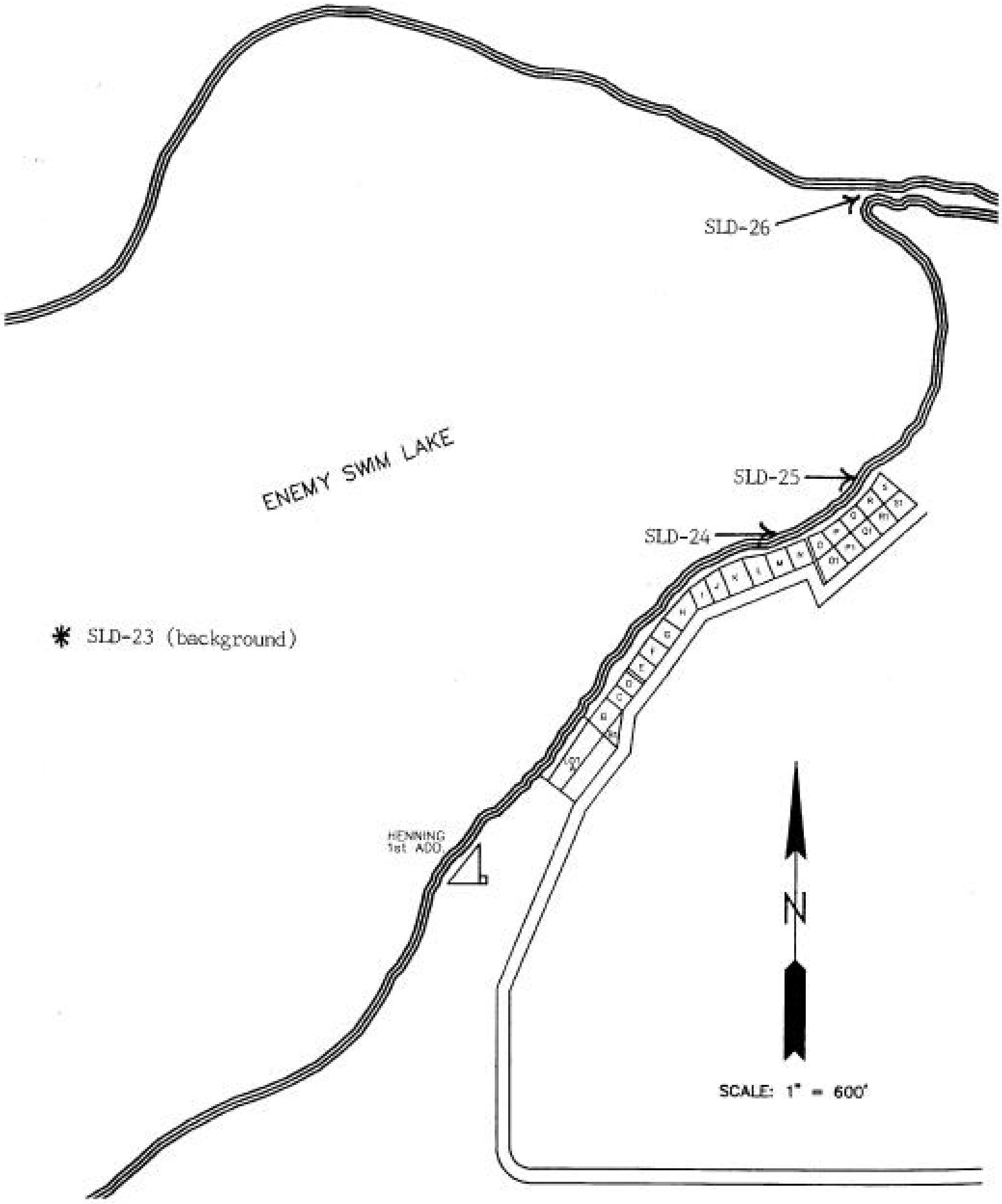

N
SCALE: 1" = 600'
SLD-2
SLD-3
BOLSEY'S PEBBLE BAY
MIDDLE BEACH
LOT 4
SLD-4 & SLD-5
BLOCK'S RESORT
SLD-6
SLD-7
SLD-8
PLEASURE PARK SUBDIVISION
ENEMY SWIM LAKE
SLD-1 (background) *



SCALE: 1" = 600'

NOTE: THIS MAP IS COMPILED FROM DATA PROVIDED BY THE DAY COUNTY REGISTER OF DEEDS.


N
SCALE: 1" = 600'
SLD-9
SLD-10
CAMP DAKOTA
SLD-22
SLD-21
ENEMY SWIM LAKE
CAMP DAKOTA
CAMP DAKOTA
SLD-20
SLD-18 (background)
SLD-19
OUTLOT B
BLOCK'S BAY
OUTLOT 1
OUTLOT A
OUTLOT 2
CAMP DAKOTA
SOUTH ENEMY SWIM ADDITION


SLD-26
ENEMY SWIM LAKE
SLD-25
SLD-24
✱ SLD-23 (background)
HENNING
1st ADD.
N
SCALE: 1" = 600'

APPENDIX B

Private Sewage Disposal Survey Sheet

SUGGESTED FORMAT: Private Sewage Disposal Survey Sheet.

Date ____________________

Date Collected By ____________________

Type of Property ____________________

Owner ______________ Address ____________________

Name of lake/stream ___________ Subdivision _________ Lot# _____

Type of System: Septic tank ___ Drainage Field ___ Seepage Pit ___ Cesspool ___

Privy ___ Holding tank size ___ Other ____________________

Number of persons served _________ Number of bedrooms _________

If restaurant etc., number of persons served per day _____ No. of seats ____

Area of drainage field or seepage pit (describe) ______________

Date of installation ___________ Name of installer ______________

Septic tank permit ____________

Elevation above lake or stream of ground surface at soil absorption system site _________

High water elevation of lake/stream (above that on date of survey) _______

Percolation test made _____ Depth of ground water _____ Depth of rock ______

Depth of borehole __________ Soil type ____________________

How often septic tank pumped __________ Vent on seepage bed ________

Slope of lot in area of soil absorption system ______________

Well above sewage system ____________________

Type of well ___________ Report of analysis and date ____________

Evidence of overflow: To ground __________ To lake ____________

Dye placed in _________ Evidence of dye: To ground ______ To lake _______

Clear water disposal, if any ____________________

Comments ____________________

From: Lake Property Sanitary Surveys, An Inland Lake Renewal and Shoreline Management Demonstration Project Report. Upper Great Lake Regional Commission, 1972.

APPENDIX C

PHOSPHORUS CONTENT OF SOME COMMON DETERGENTS

LAUNDRY DETERGENTS:

Detergent	Phosphorus Content (%PO4 as P)	Phosphorus per/load (Grams P/Load)
*A & P	trace	trace
*Ajax	2.5%	2.0 gm/1 cup
*All (powder)	trace	trace
*All (liquid)	0	0
*Amway SA8 phos. free	0	0
*Amway SA (limited phos.)	8.1%	4.5 gm/per 1/4c *used
*Arm and Hammer	0.0	0
*Bold.3	7.1%	6.0 gm/1 cup
*Cheer	9.5%	6.1 gr/3/4 cup
*Cold Power	2.5%	2.0 gm/1 cup
*Dash	8.0%	5.8 gm/1/2 cup
*Dreft with Borox	8.2%	7.0 gm/per 1/1/4 *cup
*Dynamo	0	0
*Era	0	0
*Fab (power)	7.1%	6.0 gm/1 cup
*Fab (liquid)	0	0
Fresh Start	14.7%	5.7 gm/per 1/4c *used
*Ivory Snow	0	0
*Purex	0	0
*Shaklee Basic L	0	0
*Rinso	trace	trace
Solo	0	0
*Tide (liquid)	0	0
*Tide (powder)	8.4%	6.3 gm/3/4 cup
*Trend	0	0
*Wisk	0	0
*Yes	0	0

NOTE: * indicates a product is biodegradabel which means that the ingredients (surfactants) are broken down by natural biological action. This capability helps to eliminate foaming problems in our lake.

DISHWASHING DETERGENTS:

Detergent	Phosphorus Content (%PO4 as P)	Phosphorus per/load (Grams P/Load)
A & P	8.7%	2.1 gm/2 tbsp.
All	8.7%	2.4 gm/2 tbsp.
Amway-8.7 phosphate	8.7%	1.3 gm/1 tbsp.
Amway-soft water formula	6.0%	.9 gm/1 tbsp.
Cascade	8.3%	2.2 gm/2 tbsp.
Electra Sol	8.7%	2.6 gm/2 tbsp.
Finish	8.7%	2.6 gm/2 tbsp.
Shaklee Basi-D	8.7%	.8 gm/2 tbsp.
Sun Light	8.7%	2.4 gm/2 tbsp.

APPENDIX D

WATER CONSERVATION

It is assumed that hydraulic overloading is the primary contributor to creating malfunctioning on-site systems. Hydraulic overloading can be caused by one of the two following reasons: (1) Excessive water usage by residents in the home (e.g. wasteful water habits, leaky faucets, leaky toilets, and/or long durations in the shower) or (2) Wate usage in the home beyond that which the soil is capable of absorbing. This does not necessarily mean that the residents are using excessive amounts of water, but what it does mean is that soil characterisitics make it impossible to absorb wastewater effluent flows.

Either of the two above referenced problems can be corrected with water conservation and/or recycling devices. Our studies indicate that the average home in this part of Pennsylvania uses approximately 200 and 400 gal./day, depending on the number in the family, type of water demanding household appliances and user habits.

Studies indicate that wastewater flow reduction accomplished at the source can greatly enhance the life and performance of an on-site disposal system. In many cases the homeowner incorporation of a strict water conservation program in the home can eliminate a malfunction. It is important to note that 80% of the water uses in the home is used by toilet flushing and bathing. Each consuming approximately 40% or the water usage.

The following are examples of water conservation devices and the potential water savings offered by each.

Water Conservation Showerheads - Ordinary showerheads utilize flow rates from 6 gal./min. to 10 gal./min. or even greater. It is recommended that showerheads with a discharge rate of 2 gal./min. be utilized to save water, reduce the amount of grey water generated and reduce the cost of heating hot water.

Flow Control Faucet Aerators - It is recommended that flow control faucet aerators be installed on all kitchen and bathroom sinks. These generally result in 50% water savings with a flow discharge rate of approximately 2 gal./min.

Geberit Low Flush Toilet - This tank with original Swiss design has the capability of easily being installed on any American made tiolet bowl. When this low flush tank is installed on a conventional toilet, the savings are 1.4 gallons per flush and when installed on a water saving toilet the savings are 0.3 gallons per flush. The Geberit also has the following features, quiet flushing/filling, push buttom flush, attractive styling and a ten year guarantee.

One Gallon Water Saver Toilet - When installed as a replacement model, can conserve 30-35% of water usage in a single family residence, shipping weight only 45 lbs., low silhoutte, and durable acrylic construction.

It must be noted that conventional toilets utilize approximately 6 gallons per flush.

Humus Toilet - The composting toilet utilizes no water and can result in a 40% water savings. Composting toilets generally utilize nominal amounts of electricity to provide ventilation and the optimum heat to satisfy the bacteria that breakdown the waste products into environmentally safe compost material.

Grey Water Recycling Device - The Aqua Saver can reduce water usage by approximately 40%. This device collects shower water, bathroom sink waste water and laundry wastewater. After filtration and disinfection this water is recycled (one time) for the purpose of toilet flushing. This unit is equipped with a pumping system to supply water to the toilet tanks.

Black Water Recycling Device - With today's advanced technology, products such as Thetford's Cycle-Let enable construction of commercial facilities on any site regardless of the availability of public sewer and/or DER approval of a site for on-site disposal. This unit recycles black water (toilet and urinal flushing) after advanced treatment including: the biological process of activated sludge, ultrafiltration, carbon absorbtion, and disinfection. Treated effluent can be recycled indefinately for the purpose of toilet/urinal flushing. The limitation of this unit with respect to treatment is that is can only treat up to approximately 30% grey water. Therefore, it is desired that the black water/grey water ratio be a minimum of 70/30.

Suds Saver Washing Machine - This water conservation automatic washing machine recycles the soapy water for future loads and results in water and laundry soap savings. This type machines is highly recommended when homeowners dispose of wastewater on-site.

WATER CONSERVATION EXAMPLES

EXAMPLE NO. 1

Four (4) persons in the home.
Assume 75 gallons/person/day prior to the installation of devices.
Four (4) persons X 75 gal./person/day = 300 gal./day.

Savings Calculations:

Low Flow Showerhead - 75% reductions
40% X 300 gal./day X 75% - 90 gal./day

Gerberit Toilet Tank - 23% reduction
40% X 300 gal./day X 50% = 9 gal./day

Flow Control Faucet Aerators - 50% reduction
6% X 300gal./day X 50% = 9 gal./day

Total Savings - 42.3% or 127 gal./day

EXAMPLE NO. 2

Five (5) persons in the home.
Assume 75 gallons/person/day prior to the installation of devices.
Five (5) persons X 75 gal./person/day = 375 gal./day

Savings Calculations:

Aqua Saver - 40% total reduction, recycle all grey water for toilet use.
40% X 375 gal./day = 150 gal./day

Total Savings - 40% or 150 gal./day

EXAMPLE NO. 3

Four (4) persons in home.
Assume 75 gallons/person/day usage prior to the installation of device.
Four (4) persons X 75 gal./person/day = 300 gal./day

Savings Calculations:

Low Flow Showerhead - 75% reduction
40% X 300 gal./day X 75% = 90 gal./day

One Gallon Flush Toilet - 83% reduction
40% X 300 gal./day X 83% = 100 gal./day

Flow Control Faucet Aerators - 50% reduction
6% X 300 gal./day X 50% = 9 gal./day

Total Savings - 66% or 199 gal.day

APPENDIX B

Fisheries Report

STATEWIDE FISHERIES SURVEYS, 1998
SURVEY OF PUBLIC WATERS
Part 1
Lakes-Region IV

South Dakota
Department of
Game, Fish and Parks
Wildlife Division
Joe Foss Building
Pierre, South Dakota 57501-3182

Annual Report
No. 99-19

Annual Fish Population Surveys
For
Northeastern South Dakota
(Region IV)

by

Matthew Hubers and Brian Blackwell
Webster Office
SOUTH DAKOTA DEPARTMENT OF GAME, FISH AND PARKS
WEBSTER, SOUTH DAKOTA

Annual Report

Dingell-Johnson---F-21-R-31

Job Number---2102

Date---October 3, 1999.

Fisheries Program Administrator Dennis Unkenholz	Department Secretary John Cooper
Assistant Directors Emmet Keyser George Vandel	Division Director Douglas Hanson
Federal Aid Coordinator Wayne Winter	

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY
2102-F21-R-31

Name: Enemy Swim Lake County: Day
Legal description: Sect 15-22, T117N, R53W
Location from nearest town: 8 miles north and 1.5 east of Waubay
Dates of present survey: July 14-16; Sept 21, 1998
Date last surveyed: June 11,15, July 15,16,1997.
Management classification: Warm water permanent
Contour mapped: Date: 1964
Report prepared by: Matthew J. Hubers
Scales read and digitized by: Corey Flor

PHYSICAL CHARACTERISTICS

Surface Area: 2146 acres; Watershed: 22310 acres
Maximum depth: 26 feet; Mean depth: 16 feet
Lake elevation at survey (from known benchmark): Full feet

1. Describe ownership of lake and adjacent lakeshore property:

Enemy Swim Lake is managed by the Dept. of Game, Fish and Parks and under State ownership. The Sisseton-Wahpeton Dakota Nation owns a substantial portion of the lakeshore. The remainder of the shoreline consists of private lots. The Game, Fish and Parks Dept. maintains two public access areas.

2. Describe watershed condition and estimated percentages of land use:

The watershed is comprised of approximately 70% cropland, 15% pasture, 5% woodlands and 10% other agricultural land uses.

3. Describe aquatic vegetative condition:

Submergent vegetation is fairly extensive throughout the lake. Species identified include Ceratophylum demersum, Myriophyllum spicatum, Potamogeton illinoensis, P. richardsonii, P. pussilus, P. pectinatus, P. friesii, P. zosteriformis and Najas quadelupensis. Emergent vegetation is in the form of bulrush and cattail.

4. Describe pollution problems:

No substantial pollution problems have been identified at this time.
Trophic state ranges from eutrophic to mesotrophic.

BIOLOGICAL DATA

Methods:

Enemy Swim Lake netting was conducted on July 14-16, 1998 and electrofishing was accomplished after sunset on September 21, 1889. Seven double frame trap nets with 1.3 m x 1.5 m frames and 1.9 cm mesh as well as three 45.7 m x 1.8 m monofilament gill nets with equal length panels of 1.3 cm, 1.9 cm, 2.5 cm, 3.2 cm, 3.8 cm and 5.1 cm bar mesh were utilized. Nets were fished for approximately 24-hour periods and then moved to new locations. A total of twenty-one frame net sets, six gill net sets, and 60 minutes of electrofishing were utilized. One hundred lengths (mm) and fifty weight (g) sub-samples per species were taken when possible. Fish that were counted, but not measured, were assigned to length groups based upon length distribution of sub-sample. PSD, RSD-P, Wr, length frequency distributions, catch per unit effort (CPUE) (All sizes) and other fisheries indices were calculated using P.C. MINNOW (NGPC 1997). A brief description of indices utilized is given in appendix A. Age and growth data was analyzed using DISBCAL (Frie 1982) and results imported into P.C. MINNOW (NGPC 1997). Scales were taken from walleye, largemouth and smallmouth bass. Creel surveys were conducted from winter of 1996 through the summer of 1998. Results will be briefly mentioned and a comprehensive report issued covering creel surveys upon completion.

Results and Discussion:

Species sampled during this and previous surveys:

1. Walleye (WAE)
2. Yellow Perch (YEP)
3. Bluegill (BLG)
4. Northern Pike (NOP)
5. Largemouth Bass (LMB)
6. Black Crappie (BLC)
7. Smallmouth Bass (SMB)
8. White Bass (WHB)
9. Black Bullhead (BLB)
10. Pumpkinseed (PUS)
11. White Sucker (WHS)
12. Common Carp (COC)
13. Logperch (LOG)
14. Johnny Darter (JOD)
15. Spottail Shiner (SPS)
16. Rock Bass (RKB)
17. Orangespotted Sunfish (OSF)
18. Fathead Minnow (FHM)

Enemy Swim Lake has a very diverse fish community. Almost all game, non-game and forage species common to northeast South Dakota occur. This diverse community is supported by a multitude of habitat types available in the lake itself. Shallow bays, deep-water areas, sandy and rocky shorelines, submerged boulders, underwater rock bars, as well as submergent, floating and emergent vegetation is present. It is perhaps the complexity of this system that makes it difficult to shift population parameters of a species in a direction that increases angler benefit.

Walleye

Low density, as indicated by gill net CPUE's of less than 4.0, had characterized the Enemy Swim walleye population from 1991 to 1994(Figure 3). Densities improved to moderately-low for 1995 and 1996 with gill net CPUE's of 5.6 and 7.3, respectively (Hubers and Pyle 1998). Gill net CPUE of 15.3 in 1997 and 12.8 in 1998 suggested moderate walleye densities (Figure 3). Increase in abundance can, for the most part, be attributed to the 1994 year class which comprised 60% of gill net catch in 1997. In 1998 the 1994 year class contribution to the sample declined to 30%. A second strong year class, namely the 1996 year class, which constituted 52% of the sample, helped maintain walleye abundance (Table 5). The 1996 year class coincides with a small fingerling stocking (Table 9). A 1995 stocking of 411,630 very small walleye fingerlings seems to have failed as only four fish from the 1995 year class were sampled. Year-class strength, as indicated by aged walleye sample, does not correlate well with stocked years. Annual stockings of small walleye fingerlings and/or walleye fry for the past ten years (Table 9) have not shown to significantly contribute to year class strength. Although the origin of the strong 1994 and 1996 year classes can not be fully attributed to either stocking or natural reproduction, indications are that natural reproduction is often weak and sporadic as few strong year classes have been detected since inception of annual surveys in 1991. Fall electrofishing resulted in CPUE of 36.9/hr. young of year walleye, indicating a weak natural reproduced year class in 1998. Only two age-1 fish were seen in gill nets further suggesting that reproduction in 1997 may have been weak.

Growth of walleye is comparable to that of other area lakes with fish reaching 32 cm at age-3 and surpassing the 35.6-cm minimum length limit during their fourth growing season (Table 5). Based on aged sub-sample, length at capture of age-0 fish collected by fall electrofishing ranged from 14-19 cm, age-1 fish ranged from 20-24 cm and age-2 fish were 27-32 cm (Figure 10). Gill nets sampled walleye ranging from 18-73 cm resulting in PSD of 44 and RSD-P of 9 (Figure 11, Table 2). Condition of all length groups sampled, while less than the commonly cited optimum (95-105), is still acceptable with Wr values ranging from 83 for sub-stock (<250 mm) fish to 91 for memorable (>630 mm) to trophy length categories (Table 3).

A winter creel survey conducted from December 1996 to March 1997 estimated angler catch at 36 and harvest at 18 for the four-month period. Catch rates during the winter of 1996/97 were very low and highest catch rates occurred in December at 0.06/hr. Summer anglers from May through August, 1997 caught 16,435 walleye of which 1,045 were harvested. Catch rates for the 1997 summer creel period were very high in June at 2.13/hr and lowest in

August at 0.07/hr. Anglers caught an estimated 16,435 walleye during the summer of 1997 of which 1,045 were kept. The winter creel in 1997/98 encompassed a three-month period from December through February. During this period angler success was higher than that seen the previous winter and anglers caught 1,159 walleye of which 385 were kept. Highest catch rates occurred in December at 0.57/hr. and declined to 0.09/hr. in January and 0.04 in February. The creel period from May through August 1998 yielded higher harvest estimates than seen in 1997. During the summer of 1998 anglers caught 7,720 walleye and harvested 2,282 (almost 30% of fish caught). In 1997 anglers caught more walleye (16,435) but were able to keep only 1,045 (6%). Survey data suggests that the bulk of fish caught in 1997 belonged to the 1994 year class and with the 356-mm minimum length limit in place this year class was unavailable for harvest. In 1998 catchability of this year class most likely decreased but a portion of those caught had surpassed the minimum length restriction and were harvested.

Although some older fish are available, the 1994 year class comprises the majority of fish available to anglers. The 1996 year class should enter the creel by late summer of 1999. Appearances are that the 356-mm minimum length limit serves to protect up coming year classes and extend their contributions to the fishery. Data suggests that complete year class failures are rare but also that the magnitude of year classes present during most years is insufficient to provide an acceptable fishery. A highly competitive environment most likely decreases stocking efficacy of fry and small fingerlings. Costs as well as availability may preclude the use of large fall fingerling stocks as a management tool.

Management Recommendations

1. Maintain 356-mm minimum length limit.
2. Electrofish annually during the fall to assess age-0 walleye and establish standardized electrofishing transepts.
3. Do not stock if electrofishing catch exceeds 100/hr.
4. If stocking is deemed necessary, based on electrofishing CPUE and netting, stock with good quality small fingerlings (no smaller than 1200/lb) at minimum of 100/ac. or even 200/ac. should be considered.
5. Stock in 1999.
6. Continue to conduct annual surveys and collect age and growth data from walleye.
7. As Enemy Swim Lake has a history of producing trophy walleye, consider regulations allowing anglers to keep only one walleye over 508 mm (20 inches) in order to distribute trophy fish among anglers and to aid in preventing overharvest of larger fish present.

Bluegill

Bluegill constituted 63.9% of frame net catch. Frame net CPUE of 44.2 is not a significant change from values seen over the past three years but is a substantial increase over values seen during previous years (Figure 2). Frame net CPUE indicates moderate to moderate high abundance. Fish ranging from 15-18 cm were common resulting in PSD of 70 and RSD-P of 10 (Figure 4, Table 1). Wr values of bluegill for all length categories were above 100 and indicated good condition (Table 4).

Creel data for December 1996 through March 1997 and December 1997 through February 1998 shows that bluegill do not provide a winter fishery as no bluegill were creeled. From May through August 1997 anglers caught 2161 and kept 594. During this time period the highest catch rate was seen in July and August at 0.2/hr. During the same months in 1998 angler catch increased substantially to 22,636 of which 10,181 were harvested. Catch rates ranged from 0.9/hr. in May to 1.63/hr. in August. Catch rates are not broken out by species targeted so consequently catch rates are most likely underestimated.

Length frequency suggests consistent recruitment and Wr values imply good growth. During past surveys, prior to present high waterlevels, bluegills appeared to be concentrated in Church Bay and in East Lake while during the present survey bluegill were sampled at all frame net locations. Given abundance as well as size of bluegill present, bluegill are in a position to provide an exceptional fishery.

Management Recommendations

1. Continue to conduct annual surveys and collect scales to aid in determining recruitment patterns, growth and age structure.

Rock Bass

Rock bass are consistently sampled and frame net CPUE has ranged from 5.2 to 14.4. Larger individuals, as indicated by PSD of 63, dominate size structure (Table 1). All length categories sampled exhibited good condition with Wr values of 100 or greater (Table 4). Creel survey indicates that although this species is relatively abundant and large individuals are available, very few anglers target rock bass and most are caught incidentally. Rock bass are not very popular in northeast South Dakota and are under utilized. Rock bass are well established, have consistent recruitment, good size structure and abundance.

Management Recommendations

1. Continue to collect length, weight and abundance data during annual surveys.

Black Crappie

Black crappie frame net CPUE of 4.5 is the highest value achieved since inception of annual surveys in 1992. Abundance is still classified as low. Length frequency (Figure 5) suggests presence of three year classes. No crappie less than 17 cm were sampled. PSD as well as RSD-P values were very high at 69 and 46, respectively. Wr values ranged from 100 to 110 depending on length category (Table 4). Although low density most likely precludes anglers from actively targeting this species, from May through August 1998 732 crappie were caught of which 227 were harvested.

Inconsistent recruitment, low density, and most likely fast growth characterize the black crappie population. Contribution of this species to the sport fishery is limited by low abundance and it can be speculated that frame net CPUE would have to increase to 20.0 to allow for a targetable fishery.

Management Recommendations

1. Continue to collect length, weight and abundance data during annual surveys.

Yellow Perch

With the exception of 1996, gill net CPUE has remained relatively stabile since 1993. (Figure 1). Gill net CPUE of 176.0 is indicative of moderate high density (Table 2). As during previous surveys, most of the sample consisted of sub-quality (<200 mm) length yellow perch resulting in PSD of 4 and RSD-P of 0. Lott (1991) found Enemy Swim female perch to reach 143 mm at age-3 and 162 mm at age-4. Further Lott (1991) attributed low representation of age-3 and age-4 yellow perch to high rates of natural mortality because few yellow perch in Enemy Swim Lake reach quality length and angler harvest rates were low. Low angler harvest rates are supported by 1998 creel data, which estimated harvest from May through August at 1217 yellow perch. It appears that many perch succumb to natural mortality prior to reaching quality length resulting in size structure consistently dominated by small fish. Wr values ranged from 88 to 92 for length categories sampled (Tables 3&4). Relatively low Wr values may indicate high dependence on zooplankton for forage as well as a competitive environment.

The yellow perch population appears to have consistent recruitment, slow growth, high natural mortality prior to perch reaching quality length (200 mm), and moderate-high density. It is the above named characteristics that prohibit this population from providing a acceptable fishery. It is thought that anglers often settle for fish less than 200 mm when targeting this species on Enemy Swim Lake.

Management Recommendations

1. Continue to collect length, weight and abundance data during annual surveys.
2. Consider Enemy Swim Lake as yellow perch source for trap and transfer operations.

Smallmouth Bass

Electrofishing yielded CPUE of 338.9+-117 (80% C.I) for all sizes and 85.9 for stock length (>180 mm) smallmouth bass (Table 6). Abundance is thought to be high in suitable habitat. Gill net CPUE increased from 0.5 in 1997 to 6.2 in 1998. Frame net CPUE fell form 2.9 in 1997 to 1.1 in 1998. (Tables 1&2). 1997 CPUE values for frame nets would suggest that relative abundance of smallmouth bass has declined while gill nets indicate a twelve-fold increase. Inconsistent netting results such as these are commonly seen during annual surveys and strongly indicate that both gill and frame net catches most likely do not accurately reflect relative abundance. Milewski (1990) found biases associated with electrofishing, namely that that smallmouth bass 280 mm and longer were not effectively sampled. Length frequency histograms depict bass from 7-44 cm being sampled (Figures 7&8). Despite suspected gear biases, PSD values for all three gear types were very similar, especially when viewed through 90% confidence intervals (Tables 1,2&6). Size structure most likely contains more quality (280 mm) and larger length fish then sampling indicates. Wr values ranged from mid 90's to up to 108 for length categories sampled (Tables 3&4). Fall electrofishing sample Wr values averaged 93 for stock length fish. Growth is comparable to other smallmouth bass populations in the northeastern South Dakota with fish reaching 210 mm at age-3 (Table 7). Aged electrofishing sample showed year classes from 1993-1997 present, further indicating consistent recruitment.

Creel survey from May through August 1997 shows that anglers caught 6,228 smallmouth bass of which 610 were harvested. A creel survey during the same months in 1998 showed anglers catching 6,628 smallmouth bass and keeping 710. During both creel periods approximately 10% of smallmouth bass captured were kept. Catch rates for summer months in 1998 ranged from 0.1/hr. in May to 0.62/ hr. in August. Considering that most anglers were not targeting this species, these catch rates are considered high. Winter creel in 1997/98 (December- February) consistently documented low catch rates of 0.03/hr. and less with 101 fish caught and 94 harvested. It can be speculated that ice anglers were fishing for panfish and thus more inclined to harvest any incidentally caught smallmouth bass.

Stocked from 1991 to 1993, smallmouth bass are firmly established and are providing a fishery that is increasing in popularity. Abundance and size structure are such that smallmouth bass should be in a position to provide an excellent fishery.

Management Recommendations

1. Utilize annual fall electrofishing to document reproduction, collect age and growth information, and obtain CPUE information to index relative abundance.
2. Set up standardized transepts to be used for electrofishing.
3. Continue to collect baseline data during annual summer surveys and collect scales during netting surveys.
4. Analyze creel survey information and implement harvest regulations if warranted.

Northern Pike

Gill net CPUE of 5.8 is an increase over the 1.0 seen in 1997 but not substantially different from CPUE of 7.0 and 5.2 obtained in 1995 and 1996, respectively. Gill net CPUE suggests moderate-high abundance. Although frame net catches for northern pike are low during summer surveys, CPUE of 0.7 is the highest value seen since inception of annual surveys. Gill nets provided a 35-fish sample ranging from 41-71 cm in length (Figure 6). PSD and RSD-P for gill net sample were 71 and 6, respectively (Table 2). The fifteen fish frame net sample had PSD of 80 and RSD-P of 40. The eleven fish sample obtained in 1997 ranged in length from 44-69 cm and indicates similar size structure to lengths seen in 1998. Size structure of northern pike appears to be dominated by quality length (53 cm) and larger individuals. Northern pike less than 40 cm are rarely sampled, continuous presence of 40 cm and longer individuals, however, may suggest that recruitment is relatively consistent and that smaller individuals are not effectively sampled with gear used during the survey period. Wr values were lowest for memorable (86 cm) to trophy (112 cm) length pike captured in frame nets and highest for preferred (71 cm) to memorable (86 cm) length fish from gill nets (Tables 3&4). Wr values were generally lower for frame net sampled northern pike than for gill netted northern pike. Possible explanations are that weighing of live fish results in greater error of measurements or that fish caught near shore (in frame nets) were actively searching for prey while those in deeper off shore waters were resting after consuming prey. All Wr values seen, however, still indicate good condition and values are similar to those seen in other area lakes.

From December 1996 through March 1997 anglers caught an estimated 100 and harvested 88 and from December 1997 through February 1998 anglers caught 260 and harvested 201 northern pike. Summer catch for May through August 1997 totaled 4,297 of which 414 were kept. In 1998 during the same time period 1,399 northern pike were caught and 248 harvested. Highest catch rates were observed in March 1997 at 0.67/hr. and the lowest occurred in January and February 1997 when no northern pike were creeled. Catch rates from May through August, 1998 averaged 0.07/hr. Ice anglers were more inclined to specifically target and harvest northern pike than open water anglers, which in part explains high release rates seen during summer months.

The northern pike population in Enemy Swim has moderate-high abundance and contains large individuals. Anglers targeting this species should find acceptable opportunity.

Management Recommendations

1. Continue to collect length, weight and abundance data during annual surveys.

Largemouth Bass

Electrofishing in spring of 1998 by South Dakota State University resulted in CPUE of 28.75/hr. The obtained sample has PSD of 60 and RSD-P of 10. Growth is average for N.E South Dakota lakes with fish reaching 340 mm at age-4 (Hubers and Pyle 1997). Past data suggests that recruitment is inconsistent and varies strongly in magnitude. 1997 data showed strong 1993 and 1994 year classes. Improved habitat conditions resulting from high water levels, acceptable growth rates and protection afforded by the 381-mm minimum length limit should enable largemouth bass to provide a quality fishery as present year classes move to desired lengths.

Management Recommendations

1. Utilize annual spring electrofishing to document reproduction, collect age and growth information, and obtain CPUE information to index relative abundance.
2. Set up standardized transepts to be used for electrofishing.
3. Analyze creel survey information and recommend modifications to length regulations if warranted.

Other Species

Other species sampled during the survey were common carp, white sucker, black bullhead, white bass, spottail shiner and pumpkinseed. Of the above mentioned species, only white bass appear to be of angler interest. Gear utilized does not adequately sample white bass and creel surveys often do not document the fishery provided prior to May. While highest catches occur early in spring (Personal observation), creel survey from May through August did document a total catch of 732 white bass of which 60 were harvested. As with white bass, common carp are also though not to be sampled relative to true abundance. Carp CPUE has been low for both gear types and has not exceeded 2.0 for the past seven years. Black bullhead had the highest CPUE's for both gear types but abundance is still classified as low.

Management Recommendations

1. Continue to monitor relative abundance as well as size structure during annual netting surveys.

Table 1. Catch and analysis of twenty-one 3/4 in. mesh frame net sets in Enemy Swim Lake, July 14-16,1998.

SPECIES	N	%COMP.	CPUE(80%C.I)	7-YEAR RANGE	PSD(90%C.I)	RSD-P(90%C.I)
COC	9	0.6	0.4+-0.3	0.1-1.4	-	-
WHS	5	0.3	0.2+-0.2	0.2-2.1	-	-
BLB	101	7.0	4.8+-1.8	0.2-4.8	96(93,99)	52(44,61)
NOP	15	1.0	0.7+-0.4	0.0-0.7	80(61,99)	40(17,63)
WHB	5	0.3	0.2+-0.3	0.0-0.2	-	-
RKB	241	16.6	11.5+-2.9	5.2-14.4	63(57,68)	5(2,7)
PUS	8	0.6	0.4+-0.2	0.0-0.8	-	-
BLG	928	63.9	44.2+-13.7	0.5-46.8	70(67,72)	10(8,12)
SMB	24	1.7	1.1+-0.6	0.2-2.9	22(7,37)	4(0,12)
BLC	95	6.5	4.5+-1.6	0.1-4.5	69(62,77)	46(38,55)
YEP	16	1.1	0.8+-0.4	0.8-23.4	19(1,36)	0(0,0)
WAE	5	0.3	0.2+-0.2	0.0-0.2	-	-

Table 2. Catch of six 150 ft. experimental gill net sets in Enemy Swim Lake, July 14-16,1998.

SPECIES	N	%COMP.	CPUE(80%C.I)	7-YEAR RANGE	PSD(90%C.I)	RSD-P(90%C.I)
SPS	1	0.1	0.2+-0.2	1.2-11.8	-	-
COC	3	0.2	0.5+-0.5	0.0-2.0	-	-
WHS	35	2.7	5.8+-2.4	2.2-11.8	-	-
BLB	11	0.8	1.8+-1.3	0.0-1.8	100(100,100)	10(0,28)
NOP	35	2.7	5.8+-3.4	0.7-7.0	71(58,85)	6(0,12)
WHB	1	0.1	0.2+-0.2	0.0-0.8	-	-
RKB	53	4.0	8.8+-5.2	6.2-15.5	49(37,61)	0(0,0)
BLG	7	0.5	1.2+-1.4	0.0-1.2	-	-
SMB	37	2.8	6.2+-3.1	0.0-6.2	20(6,34)	8(0,17)
BLC	4	0.3	0.7+-0.5	0.0-0.7	-	-
YEP	1056	80.0	176.0+-84.2	22.2-935.0	4(3,5)	0(0,0)
WAE	77	5.8	12.8+-5.7	1.0-15.3	44(34,54)	9(3,15)

Table 3. Weighted mean Wr by length category from gill net samples for selected species collected in Enemy Swim Lake, July 1998.

Species	NOP	RKB	SMB	YEP	WAE
<S	-	-	-	88	87
S	90	110	97	91	85
S-Q	88	112	94	91	83
Q-P	91	107	-	90	88
P-M	100	-	95	-	95
M-T	-	-	-	-	91

S=Stock; Q=Quality; P=Preferred; M=Memorable; T=Trophy Length Categories.

Table 4. Weighted mean Wr by length category for frame net samples collected in Enemy Swim Lake, July 1998.

Species	NOP	RKB	BLG	SMB	BLC	YEP
<S	-	-	-	-	-	-
S	82	112	109	95	105	91
S-Q	76	115	106	95	108	92
Q-P	84	111	111	94	110	88
P-M	88	100	104	105	100	-
M-T	68	-	-	-	102	-

S=Stock; Q=Quality; P=Preferred; M=Memorable; T=Trophy Length Categories.

Table 5. Back-calculated lengths (mm) of walleye sampled with gill nets, Enemy Swim Lake, July 1998.

			Average Back-calculated Lengths for Each Age Class				
YEAR CLASS	AGE	N	1	2	3	4	5
1997	1	2	176				
1996	2	38	141	232			
1995	3	4	127	229	326		
1994	4	22	138	222	322	400	
1993	5	7	119	223	329	415	467
ALL			140	227	326	408	467
N		73	73	71	33	29	7

Table 6. Catch of 60 minutes of electrofishing for largemouth (May 26, 1999) and smallmouth bass (September 21, 1998) in Enemy Swim Lake.

SPECIES	N	CPUE (stock length)	PSD (90% C.I)	RSD-P (90% C.I)	Wr (stock length)
SMB	86	85.92	14(8,20)	2(0,5)	93
LMB*	93	28.75	66(-)	10(-)	-

*SDSU supplied data

Table 7. Back-calculated lengths (mm) of smallmouth bass sampled by night electrofishing, September 21,1998 on Enemy Swim Lake.

Average Back-calculated Lengths for Each Age Class

YEAR CLASS	AGE	N	1	2	3	4	5
1997	1	211	87				
1996	2	44	81	151			
1995	3	5	88	146	209		
1994	4	8	84	143	207	264	
1993	5	2	86	157	214	316	333
ALL			85	149	210	290	333
N		270	270	59	15	10	2

Table 9. Stocking record for Enemy Swim Lake, 1983-1998.

SPECIES	SIZE	NUMBER	YEAR
WAE	FRY	987,500	1983
WAE	FGL	3,948	1984
WAE	ADT	400	1985
WAE	FGL	842	1985
LMB	FGL	2,000	1985
BLC	ADT	1,200	1985
WAE	FGL	37,845	1987
LMB	FGL	16,900	1988
WAE	FRY	4,290,000	1988
WAE	ADT	340	1989
WAE	LFG	59,290	1990
LMB	LFG	3,380	1991
LMB	MFG	13,210	1991
SMB	LFG	600	1991
SMB	MFG	21,460	1991
WAE	FRY	4,290,000	1991
WAE	SFG	200,000	1991
LMB	MFG	15,000	1992

Table 9 continued:

SMB	FRY	3,000	1992
SMB	MFG	50,000	1992
WAE	LFG	66,079	1992
WAE	SFG	203,000	1992
SMB	ADT	24	1993
WAE	FRY	4,290,000	1993
SMB	SFG	44,270	1993
WAE	SFG	200,000	1993
SMB	MFG	28,100	1993
WAE	LFG	36,917	1993
WAE	LFG	112,610	1994
WAE	SFG	411,630	1995
WAE	SFG	246,520	1996

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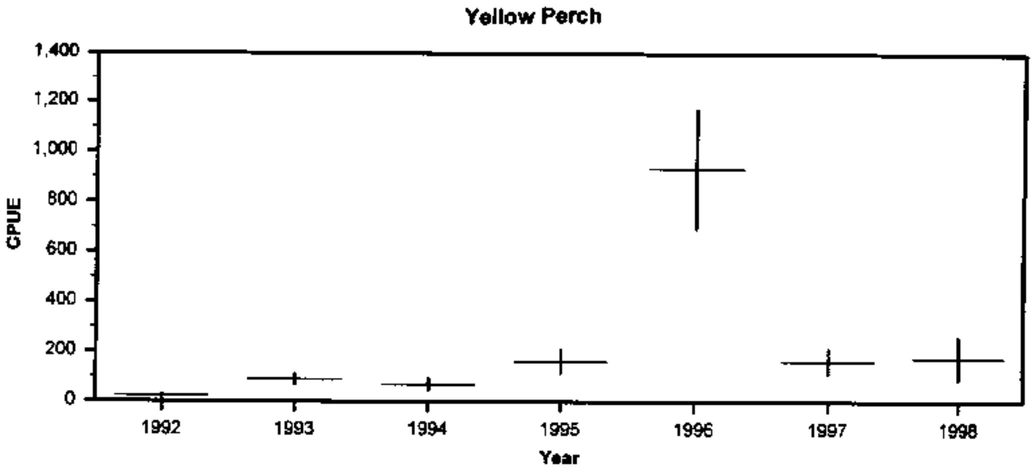


Figure 1. Yellow perch gill net CPUE (80% C.I) in Enemy Swim, 1992-98.

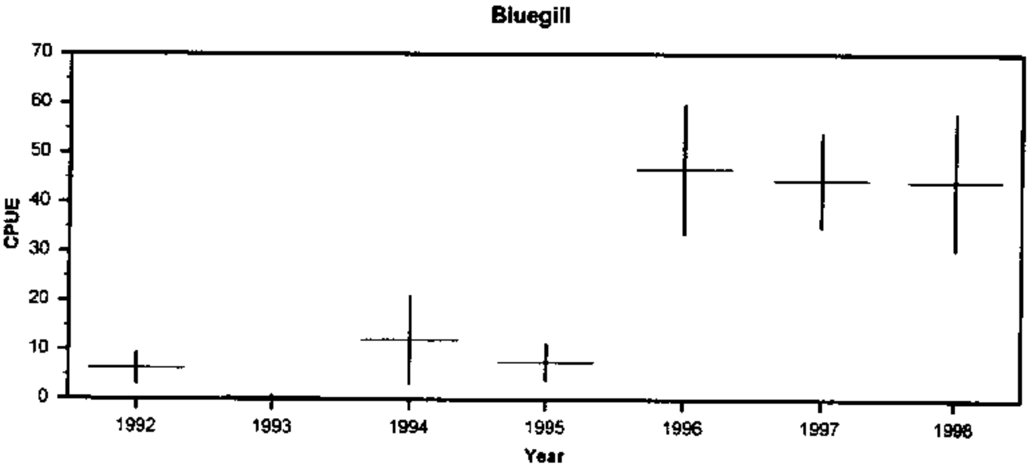


Figure 2. Bluegill frame net CPUE (80% C.I) in Enemy Swim Lake, 1992-98.

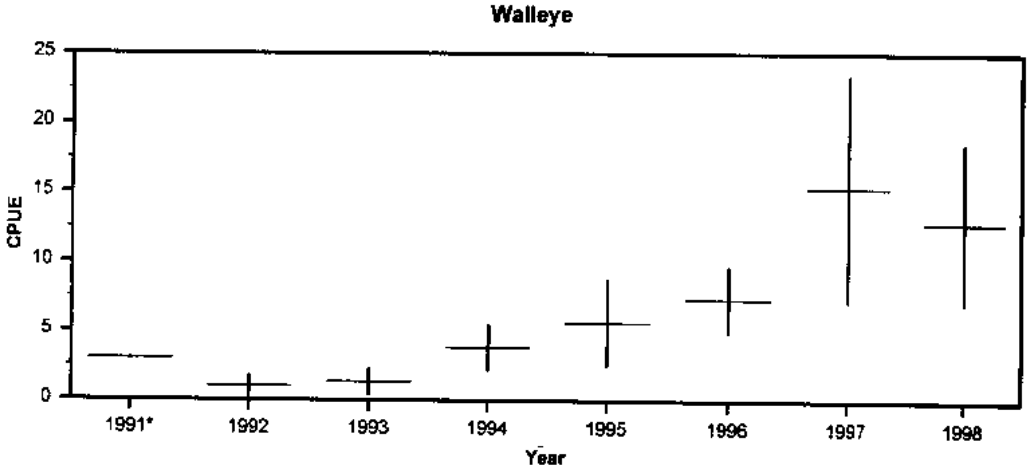


Figure 3. Walleye gill net CPUE (80% C.I) in Enemy Swim Lake, 1992-98.

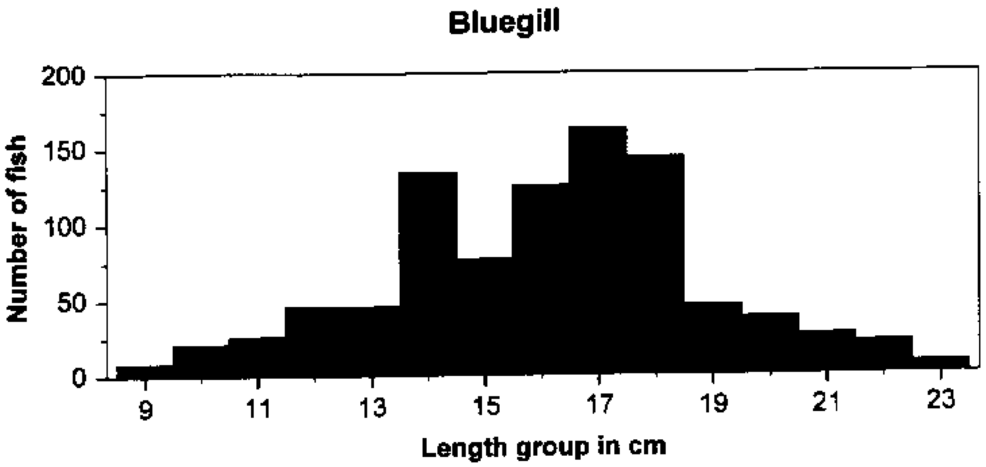


Figure 4.
Length frequency of bluegill from frame nets, Enemy Swim Lake, 1998.

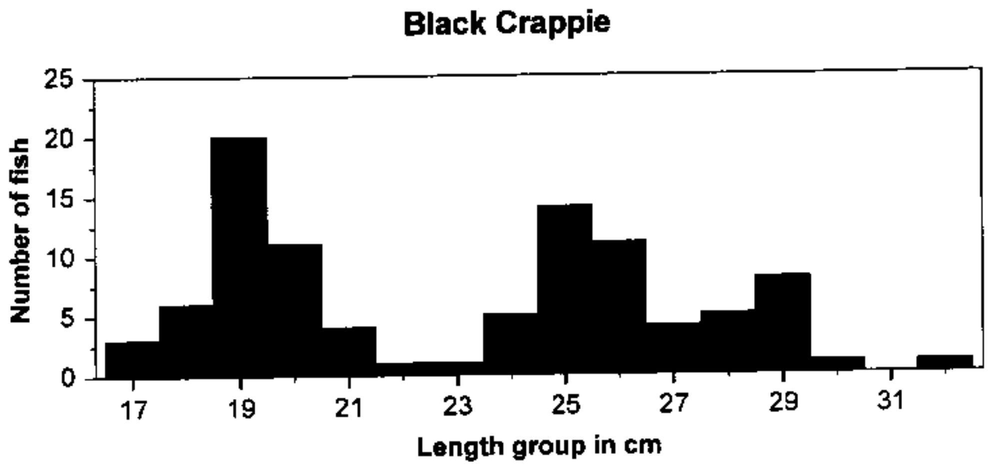


Figure 5.
Length frequency of black crappie from frame nets, Enemy Swim Lake, 1998.

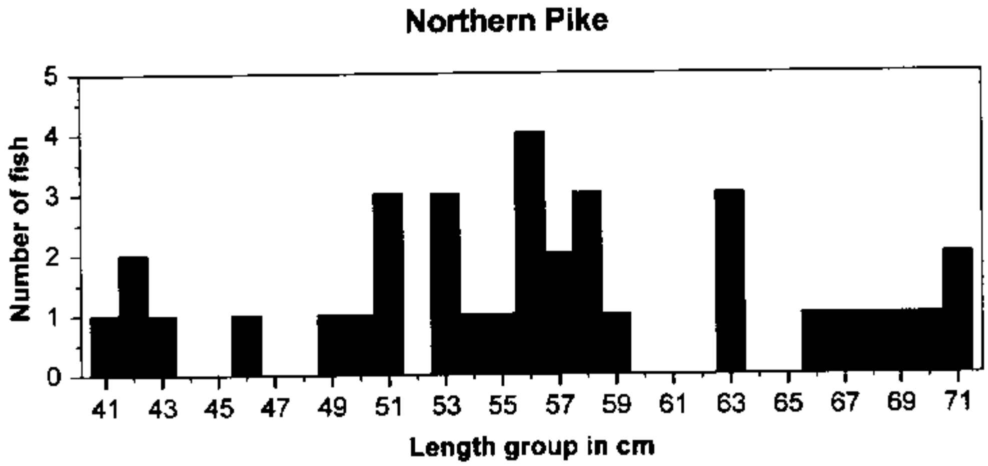


Figure 6.
Length frequency of northern pike from gill nets, Enemy Swim Lake, 1998.

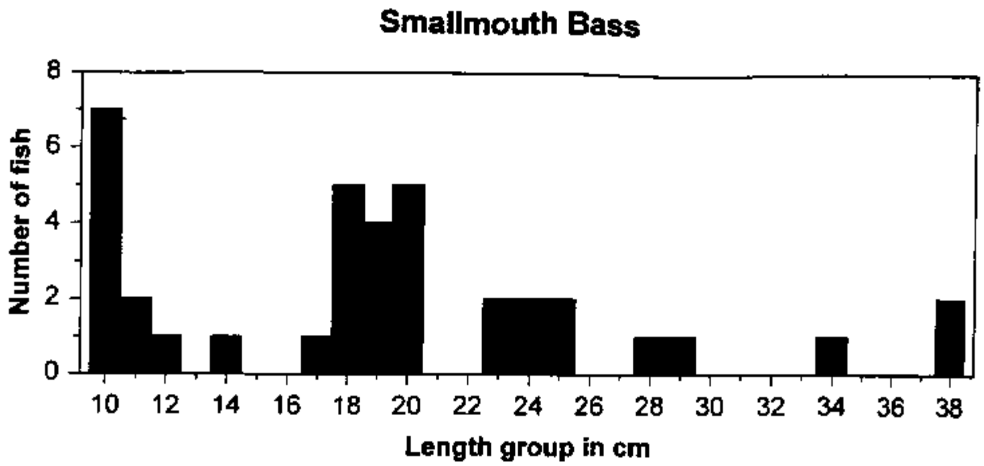


Figure 7.

Length frequency of smallmouth bass from gill nets in Enemy Swim Lake, 1998.

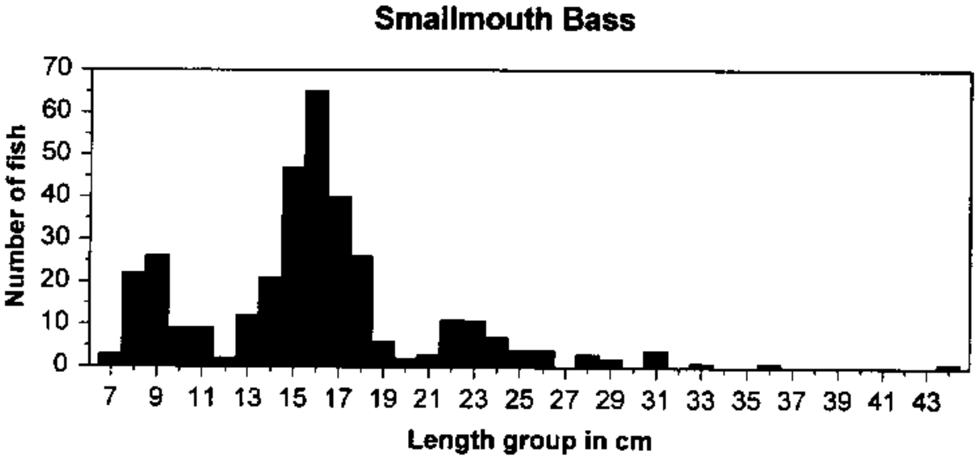


Figure 8.

Length frequency of smallmouth bass from electrofishing Enemy Swim Lake, 1998.

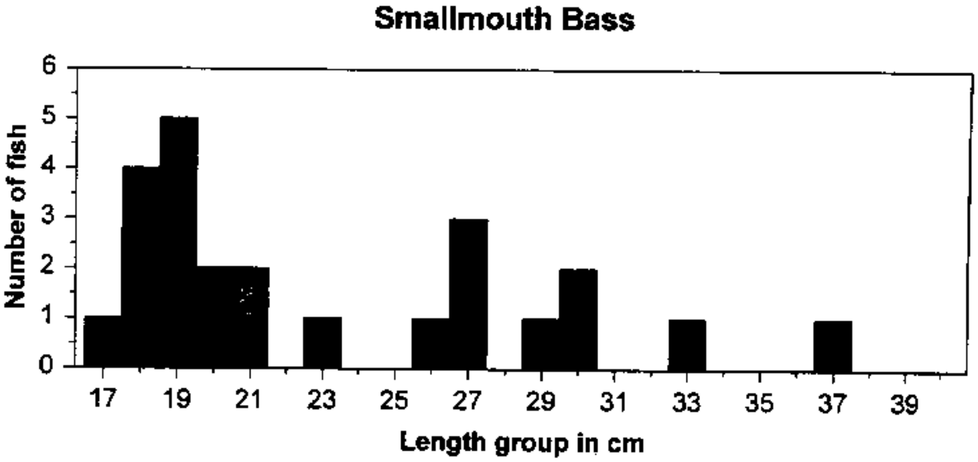


Figure 9.

Length frequency of smallmouth bass from frame nets in Enemy Swim Lake, 1998.

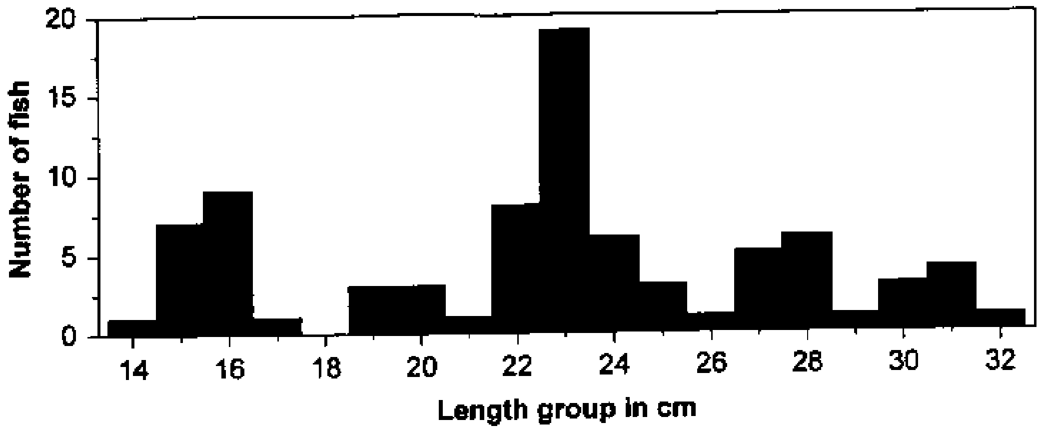


Figure 10.
Length frequency of walleye from electrofishing Enemy Swim Lake, 1998.

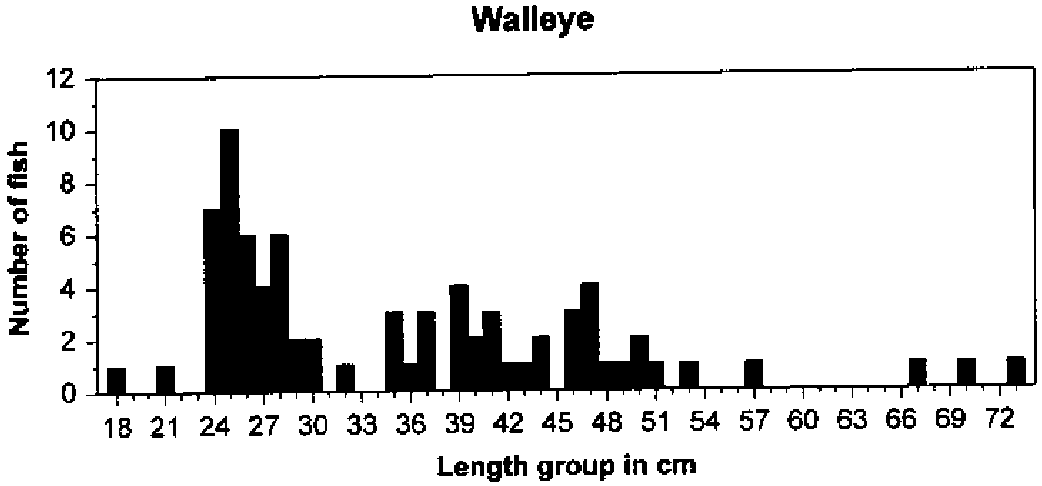


Figure 11.
Length frequency of walleye from gill nets in Enemy Swim Lake, 1998.

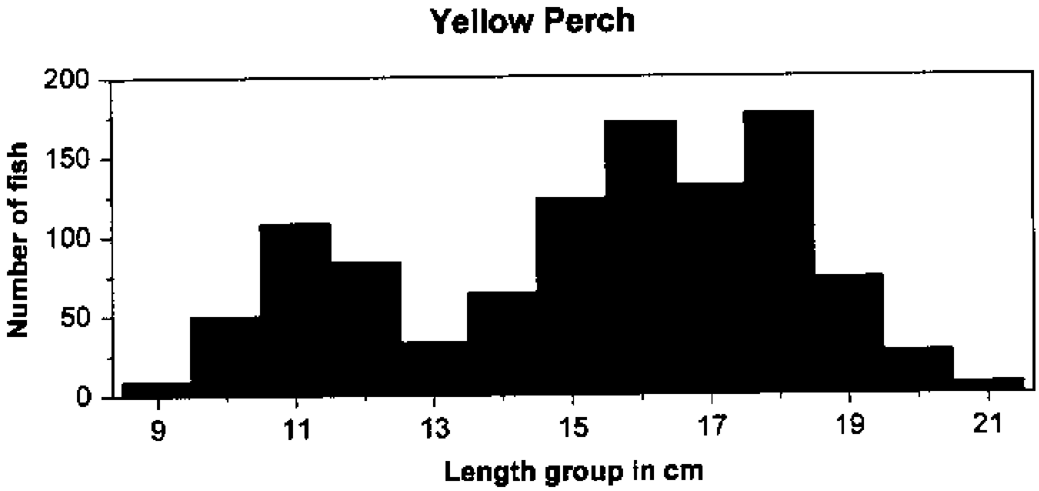
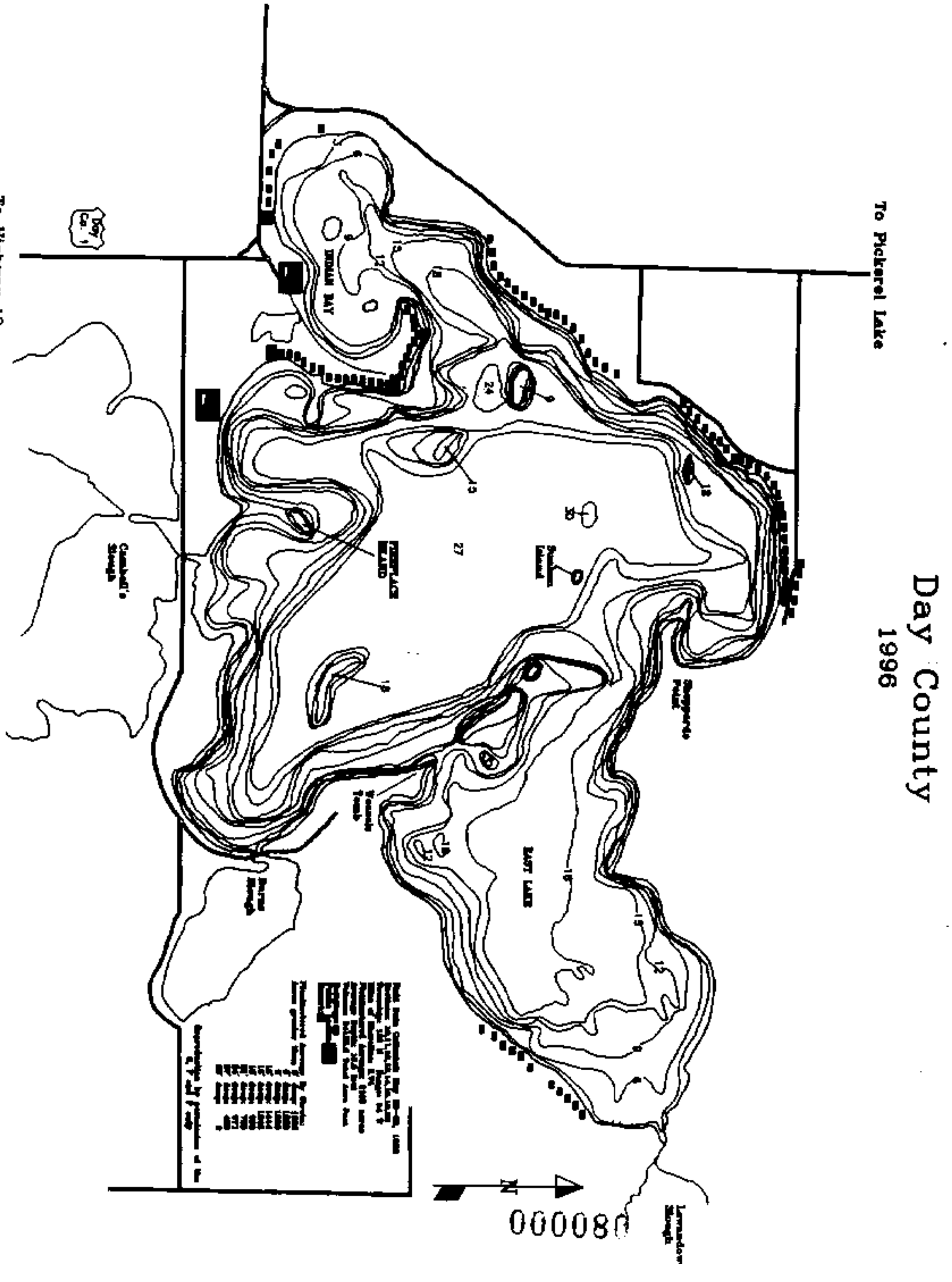


Figure 12.
Length frequency of yellow perch from gill nets in Enemy Swim Lake, 1998.

Figure 13. Lake map of Enemy Swim Lake.



APPENDIX C

AGNPS Report

REPORT ON THE
AGRICULTURAL NONPOINT SOURCE (AGNPS) ANALYSIS OF THE ENEMY SWIM LAKE WATERSHED DAY/ROBERTS COUNTIES, SOUTH DAKOTA

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

FEBRUARY 2000

OVERVIEW OF AGNPS DATA INPUTS

OVERVIEW

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

The model works on a cell basis. These cells are uniform square areas that divide the watershed (figure 1). This division makes it possible to analyze any area, down to 1.0 acres, in the watershed. The basic components of the model are hydrology, erosion, sediment transport, nitrogen (N), phosphorus (P), and chemical oxygen demand (COD) transport. In the hydrology portion of the model, calculations were made for runoff volume and peak concentration flow. Total upland erosion, total channel erosion, and a breakdown of these two sources into five particle size classes (clay, silt, small aggregates, large aggregates, and sand) for each of the cells are calculated in the erosion portion. Sediment transport is also calculated for each of the cells in the five particle classes as well as the total. The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment attached pollutants (figure 2).

PRELIMINARY EXAMINATION

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

1) Detailed topographic map of the watershed (USGS map 1:24,000)
2) Establish the drainage boundaries.
3) Divide watershed up into cells (40 acre, 1,320 feet × 1,320 feet). Only those cells with greater than 50% of their area within the watershed boundary should be included.
4) Number the cells consecutively from one to the number of cells (begin at NW corner of watershed and precede west to east then north to south.
5) Establish the watershed drainage pattern from the cells.

DATA FILE

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

Data input for watershed

1) a) Area of each cell (acres)
   b) Total number of cells in watershed
   c) Precipitation for a monthly, six month, yearly, 5 year, and 25 year, 24 hour rainfall
   d) Energy intensity value for storm event previously selected

Data input for each cell

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

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

16) **Fertilization level**, indication of the level of fertilization on the field.

	Assume Fertilization (lb./acre)		
Level	N	P	Input
No fertilization	0	0	0
Low Fertilization	50	20	1
Average Fertilization	100	40	2
High Fertilization	200	80	3

avg. manure – low fertilization
high manure – avg.fertilization
water or marsh = 0
urban or residential = 0 (for average practices)

17) **Availability factor**, the percent of fertilizer left in the top half inch of soil at the time of the
storm. Worst case 100%, water or marsh = 0, urban or residential = 100%.

18) **Point source indicator**: indicator of feedlot within the cell (0 = no feedlot, 1 = feedlot).

19) **Gully source level**: tons of gully erosion occurring in the cell or input from a sub-watershed.

20) **Chemical oxygen demand (COD) demand**, a value of COD for the land use in the cell.

21) **Impoundment factor**: number of impoundment's in the cell (max. 13)
  a) Area of drainage into the impoundment
  b) Outlet pipe (inches)

22) **Channel indicator**: number designates the type of channel found in the cell

DATA OUTPUT AT THE OUTLET OF EACH CELL

Hydrology

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

Sediment Output

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

Chemical Output

Nitrogen
  Sediment associated mass
  Concentration of soluble material
  Mass of soluble material

Phosphorus
  Sediment associated mass

Concentration of soluble material
Mass of soluble material

Chemical Oxygen Demand
Concentration
Mass

PARAMETER SENSITIVITY ANALYSIS

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

EXECUTIVE SUMMARY

The Enemy Swim Lake watershed is located on the eastern edge of Day County and the western edge of adjacent Roberts County. The watershed contains an approximate 27,000 acres of which, almost 20,000 acres is made up of native grasslands, CRP ground and hayland. The Enemy Swim Lake watershed drains into Campbell' slough which is then routed into Blue Dog Lake. Due to conditions not conducive to setting up water quality monitoring on the outlet of Enemy Swim as well a tributaries entering the lake, a computer model was selected in an effort to study and predict non-point source loadings within the watershed. This report contains the data and conclusions resulting from this study.

SUBWATERSHED ANALYSIS

The Enemy Swim Lake watershed contains twelve delineated subwatersheds. These subwatersheds have areas ranging from 520 acres to 4,440 acres and cumulatively occupy 17,480 acres (65%) of the Enemy Swim watershed. Subwatersheds were analyzed for their respective outputs of both sediment and nutrient loadings.

Sediment

The AGNPS data indicates that the Enemy Swim watershed receives 526 tons of sediment delivered from the twelve subwatersheds on an annual basis. Of these 526 tons, only 139 tons of sediment actually is delivered into Enemy Swim Lake. This is a low sediment delivery rate when compared with other watersheds in eastern South Dakota. For comparison, the Blue Dog Lake watershed delivers 1,900 tons of sediment to the watershed and the lake receives 1,460 tons of that. The AGNPS data suggests that one reason for the very small sediment load in the watershed is the low cropland acreage. There are tilled acres in the watershed that are, according to the AGNPS data, producing elevated levels of sediment when examined on a per acre loading. The cells responsible have little or no conservation tillage practices implemented and are found in an area of relatively high land slope (7%). These cells are located primarily in subwatersheds #622 and #644. These two subwatersheds lie in close proximity to the lake and have little opportunity for sediments to fall out of the runoff before entering the lake.

Nutrients

Nitrogen

The AGNPS model suggests that Enemy Swim Lake receives a total nitrogen load of 27,163-lbs./year output from the subwatersheds. This translates to 8.6 lbs./acre/year. This level seems high when compared to that of Blue Dog Lake that sees five lbs./acre/year entering the lake. The highest contributing subwatersheds are #154, #394, #622, and #644. These subwatersheds are in close proximity to the lake and are comprised mainly of cropland. This cropland has highly erodible soils with high fertilizer availability. A minor contributor to the nitrogen levels from subwatersheds #394 and #644 is the presence of an animal feeding area in each of these subwatersheds. The feedlot in subwatershed #644 is rated by AGNPS as being a very low contributor of nitrogen but the feedlot in #394 has a relatively high AGNPS rated feedlot.

Phosphorus

The phosphorus loading into Enemy Swim Lake on an annual basis was calculated to be 4,110 lbs./year or 0.0001 tons/acre/year. Comparatively, Blue Dog Lake receives 0.0005 tons/acre/year from its' watershed. The average lake input of phosphorus in eastern South Dakota watersheds was calculated to be 0.0003 tons/acre/year. The dramatic decrease in phosphorus loading compared to the nitrogen loading (determined to be high) is probably due to the fertilization level of cropland. Several of the cells in the highest phosphorus output subwatersheds had an average fertilization level of 100 lbs. Of nitrogen to 40 lbs. Of phosphorus per acre.

CRITICAL CELLS

Critical cell analysis was done on the Enemy Swim watershed to differentiate those cells contributing higher levels of sediment and/or nutrients than the acceptable levels or rates. Critical cells do not necessarily denote an immediate problem with the cell but, if the cumulative loading to the waterbody is unacceptable, the critical cell gives you a focus area for implementation of BMPs to obtain a loading reduction. The minimum levels used in the Enemy Swim watershed are the same as used in the Blue Dog Lake AGNPS analysis done in 1999.

Sediment

Very few critical cells exist in the Enemy Swim watershed that surpass the minimum level of five tons/acre using an annualized sum of storm events. The AGNPS model indicates that just eight cells (of 673 cells) exceeded this level. These eight cells are located within close proximity to the lake in a cultivated region and have a 7% land slope. The fields are primarily beans (200 acres) with a cropping factor of 0.21. The remainder of critical cells (120 acres) are planted with beans and have a c-factor of 0.15.

The c-factor is an indicator of crop residue left in the top few inches of soil after planting. By lowering the c-factor on all 320 acres to represent a minimal till situation, the reduction in sediment to the lake is 11% as calculated by the model. This brings the annual sediment load delivered to Enemy Swim Lake down from 139 tons/year to 124 tons/year. Tillage practices could also be implemented on the marginal sediment delivering cells to further the reduction but, as stated, the sediment level currently entering the lake is quite low and may not be detrimental to the lake at this point.

Nutrients

Nitrogen

The Enemy Swim watershed contains a disproportional number of critical nitrogen cells compared to the number of critical cells in either the sediment or the phosphorus category. There are 37 cells in the watershed that surpass the minimum level of 10 lbs./acre of total nitrogen. The Blue Dog watershed has extensively more cropped ground and contains 135 critical cells. By changing the fertilizer availability in each critical cell from 100% to 50%, a 20% reduction in delivered nitrogen could be realized.

Phosphorus

As with the critical sediment cell analysis, the number of critical phosphorus cells in the watershed is m minimal. Only eight cells surpassed the minimal critical level of four lbs./acre for an annualized event. These cells again were primarily croplands with high fertilizer availability. Two of the eight cells were animal feeding areas with a relatively high AGNPS ranking. In following with the reduction method used in the critical nitrogen cell analysis, the fertilizer availability level was reduced by simulating using a cultivator to incorporate the fertilizer into the soil more efficiently. This resulted in a 24% reduction in total phosphorus being delivered to the lake.

FEEDING AREA EVALUATION

The Enemy Swim Lake watershed contains thirteen identified animal feeding areas. Overall, the impact of these feeding areas on the watershed is not great. There is only one feedlot with an AGNPS rating high enough to warrant examining. This feedlot is far enough away from the lake that by the time the runoff reaches the lake, it has dropped its nutrient concentration to within acceptable levels. To give an idea of the amount of nutrient reduction could be realized by implementing animal waste systems, the model was run with the top seven feedlots removed to simulate a containment system. The result was a 5% reduction in nitrogen and a 7% reduction in phosphorus delivered to the lake. Given the cost of animal waste systems and the low resulting reductions, implementation of this nature should be carefully considered.

CONCLUSION

The most important thing to remember about this study is that these numbers are the result of a computer model and should be compared to actual water quality and tributary data before any implementation is undertaken. All cells should be field checked for validity. The primary purpose of this computer model is to aid in estimating expected results from implemented BMPs and is not meant to be an indictment against any landowner or farming operation.

If implementation is to take place in the watershed, the effort should concentrate on those cells located within close proximity to the watershed and that have high fertilization levels as well as high cropping factors. This effort on these cells will provide a significant reduction in nutrients as well as a reduction in sediment.

ENEMY SWIM LAKE WATERSHED AGNPS ANALYSIS

In order to further understand the Nonpoint Source (NPS) loadings in the Enemy Swim watershed as well as aid in predicting the impacts of Best Management Practices (BMPs) in the watershed, a computer model was selected in order to asses the NPS loadings throughout the drainage. The model selected was the Agricultural Nonpoint Source Pollution Model (AGNPS) version 3.65. This model was developed by the USDA – Agricultural Research Service to analyze the water quality of runoff events in the watershed. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand (COD) concentrations in the runoff and sediment, The model was designed to run utilizing a single storm event of equal magnitude for all acreage in the watershed. The model then analyzes the runoff data from the headwaters of the watershed to the outlet. The pollutants are routed in a step-wise fashion so the flow at any point may be examined. The AGNPS model was to be used to objectively compare different subwatersheds and individual cells within a watershed to other watersheds within a drainage basin.

The Enemy Swim Lake watershed is located in the northeast edge of Day County and the western portion of adjoining Roberts County. The area affected by the AGNPS model analysis is defined by the area extending from just east of Oneroad Lake in the north-east corner of the watershed, to the outlet of Enemy Swim Lake which drains directly into Campbell’s Slough. The total area defined by the watershed boundaries is 26,920 acres.

Initially, the watershed was divided into cells each of which had an area of 40 acres with the dimensions of 1,320 feet by 1,320 feet. The dominant fluid flow direction within each cell was then determined. Based on the fluid flow directions and drainage patterns, twelve subwatersheds were delineated. Along with the dominant fluid flow direction, 21 watershed parameters were collected and entered into the model for each cell. The model then calculated the nonpoint source pollution loadings for each cell, subwatershed, and animal feeding area and estimated hydrology runoff volume for each of the storm events modeled.

The storm events chosen for the model are indicative of the regions average annual rainfall. By using storm event intensities common in the studied watershed, the AGNPS model can more accurately represent nutrient and sediment loadings resulting from a single storm event of variable intensity or a composite of an average years’ rainfall events. Both the subwatershed and the critical single cell analysis were performed using an annualized (average year) sum of individual events. The feeding area analysis was performed using a single rainfall event of 25-year intensity. This storm event results in higher runoff volumes than the annualized event and will produce a wider range in the AGNPS animal feeding area ranking which makes it more conducive to selecting a problem feedlot. The rainfall and energy intensity values associated with the annualized as well as the 25-year events can be found in **Table 1**.

RAINFALL SPECS FOR THE ENEMY SWIM LAKE STUDY

EVENT	RAINFALL	ENERGY INTENSITY
Monthly	0.8 inches	3.0
Six Month	1.5 inches	11.7
One Year	2.0 inches	21.8
Twenty Five Year	4.4 inches	121.2

NRCS R-factor for the Enemy Swim Lake watershed = 93

Annual Loading Calculation
monthly events: 12 events x 3.0 = 36
six month events: 3 events x 11.7 = 35.1
one year event: 1 event x 21.8 = 21.8
TOTAL = 93

(Table 1)

The primary objectives of running the AGNPS model on the Enemy Swim Lake watershed were to:

1. Evaluate and quantify NPS loadings from each subwatershed.
2. Define critical NPS cells within each subwatershed (elevated sediment, nitrogen, phosphorus).
3. Priority ranking of each animal feeding area and quantify the nutrient loadings from each area.

The following is an overview of the stated objectives.

OBJECTIVE 1 – EVALUATE SUBWATERSHED LOADINGS

The first step in the analysis of a watershed using the AGNPS model is to delineate the watershed drainage for the water body in focus. Using a 7.5-minute quad map of the region, the watershed is delineated and then broken into 40-acre cells. Each of these 40-acre cells is assigned a runoff flow direction where it drains into an adjacent cell. The flow is routed step-wise until it ultimately drains into a primary waterbody. By examining these flow paths, small pockets of cells display runoff patterns, which will sometimes converge at a central point. These pockets of cells within a watershed are called “subwatersheds”.

The Enemy Swim watershed contains twelve subwatersheds varying in total drainage area of 4,440 acres to 520 acres. Information regarding each of the twelve delineated subwatersheds can be found in **Table 2** below.

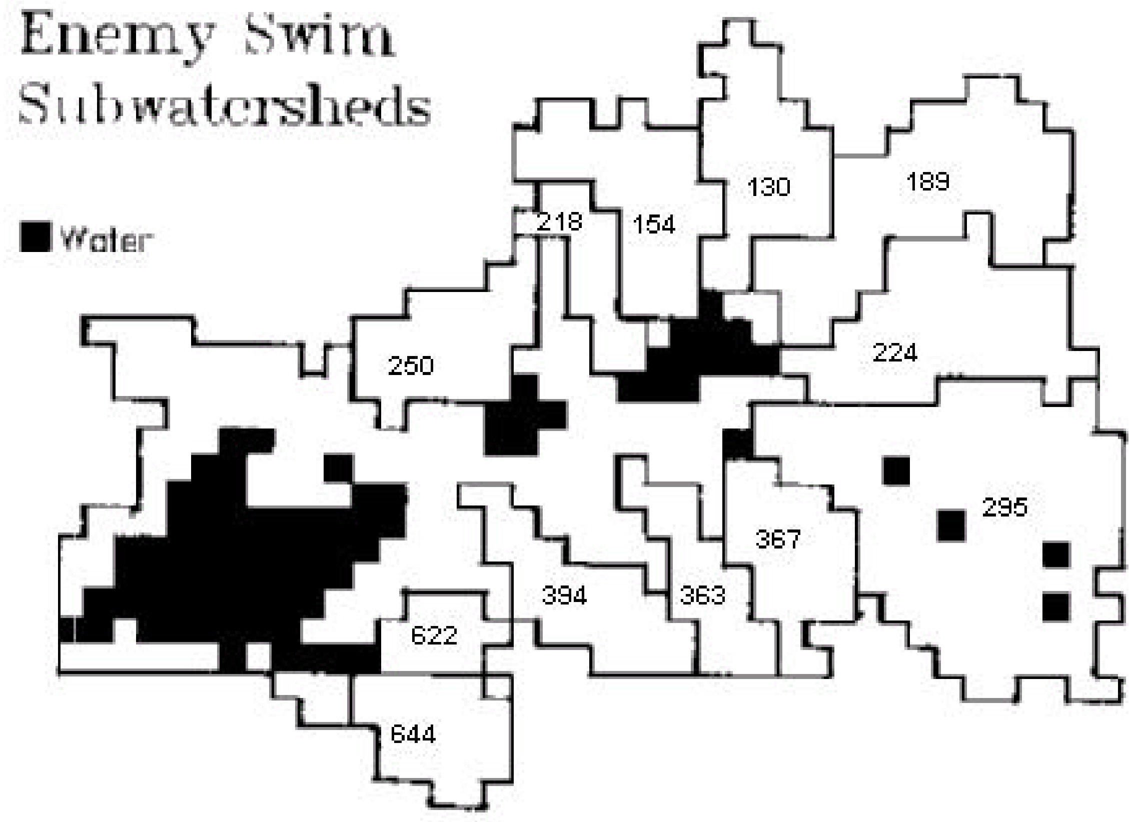
SUBWATERSHED NUMERATION

SUBWATERSHED #	OUTLET CELL #	DRAINAGE AREA
1	130	1280
2	154	1400
3	189	2280
4	218	640
5	224	1880
6	250	1120
7	295	4440
8	363	800

9	367	1080
10	394	1120
11	622	520
12	920	920

(Table 2)

Once the subwatersheds have been established, one may then examine both the sediment and nutrient loadings from the subwatersheds on a broader scale than if done on a cell by cell basis. Some factors pertaining to a subwatershed's relevance to waterbody loadings are the proximity to the waterbody, volume of runoff draining from the subwatershed, and velocity of runoff from the subwatershed. Both the subwatershed and the critical individual cell analysis will concentrate on loadings of sediment, nitrogen and phosphorus.



(Figure 1)

Subwatershed delineation is shown in **Figure 1** above. The subwatersheds are identified according to their drainage outlet cell number. Waterbodies are displayed on the AGNPS model map as the darkened cell with Enemy Swim Lake being on the left-hand side of the watershed delineation.

Subwatershed Sediment Analysis

The AGNPS model calculated that the Enemy Swim Lake watershed had a low sediment deliverability rate to the lake. Calculating sediment delivery to the lake by studying just those cells that drain directly to the lake (cell # 310,311,392,621) and not what is delivered by the individual subwatersheds, the yearly sediment load into Enemy Swim Lake is approximately 526 tons. Compared to the watershed directly south of Enemy Swim, Blue Dog Lake receives 1,465 tons of sediment on an average year due primarily to the much larger amount of crop land contained in that watershed.

The sediment load for each of the twelve subwatersheds located in the Enemy Swim watershed also appeared to be quite low when compared to other regional subwatersheds. The subs with markedly higher outputs of sediment are outlet cell # 218, 394, 622 and 644. The annual sediment outputs of both the subwatersheds as well as the lake input cells can be found in **Table 3** below.

Sediment Yield Results

SUB-WATERSHED OUTLET CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT Sed. Yield (tons)	6 MONTH EVENT Sed. Yield (tons)	1 YEAR EVENT Sed. Yield (tons)	ANNUAL Sed. Yield (tons)	% of Total Sediment Yield	% of Watershed Area
130	1280	0.11	2.29	4.01	12.2	2	5
154	1400	1.2	6.8	12.68	47.48	9	5
189	2280	0.59	3.9	6.64	25.42	5	8
218	640	0.67	10.31	18.81	**57.78**	11	2
224	1880	0.2	1.59	2.8	9.97	2	7
250	1120	1.02	5.23	9.51	37.44	7	4
295	4440	1.02	2.17	3.18	21.93	4	16
363	800	0.4	1.84	3.35	13.67	3	3
367	1080	0.29	1.27	2.09	9.38	2	4
394	1120	2.02	13.23	31.59	**95.52**	18	4
622	520	1.44	8.27	17.23	**59.32**	11	2
644	920	2.89	19.05	44.2	**136.03**	26	3
				TOTALS	**526.14**	**100**	**65**

ENEMY SWIM INLET CELL	DRAINAGE AREA	1 MONTH EVENT Sed. Yield	6 MONTH EVENT Sed. Yield	1 YEAR EVENT Sed. Yield	ANNUAL Sed. Yield	% of Total Sediment	% of Watershed

#	(acres)	(tons)	(tons)	(tons)	(tons)	Yield	Area
310	600	0.07	1.66	3.27	9.09	7	2
311	560	0.44	1.01	1.64	9.95	7	2
392	19680	2.65	9.18	19.59	78.93	57	73
621	1480	0.37	6.89	15.34	40.45	29	5
				TOTALS	**138.42**	**100**	**83**
OUTLET	26920	3.27	6.18	11.02	68.8	50	100

(Table 3)

Using the AGNPS model input data, one can surmise that the reason for the elevated sediment yields for the four subwatersheds is primarily from cropped lands which have an average land slope of 7% or greater. The practice factor of these cells would indicate little or no contour farming or conservation tillage practices. The benefits of conservation tillage as well as the reductions in sediment loadings realized by implementing conservation farming practices will be discussed later in the section pertaining to individual priority cells.

Bearing in mind that the AGNPS model does not take into consideration that sediment basins or traps will eventually fill and release sediment with time, compared to regional watersheds, it does not appear that Enemy Swim Lake has a sediment problem resulting from watershed drainage. If BMPs are to be implemented however, they should be concentrated in the three subwatersheds that are immediately adjacent to the lake (outlet cell # 644,622,394). These subwatersheds do not have the advantage of considerable acres of CRP or rangeland in which runoff sediments can be captured before entering the lake.

Subwatershed Nitrogen Analysis

The AGNPS model suggest that the Enemy Swim Lake watershed has a total nitrogen deliverability rate of
8.64 lbs./acre/year. Compared to the Blue Dog Lake watershed, which receives approximately five lbs./acre/year, this value is elevated. Using data from other eastern South Dakota watersheds that have an average nitrogen deliverance of 3.5 lbs./acre/year, the Enemy Swim nitrogen delivery rate is, again, elevated. The data associated with each of the Enemy Swim subwatersheds can be found below in **Table 4.**

Nitrogen Yield Results

SUB-WATERSHED OUTLET CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT Total Nit. (lbs./acre)	6 MONTH EVENT Total Nit. (lbs./acre)	1 YEAR EVENT Total Nit. (lbs./acre)	ANNUAL Total Nit. (lbs./acre)	ANNUAL Total Nit. (lbs.)	% of Total Nitrogen Yield	% of Watershed Area
130	1280	0	0.04	0.08	0.2	256	1	5
154	1400	0.06	0.39	0.61	2.5	3500	14	5
189	2280	0.01	0.07	0.13	0.46	1048.8	4	8
218	640	0.01	0.19	0.32	1.01	646.4	3	2
224	1880	0	0.03	0.07	0.16	300.8	1	7
250	1120	0.02	0.15	0.27	0.96	1075.2	4	4
295	4440	0.01	0.04	0.07	0.31	1376.4	5	16
363	800	0.05	0.25	0.39	1.74	1392	6	3
367	1080	0.04	0.15	0.26	1.19	1285.2	5	4
394	1120	0.12	0.64	1.03	4.39	4916.8	19	4
622	520	0.12	0.83	1.3	5.23	2719.6	11	2
644	920	0.16	1.18	1.86	7.32	6734.4	27	3
					TOTALS	**25251.6**	**100**	**65**

ENEMY SWIM INLET CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT Total Nit. (lbs./acre)	6 MONTH EVENT Total Nit. (lbs./acre)	1 YEAR EVENT Total Nit. (lbs./acre)	ANNUAL Total Nit. (lbs./acre)	ANNUAL Total Nit. (lbs.)	% of Total Nitrogen Yield	% of Watershed Area
310	600	0	0.09	0.17	0.44	264	1	2
311	560	0.05	0.21	0.33	1.56	873.6	3	2
392	19680	0.02	0.14	0.23	0.89	17515.2	64	73
621	1480	0.12	0.95	1.46	5.75	8510	31	5
					TOTALS	**27162.8**	**100**	**83**
OUTLET	26920	0.04	0.19	0.32	1.37	36880.4	100	100

(Table 4)

One can see from the Table 4 that the sum of subwatershed total nitrogen is considerably more than what is delivered to the lake. This again is a result of considerable numbers of acres of rangeland and CRP that filters the runoff. As with the sediment loadings delivered from subwatersheds, those with the outlet cell #s 154, 394, 622 and 644 are shown by the model to be delivering the highest amounts of total nitrogen (both soluble and sediment bound). Although both #644 and #394 contain feedlots (often a source of elevated nitrogen runoff), the model suggests that the most direct source is field applied fertilizers which are either unincorporated or only minimally incorporated (such as with a planter or anhydrous applicator). A large number of cells in both subwatersheds have data inputs of 100 % fertilizer availability. This means that the applied fertilizers are left in the top two inches of topsoil and are immediately available to runoff pending a storm event.

Subwatershed Phosphorus Analysis

The AGNPS model suggests that the Enemy Swim inlet cells deliver a cumulative load of 4,110 lbs. (or .0001 ton/acre/year) of phosphorus a year. When compared to sixteen other watersheds in the area, this loading is lower than the average of .0003 ton/acre/year. The Blue Dog Lake watershed has an annual phosphorus delivery rate of .0005 ton/acre/year. As with the nitrogen loading, the number of acres of CRP and rangeland in the Enemy Swim watershed is much higher than that of the Blue Dog Lake watershed.

Phosphorus Yield Results

SUB-WATERSHED OUTLET CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT Total Phos. (lbs./acre)	6 MONTH EVENT Total Phos. (lbs./acre)	1 YEAR EVENT Total Phos. (lbs./acre)	ANNUAL Total Phos. (lbs./acre)	ANNUAL Total Phos. (lbs.)	% of Total Phosph. Yield	% of Watershe Area
130	1280	0	0.01	0.02	0.05	64	1	5
154	1400	0.02	0.09	0.14	0.65	910	15	5
189	2280	0	0.02	0.03	0.09	205.2	3	8
218	640	0.01	0.07	0.11	0.44	281.6	5	2
224	1880	0	0.01	0.01	0.04	75.2	1	7
250	1120	0.01	0.04	0.06	0.3	336	6	4
295	4440	0	0	0	0	0	0	16
363	800	0.01	0.05	0.09	0.36	288	5	3
367	1080	0.01	0.04	0.06	0.3	324	5	4
394	1120	0.03	0.16	0.26	1.1	1232	20	4
622	520	0.03	0.2	0.31	1.27	660.4	11	2
644	920	0.05	0.27	0.45	1.86	1711.2	28	3
					TOTALS	**6087.6**	**100**	**65**

ENEMY SWIM INLET CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT Total Phos. (lbs./acre)	6 MONTH EVENT Total Phos. (lbs./acre)	1 YEAR EVENT Total Phos. (lbs./acre)	ANNUAL Total Phos. (lbs./acre)	ANNUAL Total Phos. (lbs.)	% of Total Phosph. Yield	% of Watershe Area
310	600	0	0.02	0.04	0.1	60	1	2
311	560	0.01	0.04	0.06	0.3	168	4	2
392	19680	0	0.02	0.05	0.11	2164.8	53	73
621	1480	0.02	0.2	0.32	1.16	1716.8	42	5
					TOTALS	**4109.6**	**100**	**83**
OUTLET	26920	0	0.03	0.05	0.14	3768.8	92	100

(Table 5)

The above **Table 5** shows that the same subwatersheds as the nitrogen analysis deliver the highest loadings of phosphorus to the watershed. The AGNPS data indicates that these subwatersheds (outlet cell #s 154, 394, 622, 644) contain a large percentage of cells which have high levels of fertilizer availability and fertilizer application per acre. By examining the nutrient output from one cell into the receiving cell, one can see that subwatershed # 194 has little impact on Enemy Swim Lake. This subwatershed actually routes through Oak Island before continuing on to Enemy Swim Lake therefore losing some of its' delivered phosphorus enroute. The other subwatersheds (#s 394, 622, and

644) are draining almost directly into the lake. Any BMPs implemented on a subwatershed basis should be directed toward these three adjacent subwatersheds.

OBJECTIVE 2 – EVALUATE CRITICAL CELL LOADINGS

Once the initial study and selection of critical subwatersheds is complete, the next step is to examine individual cells within these subwatersheds in an effort to narrow down problem areas even more. One important consideration for evaluating critical forty-acre cells is its proximity to the waterbody draining the entire watershed. A cell may have a particularly high loading but it may also lie at the head of the watershed. The amount of the sediment or nutrient may decrease dramatically as it drains to the waterbody. Therefore, many of the critical cells listed below are noted not necessarily for their loading, but for the loading delivered to the lake.

As with the subwatershed analysis, the study of critical cells will be broken into three aspects: sediment analysis, nitrogen analysis, and phosphorus analysis. The loadings from the critical cells are the result of running the model using an annualized (average year) string of storm events.

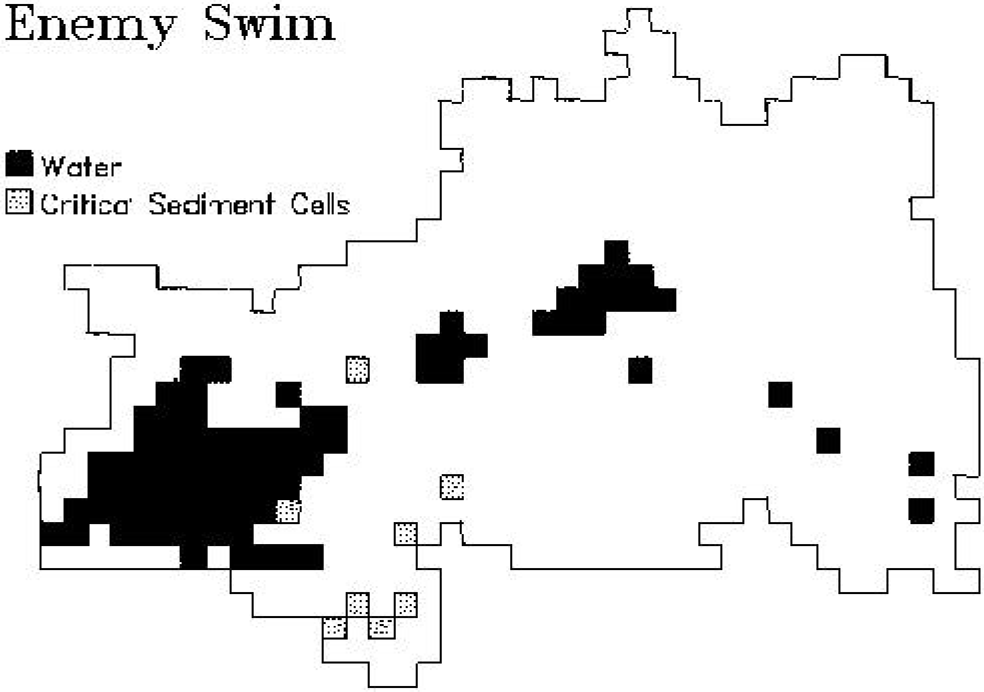
Critical Cell Sediment Analysis

An analysis of the Enemy Swim Lake watershed indicates that there are only eight cells having erosion rates greater than five ton/acre. This number compared to that of the Blue Dog Lake watershed, which had 55 cells higher than five tons/acre, is very low. The eight cells given a critical rating are listed below in **Table 6**.

AGNPS Cell #	Annual Cell Erosion (tons)	Annual Cell Erosion (ton/acre)
591	332.56	8.31
660	332.56	8.31
547	287.99	7.20
664	262.9	6.57
318	260.52	6.51
515	237.54	5.94
658	205.68	5.14
662	205.68	5.14

(Table 6)

The interesting thing to note is that four of the eight critical cells fall within subwatershed # 644. Looking back at the subwatershed analysis, one notes that this particular subwatershed was by far the highest sediment delivery subwatershed in the drainage. The common denominator of all eight critical cells is that the land slope is 7 % as is the case in most of the watershed. The increased land slope coupled with small grain cropland with little or no conservation tillage combines to form a cell with high levels of sediment erosion. The location of the critical sediment cells is displayed in **Figure 2** below.



(Figure 2)

Having stated that the above cells are the result of farming practices on highly erodible soils, the AGNPS model was run with these eight cells set to a cover management factor (c-factor) which would represent a limited till or no till practice. The resulting data indicates that an 11 % reduction in sediment delivered to the lake could be realized by implementing conservation tillage on the 320 acres comprising the critical erosion area. By manipulating the c-factor on a number of cells that were slightly below the critical level, a marginally larger percentage reduction in sediment could be realized. However, using only the data presented for use in the AGNPS model, these numbers do not indicate a sediment problem within the Enemy Swim Lake watershed.

Critical Cell Nitrogen Analysis

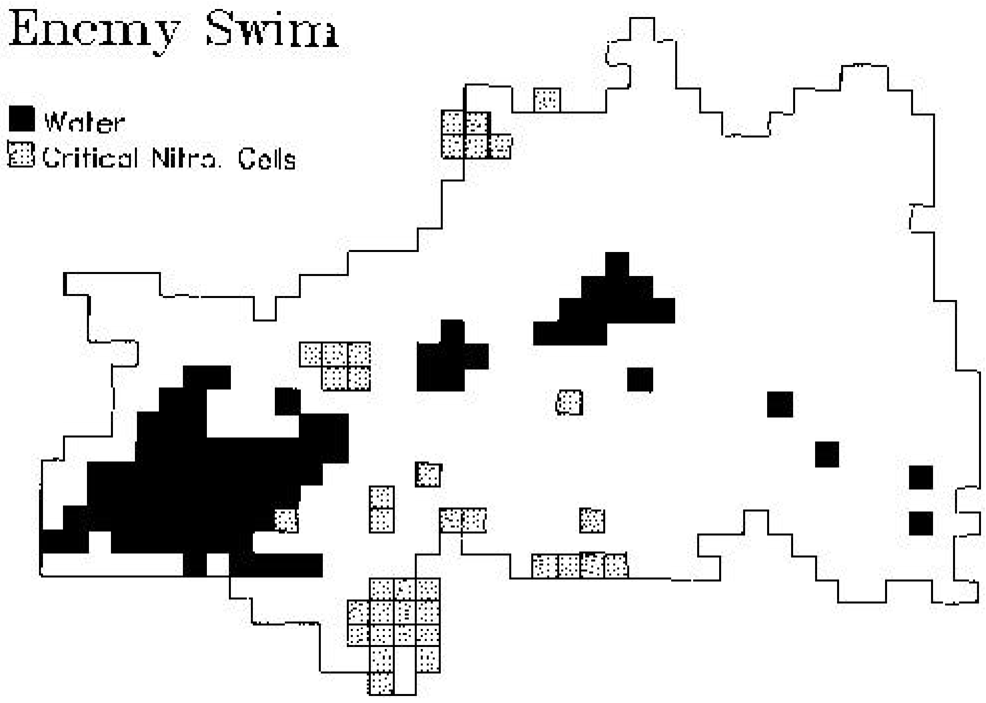
The AGNPS model indicates that the Enemy Swim watershed contains 37 cells that have an annual nitrogen output of 10 lbs./acre or more. This number of critical cells is also quite small when compared to regional watersheds. The Blue Dog Lake watershed has 135 critical nitrogen cells using the same cut off point of 10 lbs./acre. The critical nitrogen cells are listed in **Table 7**.

AGNPS Cell #	Annual Nitrogen (lbs./a)	AGNPS Cell #	Annual Nitrogen (lbs./a)	AGNPS Cell #	Annual Nitrogen (lbs./a)
364	28.38	281	11.57	555	11.34
671	20.66	317	11.57	660	11.16

547	16.99
11	15.78
627	15.37
318	15.24
41	13.99
669	13.48
664	12.54
672	11.76
512	11.66
21	11.57
42	11.44
560	11.44
551	11.4
648	11.4
649	11.4
659	11.4
666	11.4
280	11.39
282	11.39
554	11.34
665	11.16
40	11.14
647	11.09
22	10.92
663	10.65
628	10.62
630	10.42
629	10.38
658	10.14
661	10.11
474	10.06

(Table 7)

Upon examination of the nitrogen data, the common thread among most of the 37 critical cells is the fertilizer availability factor on croplands. Fields with 100% fertilizer availability at a storm event make up the majority of the critical cells. The data would indicate that land slope plays a minor role in the amount of total nitrogen delivered from each cell as the range of land slopes is anywhere from 1% to 7%. Among the top eight critical cells are three animal feeding areas. Cells # 364, 627 and 669 also have high levels of total nitrogen in their runoff. Cell #364 has the highest AGNPS rated feedlot in the watershed while cell #627 also has a highly rated feedlot. The feedlot in cell #669 is rated by AGNPS as being an insignificant feedlot, however; the remainder of the forty-acre cell is comprised of a bean field on a 4% slope with 100% fertilizer availability.



(Figure 3)

The locations of critical nitrogen cells within the Enemy Swim watershed are shown above in **Figure 3**. Those critical cells towards the top of the watershed are routed through the Oak Island slough where the high flow rate dilutes the nutrient concentration. The cells located within close proximity to Enemy Swim Lake do no have the advantage of dilution and drain into the lake with very little loss in nitrogen concentration. The AGNPS model was run with the input data altered on 23 of the critical cells (920 acres of cropland) closest to the lake to represent better incorporation of field applied fertilizers. The availability of the fertilizer to runoff from storm events was changed from 100% to 50% availability in these cells. A 50% availability factor is comparable to disking a field after surface applied fertilizer has been spread. The result was a 20% reduction in total nitrogen delivered to Enemy Swim Lake.

Critical Cell Phosphorus Analysis

As stated in the subwatershed analysis earlier, the Enemy Swim watershed has a below average deliverability of phosphorus to the lake. This is undoubtedly a result of the large quantity of rangeland within the watershed. Using the output from the AGNPS model, the data indicates there are only eight priority cells above the 4-lbs./acre cutoff. This same cutoff point was used in the Blue Dog lake analysis, which resulted in 78 cells greater than four lbs./acre.

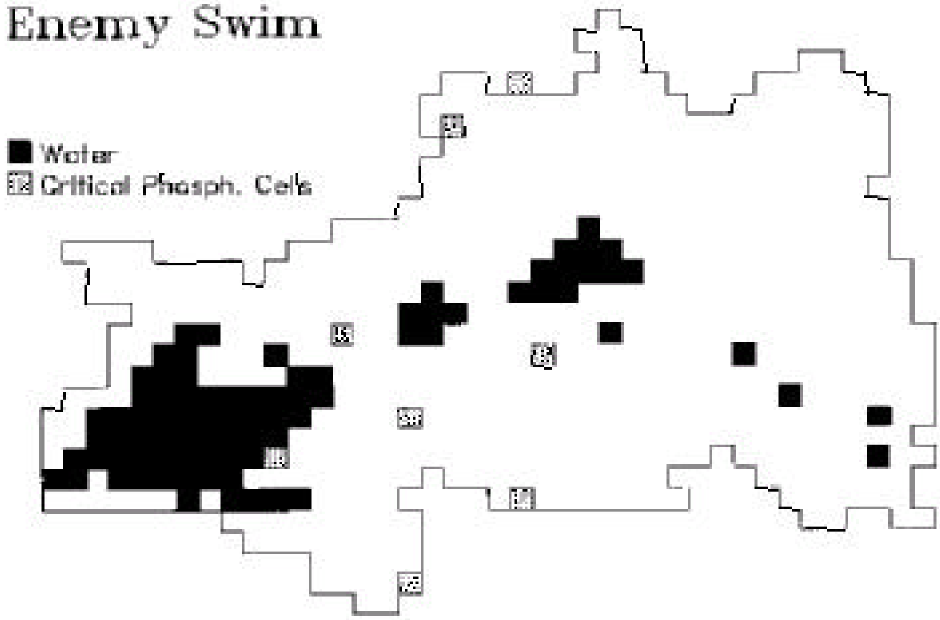
In comparison with regional watersheds, Enemy Swim Lake sees approximately 0.0001 ton/acre/year of total phosphorus. The average total phosphorus delivery rate for eastern South Dakota watersheds is 0.0003 ton/acre/year. Below is **Table 8** which list the critical cell number along with the respective phosphorus loading.

AGNPS Critical Phosphorus Cells

AGNPS Cell #	Annual Phosphorus (lbs./a)
547	6.95
364	6.81
11	4.96
671	4.76
318	4.68
474	4.24
41	4.14
627	3.9

(Table 8)

Of the eight critical phosphorus cells above, two of them contain animal feeding areas. These cells are #364 and #627. The balance of the critical cells is comprised of croplands of varying slopes. The croplands have 100% fertilizer availability, much the same as with the critical nitrogen cell analysis. Below is **Figure 4, which** graphically illustrates the locations of the critical phosphorus cells with respect to Enemy Swim Lake.



(Figure 4)

In an example of the type of reduction in phosphorus that may be obtained, the AGNPS model was run by simply converting these eight cells to 50% fertilizer availability. This would represent using a row cultivator to incorporate the fertilizer after it has been spread on the field. The response was a 13% reduction in total phosphorus entering Enemy Swim Lake. A larger percentage reduction could be obtained, according to the model, when the combination of cells from both the critical nitrogen and critical phosphorus cells were addressed in a combined effort. By introducing row cultivating, or some other method resulting in a reduction in fertilizer availability, a 24% reduction could be realized.

OBJECTIVE 3 – FEEDLOT ANALYSIS

Thirteen animal feeding areas were identified by AGNPS as being a potential source of non-point pollution in the Enemy Swim watershed. The AGNPS model recognizes feedlots as a point source of nutrients and ranks them according to severity of nutrient output from 0 to 100 using a number of factors exclusive to the feedlots. Some of the factors taken into account by the model are: feeding area size in acres, number and type of animals, area in acres of land draining through the feedlot, and the specific data relating to the presence of a buffer (grassed) area designed to limit nutrient runoff from the feedlot. Below is a listing of the AGNPS analysis of each animal feeding area complete with ranking. This data is the result of running the model with a single storm event of a 25-year intensity.

AGNPS Animal Feeding Area Data Output

Cell # 189

Nitrogen concentration (ppm) 75.000
Phosphorus concentration (ppm) 18.063
COD concentration (ppm) 1312.500
Nitrogen mass (lbs.) 498.492
Phosphorus mass (lbs.) 120.053
COD mass (lbs.) 8723.607

Animal feedlot rating number **61**

Cell # 209

Nitrogen concentration (ppm) 45.000
Phosphorus concentration (ppm) 10.837
COD concentration (ppm) 787.500
Nitrogen mass (lbs.) 211.758
Phosphorus mass (lbs.) 50.998
COD mass (lbs.) 3705.766

Animal feedlot rating number **48**

Cell # 214

Nitrogen concentration (ppm) 34.414
Phosphorus concentration (ppm) 8.229
COD concentration (ppm) 592.336
Nitrogen mass (lbs.) 292.991
Phosphorus mass (lbs.) 70.061
COD mass (lbs.) 5042.958

Animal feedlot rating number **54**

Cell # 244

Nitrogen concentration (ppm) 47.592
Phosphorus concentration (ppm) 9.772
COD concentration (ppm) 810.360
Nitrogen mass (lbs.) 369.751
Phosphorus mass (lbs.) 75.917
COD mass (lbs.) 6295.843

Animal feedlot rating number **57**

Cell # 334

Nitrogen concentration (ppm) 54.000
Phosphorus concentration (ppm) 13.005
COD concentration (ppm) 945.000
Nitrogen mass (lbs.) 74.609
Phosphorus mass (lbs.) 17.968
COD mass (lbs.) 1305.660

Cell # 346

Nitrogen concentration (ppm) 64.800
Phosphorus concentration (ppm) 15.138
COD concentration (ppm) 1147.909
Nitrogen mass (lbs.) 254.273
Phosphorus mass (lbs.) 59.400
COD mass (lbs.) 4504.347

Animal feedlot rating number **32**

Cell # 359

Nitrogen concentration (ppm) 23.600
Phosphorus concentration (ppm) 5.610
COD concentration (ppm) 409.000
Nitrogen mass (lbs.) 187.176
Phosphorus mass (lbs.) 44.494
COD mass (lbs.) 3243.862

Animal feedlot rating number **48**

Cell # 459 000

Nitrogen concentration (ppm) 104.000
Phosphorus concentration (ppm) 23.942
COD concentration (ppm) 1875.000
Nitrogen mass (lbs.) 194.862
Phosphorus mass (lbs.) 44.859
COD mass (lbs.) 3513.139

Animal feedlot rating number **45**

Cell # 602

Nitrogen concentration (ppm) 67.500
Phosphorus concentration (ppm) 16.256
COD concentration (ppm) 1181.250
Nitrogen mass (lbs.) 718.147
Phosphorus mass (lbs.)

Animal feedlot rating number **50**

Cell # 364 000

Nitrogen concentration (ppm) 54.931
Phosphorus concentration (ppm) 12.852
COD concentration (ppm) 897.688
Nitrogen mass (lbs.) 839.159
Phosphorus mass (lbs.) 196.332
COD mass (lbs.) 13713.590

Animal feedlot rating number **69**

Cell # 483

Nitrogen concentration (ppm) 15.000
Phosphorus concentration (ppm) 3.612
COD concentration (ppm) 262.500
Nitrogen mass (lbs.) 66.211
Phosphorus mass (lbs.) 15.946
COD mass (lbs.) 1158.688

Animal feedlot rating number **32**

Cell # 627

Nitrogen concentration (ppm) 135.000
Phosphorus concentration (ppm) 32.513
COD concentration (ppm) 2362.500
Nitrogen mass (lbs.) 478.424
Phosphorus mass (lbs.)

	172.954
COD mass (lbs.)	12567.570
Animal feedlot rating number	**67**

	115.220
COD mass (lbs.)	8372.413
Animal feedlot rating number	**58**

Cell # 669

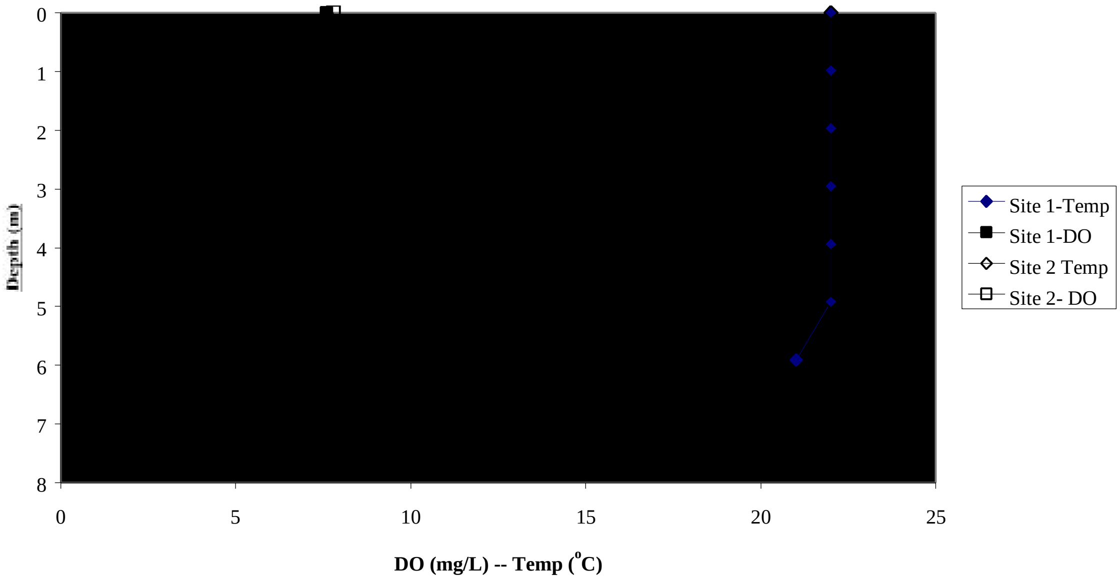
Nitrogen concentration (ppm)	10.212
Phosphorus concentration (ppm)	2.076
COD concentration (ppm)	233.100
Nitrogen mass (lbs.)	59.686
Phosphorus mass (lbs.)	12.132
COD mass (lbs.)	1362.389
Animal feedlot rating number	**35**

When the model was run with those cells having a feedlot ranking of 50 or greater removed to simulate construction of animal waste containment systems, the delivered load of total nitrogen to Enemy Swim Lake dropped 5%. The reduction in phosphorus entering the lake dropped 7% according to the model.

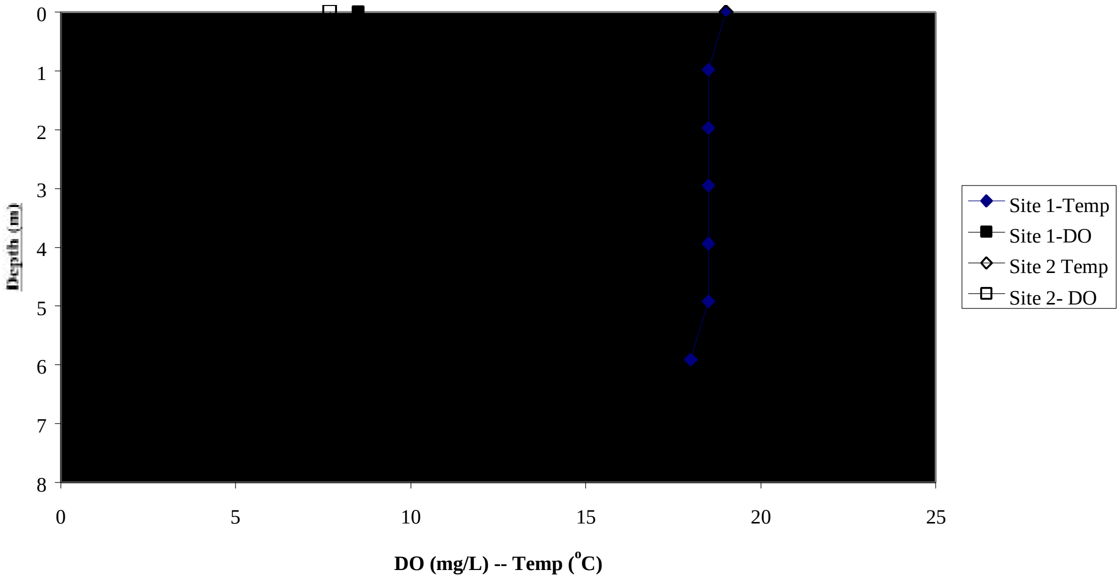
APPENDIX D

Dissolved Oxygen Profiles

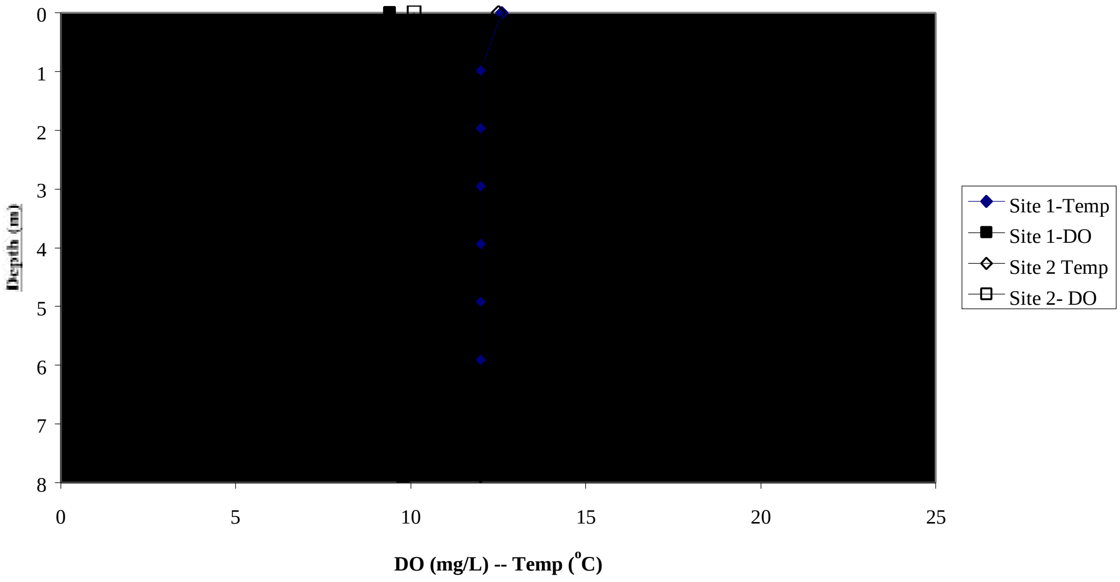
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
8/26/96



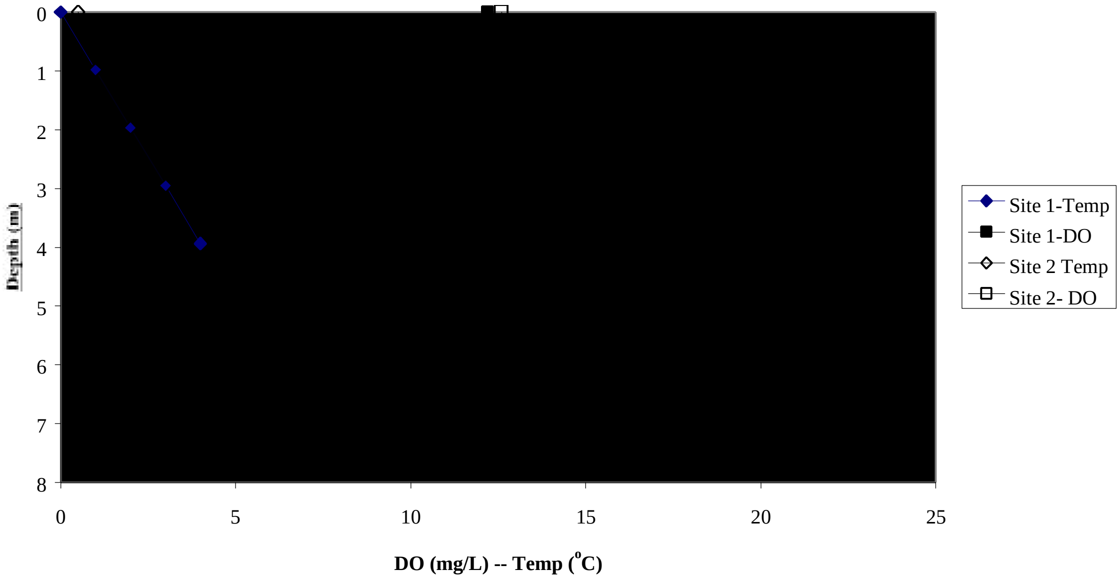
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
9/16/96



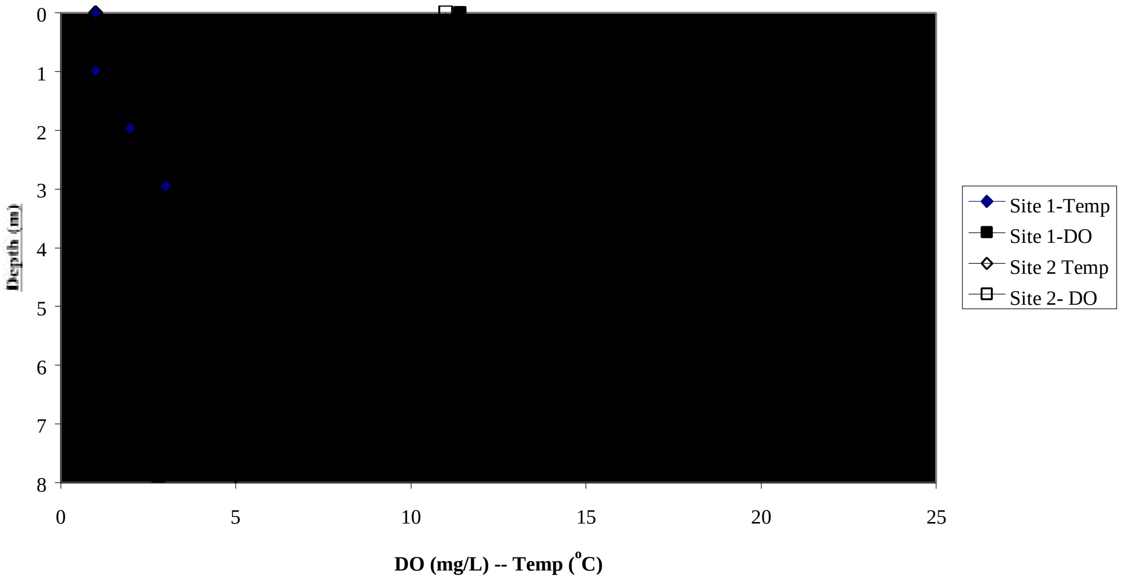
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
10/15/96



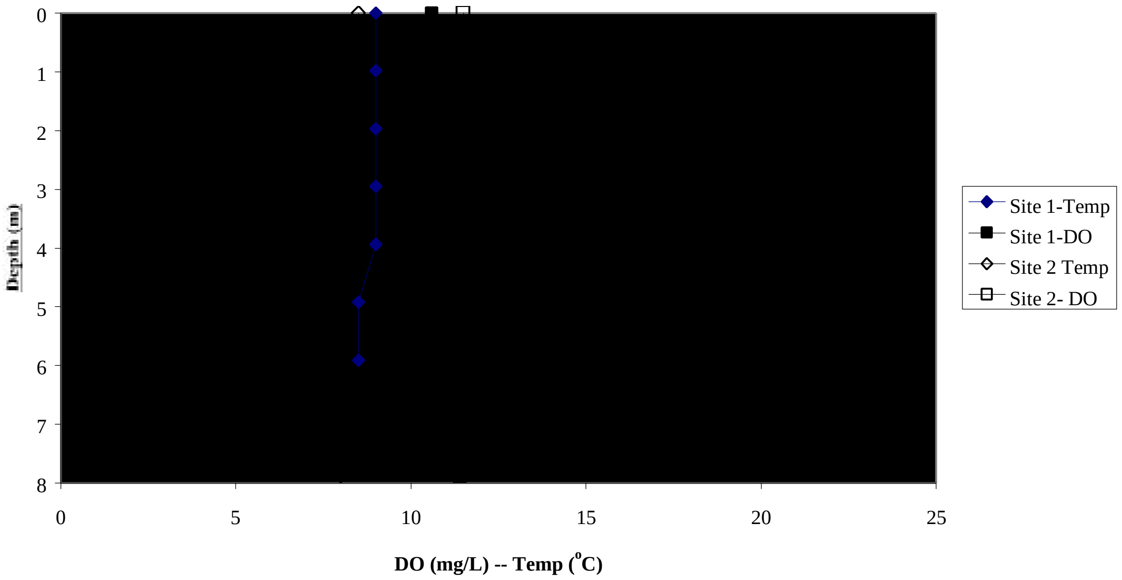
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
2/25/97



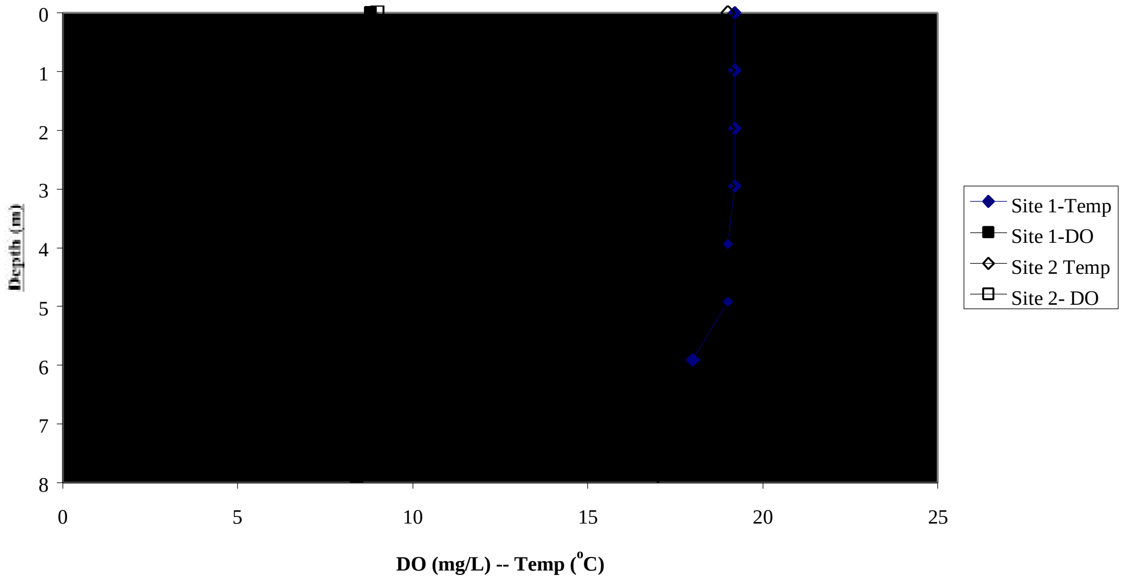
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
3/26/97



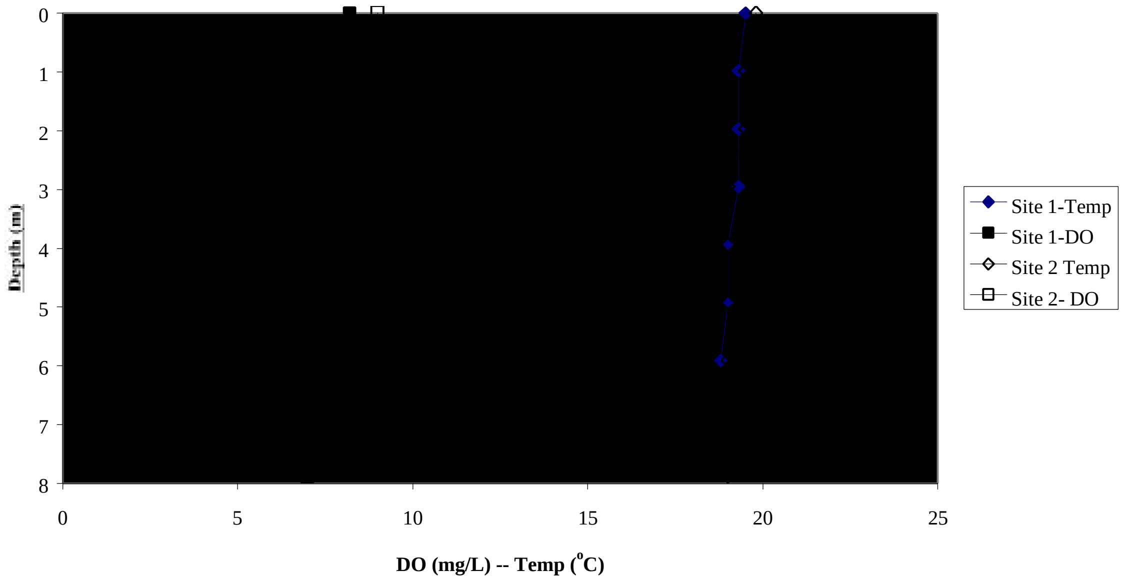
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
5/6/97



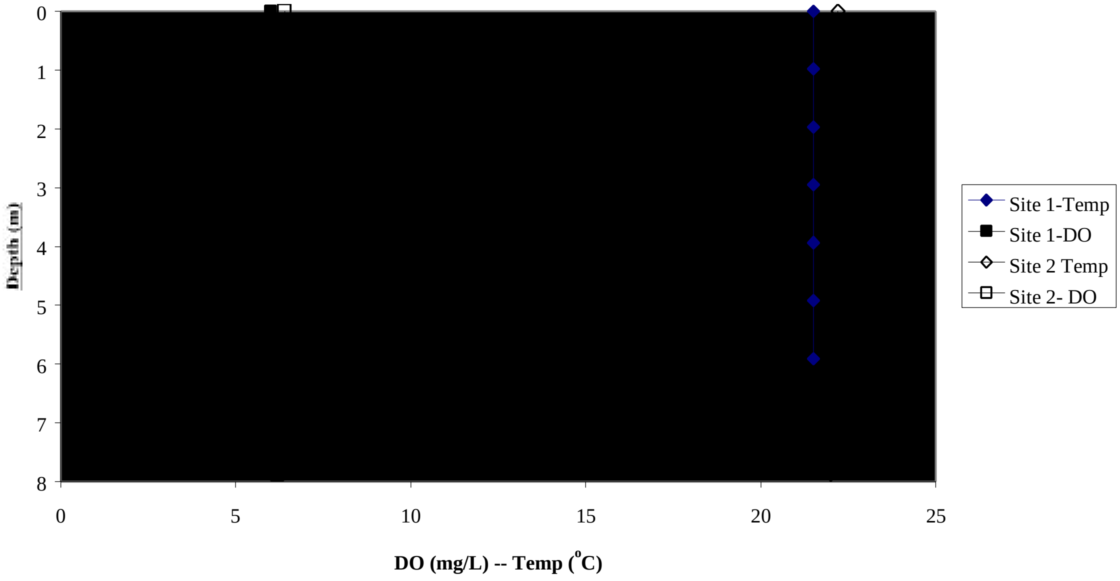
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
6/11/97



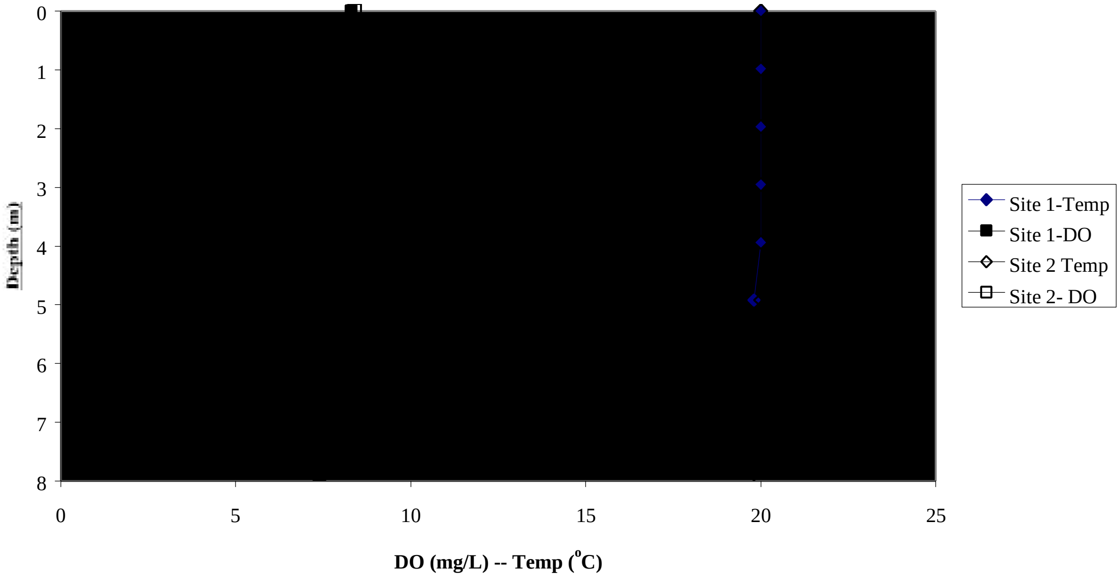
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
7/8/97



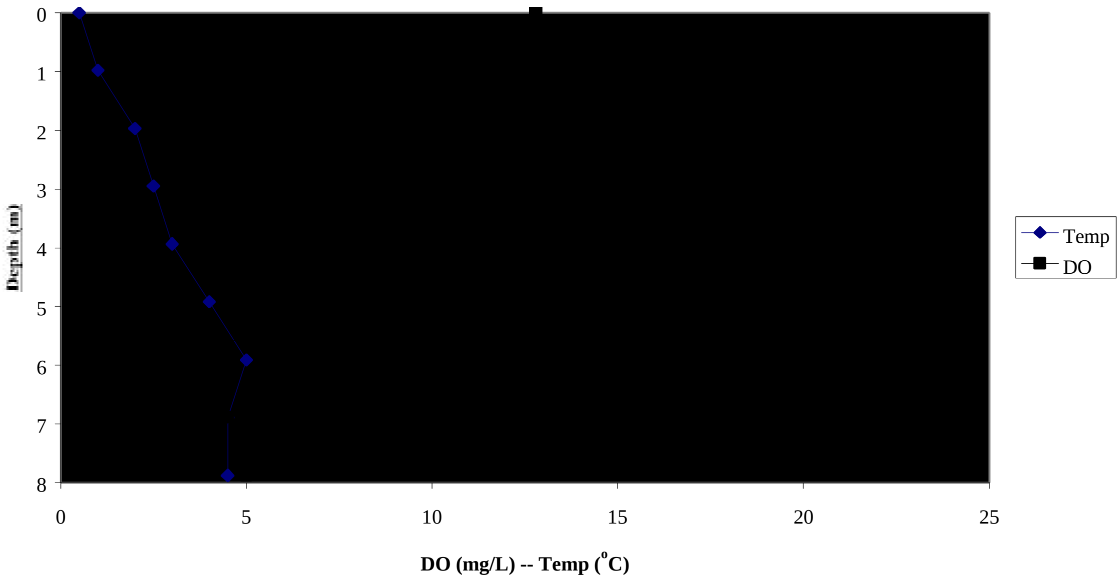
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
8/12/97



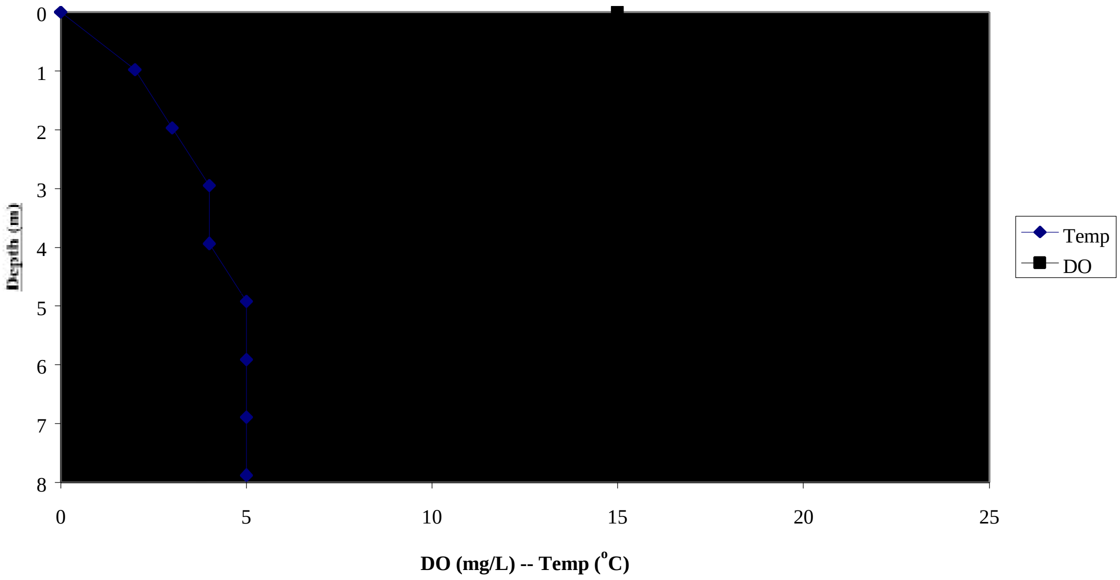
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
9/15/97



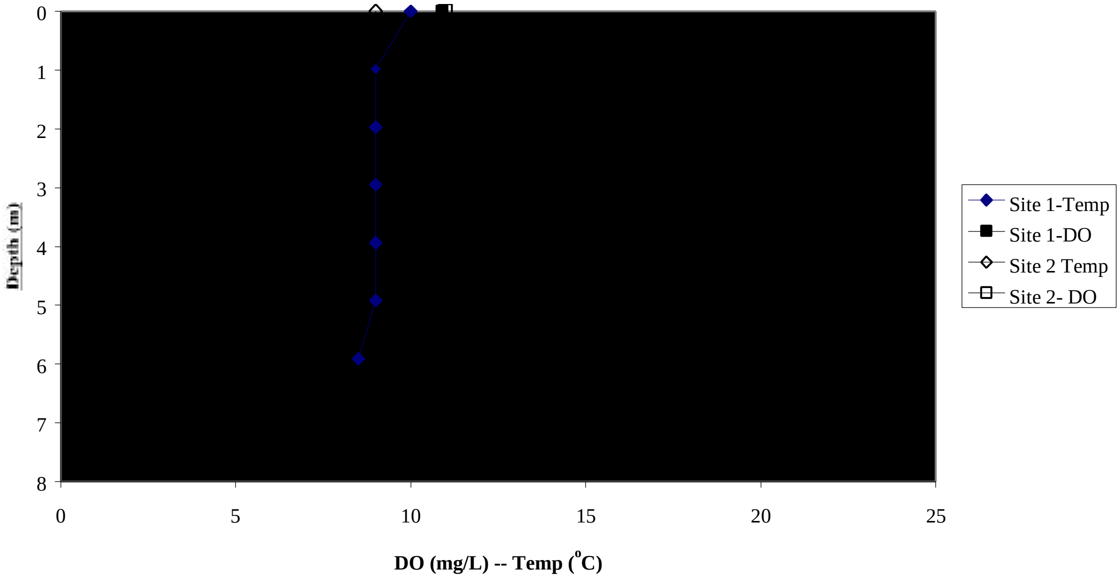
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
2/23/98   ESL-2



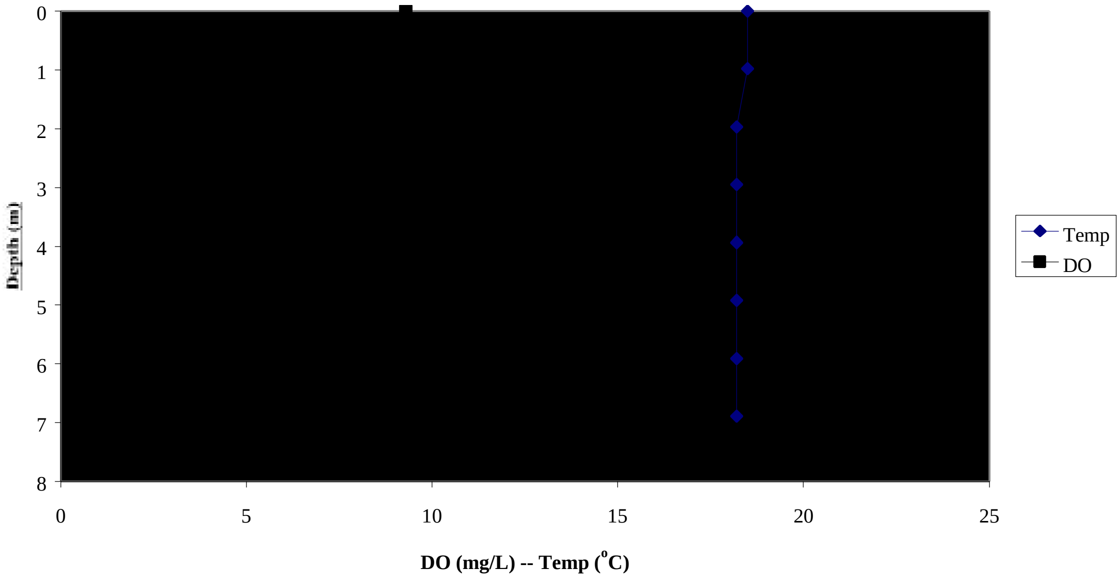
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
3/15/98   ESL-2



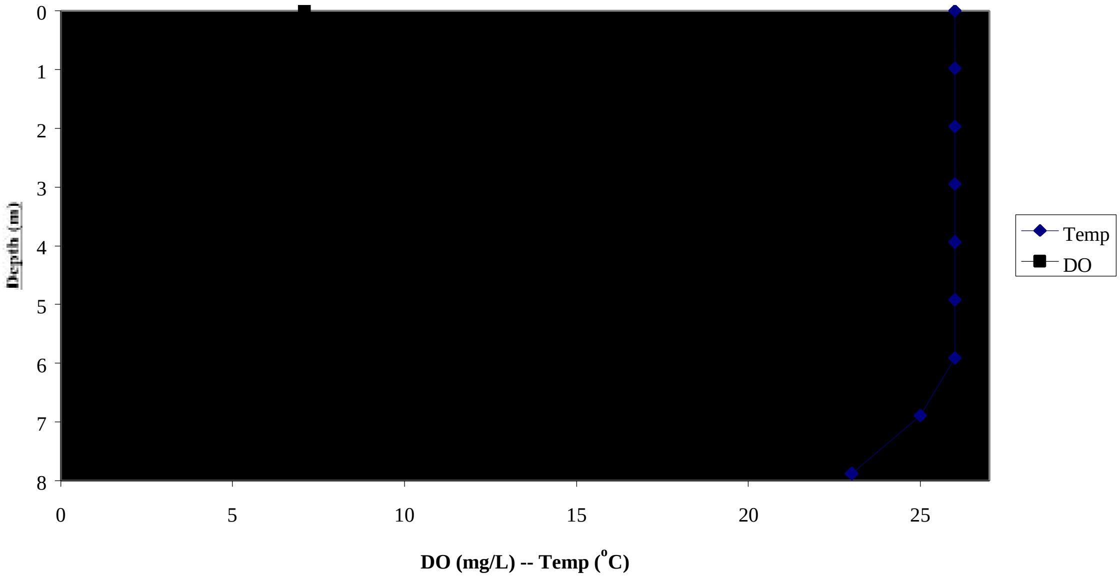
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
4/22/98



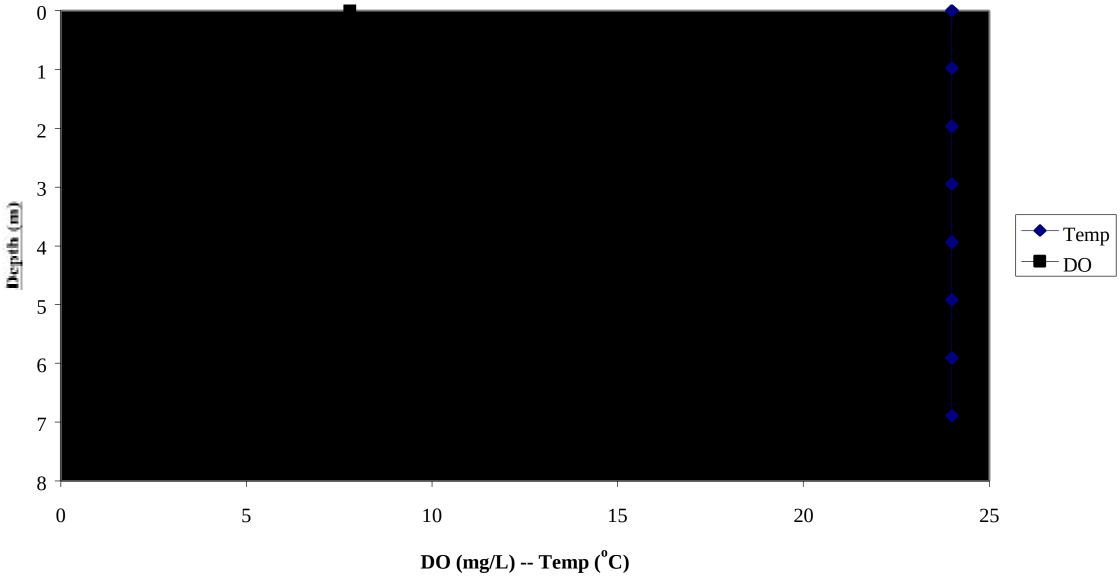
Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
5/27/98 ESL-1&2



Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
7/15/98   ESL-1&2



Enemy Swim Lake
Dissolved Oxygen/Temperature Profiles
8/24/98   ESL-1&2



APPENDIX E

Phytoplankton Tables

Table 1 Biological Monitoring of Algae in Enemy Swim Lake (1997 and 1998)

Algae Type	Taxa	25-Feb-97		26-March-97		6-May-97		11-June-97	
		ESL-1	ESL-2	ESL-1	ESL-2	ESL-1	ESL-2	ESL-1	ESL-2
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Flagellated Algae	Chroomonas sp.	320	398	100	200	750	780	100	110
Flagellated Algae	Cryptomonas spp.	7	5	2	2	84	130	19	48
Flagellated Algae	Chrysochromulina parva	10	20	0	0	13260	7350	310	220
Flagellated Algae	Chlamydomonas spp.	0	0	1	20	120	270	0	0
Flagellated Algae	Dinobryon sertularia	0	0	0	0	796	1160	0	0
Flagellated Algae	Chrysococcus amphora	0	0	0	0	0	0	0	0
Flagellated Algae	Glenodinium spp.	0	0	0	0	0	0	0	0
Flagellated Algae	Glenodinium gymnodinium	0	0	0	0	0	0	0	0
Flagellated Algae	Glenodinium quadridens	0	0	0	0	0	0	0	0
Flagellated Algae	Peridinium willei	0	0	0	0	0	0	0	0
Flagellated Algae	Peridinium spp.	0	0	0	4	30	0	1	2
Flagellated Algae	Mallomonas acaroides	0	0	0	0	8	8	0	0
Flagellated Algae	Mallomonas caudata	0	0	0	0	2	0	1	3
Flagellated Algae	Mallomonas alpina	0	0	0	0	3	3	0	0
Flagellated Algae	Mallomonas sp.	0	0	0	0	0	0	0	0
Flagellated Algae	Mallomonas tonsurata	0	0	0	0	0	0	0	0
Flagellated Algae	Ochromonas sp.	0	0	0	0	30	60	0	30
Flagellated Algae	Ceratium hirundinella	0	0	0	0	0	0	0	0
Flagellated Algae	Euglena gracilis	0	0	0	0	4	0	0	1
Flagellated Algae	Phacus spp.	0	0	0	0	0	0	0	1
Flagellated Algae	Phacus pseudonordstedtii	0	0	0	0	0	0	0	0
Flagellated Algae	Unidentified misc. flagellates	470	480	180	520	13301	9474	1480	2190
Flagellated Algae	Trachelomonas spp.	0	0	0	0	0	0	0	0
Total Flagellated Algae		**807**	**903**	**283**	**746**	**28388**	**19235**	**1911**	**2605**
Blue Green Algae	Aphanocapsa spp.	0	0	0	0	0	0	4046	1984
Blue-Green Algae	Aphanizomenon flos-aquae	0	0	0	0	0	0	0	0
Blue-Green Algae	Aphanothece spp.	0	0	0	0	0	0	11164	5476
Blue-Green Algae	Coelosphaerium naegelianum	0	0	0	0	0	0	0	40
Blue-Green Algae	Chroococcus spp.	0	0	0	0	0	0	0	20

Table 1 Enemy Swim Lake (continued)

Algae Type	Taxa	25-Feb-97		26-March-97		6-May-97		11-June-97	
		ESL-1	ESL-2	ESL-1	ESL-2	ESL-1	ESL-2	ESL-1	ESL-2
		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Blue-Green Algae	Anabaena flos-aquae	0	0	0	0	0	0	0	0
Blue-Green Algae	Anabaena sp.	0	0	0	0	0	0	0	100
Blue-Green Algae	Gomphosphaeria aponina	0	0	0	0	0	0	0	0
Blue-Green Algae	Merismopedia sp.	0	0	0	0	0	0	0	0
Blue-Green Algae	Phormidium mucicola	0	0	0	0	0	0	0	0
Blue-Green Algae	Microcystis aeruginosa	0	0	0	120	0	0	0	0
Blue-Green Algae	Microcystis incerta	0	0	0	0	0	0	0	125
Blue-Green Algae	Microcystis sp.	0	0	0	0	0	0	0	240
Blue-Green Algae	Lyngbya birgei	0	0	0	0	0	0	100	170
Blue-Green Algae	Lyngbya subtilis	0	0	0	0	50	30	0	0
Blue-Green Algae	Gomphosphaeria sp.	0	0	0	0	0	0	45	0
Total Blue-Green Algae		**0**	**0**	**0**	**120**	**50**	**30**	**15355**	**8155**
Diatoms	Asterionella formosa	0	0	0	0	103	119	53	63
Diatoms	Fragilaria crotonensis	0	0	0	0	100	303	215	379
Diatoms	Tabellaria fenestrata	0	0	0	0	9	0	0	0
Diatoms	Stephanodiscus hantzschii	0	0	0	0	92	146	0	3
Diatoms	Stephanodiscus niagarae	0	0	0	0	2	3	5	6
Diatoms	Cyclotella comta	0	0	0	0	36	57	73	64
Diatoms	Cyclotella ocellata	0	0	0	0	185	291	52	124
Diatoms	Cyclotella spp.	0	0	0	0	15	11	1	0
Diatoms	Melosira granulata	0	0	0	0	15	44	11	82
Diatoms	Melosira sp.	0	0	0	0	0	0	0	20

Table 1 Enemy Swim Lake (continued)

Algae Type	**Taxa**	**25-Feb-97**		**26-March-97**		**6-May-97**		**11-June-97**	
		ESL-1	**ESL-2**	**ESL-1**	**ESL-2**	**ESL-1**	**ESL-2**	**ESL-1**	**ESL-2**
		cells/ml	**cells/ml**	**cells/ml**	**cells/ml**	**cells/ml**	**cells/ml**	**cells/ml**	**cells/ml**
Diatoms	Nitzschia acicularis	0	0	0	0	32	19	28	15
Diatoms	Nitzschia sp.	0	0	0	0	12	9	0	0
Diatoms	Synedra acus	0	0	0	0	3	8	0	1
Diatoms	Synedra radians	0	0	0	0	0	0	0	0
Diatoms	Rhizosolenia sp.	0	0	0	0	1	0	0	1
Diatoms	Cymbella spp.	0	0	0	0	2	0	0	0
Diatoms	Amphora sp.	0	0	0	0	0	0	0	0
Diatoms	Achnanthes spp.	0	0	0	0	0	0	0	0
Diatoms	Rhizosolenia eriensis	0	0	0	0	0	0	0	0
Diatoms	Navicula spp.	0	0	0	0	0	0	0	0
Diatoms	Unidentified pennate diatoms	0	0	0	0	1	0	0	2
Total Diatoms		**0**	**0**	**0**	**0**	**608**	**1010**	**438**	**760**
Non-Motile Green Algae	Ankistrodesmus falcatus	0	0	60	0	60	10	0	0
Non-Motile Green Algae	Ankistrodesmus spp.	10	0	0	0	0	0	0	50
Non-Motile Green Algae	Pediastrum boryanum	0	0	0	0	0	0	12	30
Non-Motile Green Algae	Pediastrum duplex	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Scenedesmus bijuga	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Scenedesmus spp.	0	0	0	0	0	0	4	11
Non-Motile Green Algae	Scenedesmus quadricauda	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Oocystis spp.	0	0	0	0	0	0	110	18
Non-Motile Green Algae	Dictyosphaerium pulchellum	0	0	0	0	0	0	8	0
Non-Motile Green Algae	Botryococcus braunii	0	0	0	0	0	0	170	53

Table 1 Enemy Swim Lake (continued)

Algae Type	Taxa	25-Feb-97		26-March-97		6-May-97		11-June-97	
		ESL-1	**ESL-2**	**ESL-1**	**ESL-2**	**ESL-1**	**ESL-2**	**ESL-1**	**ESL-2**
		cells/ml	**cells/ml**	**cells/ml**	**cells/ml**	**cells/ml**	**cells/ml**	**cells/ml**	**cells/ml**
Non-Motile Green Algae	Botryococcus sudeticus	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Sphaerocystis schroeteri	0	0	0	0	0	0	48	80
Non-Motile Green Algae	Elakatothrix viridis	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Kirchneriella spp.	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Staurastrum sp.	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Crucigenia quadrata	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Micractinium pusillum	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Actinastrum sp.	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Tetraedron minimum	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Tetraedron spp.	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Golenkinia radiata	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Closterium sp.	0	0	0	0	0	0	0	0
Non-Motile Green Algae	Unidentified green algae	0	0	0	0	0	0	37	30
Total Non-Motile Green Algae		**10**	**0**	**60**	**0**	**60**	**10**	**389**	**272**
Unidentified Algae		0	0	70	140	2730	2490	840	1600
Total Algae		**817**	**903**	**413**	**1006**	**31836**	**22775**	**18933**	**13392**

Table 2 Biological Monitoring of Algae in Enemy Swim Lake (1997)

Algae Type	Taxa	8-July-97		12-August-	
		ESL-1	**ESL-2**	**ESL-1**	**ES**
		cells/ml	**cells/ml**	**cells/ml**	**ce**
Flagellated Algae	Cryptomonas spp.	210	170	90	
Flagellated Algae	Chlamydomonas spp.	560	780	960	
Flagellated Algae	Dinobryon cylindricum	270	0	0	
Flagellated Algae	Dinobryon sociale	100	0	0	
Flagellated Algae	Dinobryon spp.	0	310	0	
Flagellated Algae	Dinobryon bavaricum	0	0	20	
Flagellated Algae	Chrysococcus sp.	0	30	0	
Flagellated Algae	Peridinium sp.	0	10	0	
Flagellated Algae	Unidentified euglenoid flagellates	0	0	120	
Flagellated Algae	Unidentified flagellates	570	300	380	
Flagellated Algae	Ceratium hirundinella	0	0	0	
Total Flagellated Algae		**1710**	**1600**	**1570**	
Blue-Green Algae	Aphanocapsa spp.	20	450	0	
Blue-Green Algae	Aphanocapsa elachista v. conferva	0	0	330	
Blue-Green Algae	Aphanizomenon flos-aquae	1430	1120	0	
Blue-Green Algae	Aphanothece spp.	240	80	510	
Blue-Green Algae	Coelosphaerium sp.	0	0	0	
Blue-Green Algae	Chroococcus spp.	0	0	0	
Blue-Green Algae	Chroococcus cohaerens	0	0	120	
Blue-Green Algae	Chroococcus pallidus	0	0	30	
Blue-Green Algae	Anabaena sp.	90	160	130	
Blue-Green Algae	Gomphosphaeria wichurae	0	0	0	
Blue-Green Algae	Gomphosphaeria aponina	0	120	0	
Blue-Green Algae	Merismopedia sp.	50	30	0	
Blue-Green Algae	Merismopedia glauca	0	0	0	
Blue-Green Algae	Merismopedia punctata	0	0	140	
Blue-Green Algae	Lyngbya birgei	0	0	0	
Blue-Green Algae	Lyngbya subtilis	550	210	810	
Blue-Green Algae	Oscillatoria sp.	180	1200	120	
Blue-Green Algae	Gomphosphaeria lacustris	0	0	0	
Blue-Green Algae	Polycystis sp.	0	0	0	
Total Blue-Green Algae		**2560**	**3370**	**2190**	

Table 2 Enemy Swim Lake (Continued)

Algae Type	Taxa	8-July-97		12-A
		ESL-1	**ESL-2**	**ESL-1**
		cells/ml	**cells/ml**	**cells/ml**
Diatoms	Gyrosigma sp.	10	0	0
Diatoms	Fragilaria crotonensis	460	420	830
Diatoms	Stephanodiscus spp.	20	20	80
Diatoms	Stephanodiscus hantzschii	0	0	0
Diatoms	Melosira granulata	160	190	1290
Diatoms	Melosira sp.	0	0	0
Diatoms	Nitzschia acicularis	30	10	40
Diatoms	Synedra sp.	0	0	30
Diatoms	Surirella sp.	0	0	0
Diatoms	Unidentified centric diatoms	30	40	90
Diatoms	Unidentified pennate diatoms	10	0	20
Total Diatoms		**720**	**680**	**2380**
Non-Motile Green Algae	Ankistrodesmus convolutus	30	30	10
Non-Motile Green Algae	Ankistrodesmus sp.	0	0	0
Non-Motile Green Algae	Pediastrum duplex	0	0	0
Non-Motile Green Algae	Scenedesmus bijuga	20	10	70
Non-Motile Green Algae	Scenedesmus quadricauda	110	20	240
Non-Motile Green Algae	Oocystis spp.	30	30	430
Non-Motile Green Algae	Dictyosphaerium sp.	10	20	0
Non-Motile Green Algae	Dictyosphaerium pulchellum	0	0	80
Non-Motile Green Algae	Elakatothrix sp.	0	0	0
Non-Motile Green Algae	Crucigenia quadrata	0	0	0
Non-Motile Green Algae	Crucigenia tetrapedia	0	0	50
Non-Motile Green Algae	Schroederia setigera	0	0	0
Non-Motile Green Algae	Golenkinia radiata	0	10	0
Total Non-Motile Green Algae		**210**	**120**	**880**
Total Algae		**5200**	**5770**	**7020**

Table 3 Biological Monitoring of Algae in Enemy Swim Lake (1997)

Algae Type	Taxa	8-July-97		12-August-	
		ESL-C	ESL-T	ESL-C	ES
		cells/ml	cells/ml	cells/ml	ce
Flagellated Algae	Cryptomonas spp.	120	30	90	
Flagellated Algae	Chlamydomonas spp.	840	730	840	
Flagellated Algae	Chrysococcus sp.	30	10	0	
Flagellated Algae	Trachelomonas volvocina	80	10	0	
Flagellated Algae	Trachelomonas sp.	0	0	0	
Flagellated Algae	Phacus sp.	0	0	0	
Flagellated Algae	Unidentified euglenoid flagellates	40	20	50	
Flagellated Algae	Unidentified flagellates	410	300	150	
Flagellated Algae	Dinobryon spp.	230	270	80	
Total Flagellated Algae		**1750**	**1370**	**1210**	
Blue-Green Algae	Anabaena circinalis	0	0	0	
Blue-Green Algae	Aphanocapsa spp.	890	640	0	
Blue-Green Algae	Aphanocapsa elachista	0	0	0	
Blue-Green Algae	Aphanocapsa pulchra	0	0	100	
Blue-Green Algae	Aphanocapsa elachista v. conferva	0	0	170	
Blue-Green Algae	Aphanizomenon flos-aquae	320	90	240	
Blue-Green Algae	Aphanothece spp.	240	70	60	
Blue-Green Algae	Chroococcus spp.	30	20	200	
Blue-Green Algae	Chroococcus pallidus	0	0	280	
Blue-Green Algae	Anabaena sp.	80	1020	0	
Blue-Green Algae	Gomphosphaeria wichurae	0	30	130	
Blue-Green Algae	Gomphosphaeria aponina	60	0	0	
Blue-Green Algae	Merismopedia sp.	50	50	40	
Blue-Green Algae	Lyngbya birgei	2400	0	14980	
Blue-Green Algae	Lyngbya subtilis	1230	4950	2200	
Blue-Green Algae	Oscillatoria sp.	320	300	0	
Blue-Green Algae	Polycystis sp.	110	10	50	
Total Blue-Green Algae		**5730**	**7180**	**18450**	

Table 3 Enemy Swim Lake (Continued)

Algae Type	Taxa	8-July-97		12-
		ESL-C	ESL-T	ESL-C
		cells/ml	cells/ml	cells/ml
Diatoms	Cymbella sp.	20	0	0
Diatoms	Fragilaria crotonensis	2580	3280	880
Diatoms	Stephanodiscus spp.	90	160	40
Diatoms	Melosira granulata	750	1120	210
Diatoms	Melosira sp.	0	0	0
Diatoms	Nitzschia spp.	0	0	30
Diatoms	Nitzschia acicularis	10	30	0
Diatoms	Synedra sp.	0	10	0
Diatoms	Unidentified centric diatoms	30	40	90
Total Diatoms		**3480**	**4720**	**1180**
Non-Motile Green Algae	Ankistrodesmus convolutus	80	40	0
Non-Motile Green Algae	Ankistrodesmus sp.	0	0	0
Non-Motile Green Algae	Pediastrum sp.	0	0	30
Non-Motile Green Algae	Pediastrum duplex	0	0	0
Non-Motile Green Algae	Scenedesmus spp.	70	80	110
Non-Motile Green Algae	Scenedesmus bijuga	0	0	0
Non-Motile Green Algae	Scenedesmus quadricauda	0	0	0
Non-Motile Green Algae	Oocystis spp.	120	150	40
Non-Motile Green Algae	Dictyosphaerium sp.	30	30	0
Non-Motile Green Algae	Dictyosphaerium pulchellum	0	0	0
Non-Motile Green Algae	Elakatothrix sp.	0	0	0
Non-Motile Green Algae	Elakatothrix viridis	0	30	0
Non-Motile Green Algae	Crucigenia quadrata	0	70	0
Non-Motile Green Algae	Schroederia setigera	10	10	0
Total Non-Motile Green Algae		**310**	**410**	**180**
Total Algae		**11270**	**13680**	**21020**

Table 4 Biological Monitoring of Algae in Enemy Swim Lake (1998)

Algae Type	Taxa	22-April-98		27-May-98	24-June-
		ESL-1	ESL-2	ESL-2	ESL-2
		cells/ml	cells/ml	cells/ml	cells/m
Flagellated Algae	Chroomonas sp.	10	1	130	
Flagellated Algae	Cryptomonas spp.	13	3	32	
Flagellated Algae	Chrysochromulina parva	40	500	70	4
Flagellated Algae	Chlamydomonas spp.	10	0	0	
Flagellated Algae	Dinobryon sertularia	174	96	1	1
Flagellated Algae	Euglena spp.	0	0	1	
Flagellated Algae	Chrysococcus amphora	530	160	0	
Flagellated Algae	Glenodinium spp.	0	1	0	
Flagellated Algae	Glenodinium gymnodinium	0	0	0	
Flagellated Algae	Glenodinium quadridens	0	0	0	
Flagellated Algae	Peridinium willei	0	0	6	
Flagellated Algae	Peridinium spp.	0	0	0	
Flagellated Algae	Mallomonas pseudocoronata	0	0	0	
Flagellated Algae	Mallomonas sp.	0	1	0	
Flagellated Algae	Ceratium hirundinella	0	0	0	
Flagellated Algae	Phacus spp.	0	0	0	
Flagellated Algae	Unidentified misc. flagellates	4630	7070	712	26
Flagellated Algae	Trachelomonas spp.	0	1	0	
Total Flagellated Algae		**5407**	**7833**	**952**	**32**
Blue Green Algae	Aphanocapsa spp.	840	1225	6426	310
Blue-Green Algae	Aphanizomenon flos-aquae	0	0	0	
Blue-Green Algae	Aphanothece spp.	0	0	17374	201
Blue-Green Algae	Coelosphaerium naegelianum	0	95	860	9
Blue-Green Algae	Chroococcus spp.	0	0	44	
Blue-Green Algae	Anabaena flos-aquae	0	0	0	51
Blue-Green Algae	Anabaena spiroides	0	0	0	
Blue-Green Algae	Anabaena planctonica	0	0	0	
Blue-Green Algae	Gomphosphaeria aponina	0	0	0	
Blue-Green Algae	Merismopedia sp.	0	0	0	

Table 4 Enemy Swim Lake (continued)

Algae Type	Taxa	22-April-98		27-May-98	24-June-98	17
		ESL-1	**ESL-2**	**ESL-2**	**ESL-2**	**ES**
		cells/ml	**cells/ml**	**cells/ml**	**cells/ml**	
Blue-Green Algae	Phormidium mucicola	0	0	0	280	
Blue-Green Algae	Microcystis aeruginosa	210	45	550	762	
Blue-Green Algae	Microcystis incerta	0	0	0	1450	
Blue-Green Algae	Microcystis sp.	0	0	0	545	
Blue-Green Algae	Lyngbya birgei	0	0	0	200	
Blue-Green Algae	Lyngbya subtilis	480	120	0	205	
Total Blue-Green Algae		**1530**	**1485**	**25254**	**60831**	
Diatoms	Asterionella formosa	581	680	46	0	
Diatoms	Fragilaria crotonensis	809	607	313	98	
Diatoms	Tabellaria fenestrata	10	14	37	2	
Diatoms	Stephanodiscus hantzschii	14	23	7	20	
Diatoms	Stephanodiscus niagarae	2	3	12	1	
Diatoms	Cyclotella comta	5	11	47	4	
Diatoms	Cyclotella ocellata	116	47	0	80	
Diatoms	Melosira granulata	0	0	51	2	
Diatoms	Melosira granulata v. angustissima	0	0	0	23	
Diatoms	Melosira sp.	4	6	0	0	
Diatoms	Nitzschia acicularis	25	19	30	138	
Diatoms	Nitzschia spp.	9	11	0	19	
Diatoms	Synedra acus	3	4	0	0	
Diatoms	Synedra radians	0	0	15	0	
Diatoms	Cymbella spp.	2	0	0	0	
Diatoms	Amphora sp.	3	0	0	0	
Diatoms	Rhizosolenia eriensis	0	0	0	1	
Diatoms	Navicula spp.	2	0	0	0	
Diatoms	Unidentified pennate diatoms	6	4	0	5	
Total Diatoms		**1591**	**1429**	**558**	**393**	

Table 4 Enemy Swim Lake (continued)

Algae Type	Taxa	22-April-98		27-May-98	24-June-98	17-
		ESL-1	ESL-2	ESL-2	ESL-2	
		cells/ml	cells/ml	cells/ml	cells/ml	
Non-Motile Green Algae	Ankistrodesmus spp.	40	20	0	0	
Non-Motile Green Algae	Pediastrum boryanum	3	47	24	26	
Non-Motile Green Algae	Pediastrum duplex	0	0	0	0	
Non-Motile Green Algae	Pediastrum simplex v. duodenarium	0	0	0	0	
Non-Motile Green Algae	Scenedesmus spp.	8	38	25	0	
Non-Motile Green Algae	Scenedesmus quadricauda	0	0	0	72	
Non-Motile Green Algae	Oocystis spp.	0	0	57	25	
Non-Motile Green Algae	Dictyosphaerium pulchellum	0	0	90	0	
Non-Motile Green Algae	Botryococcus braunii	0	30	70	65	
Non-Motile Green Algae	Botryococcus sudeticus	0	0	120	0	
Non-Motile Green Algae	Sphaerocystis schroeteri	0	0	160	0	
Non-Motile Green Algae	Echinosphaerella limnetica	6	4	0	0	
Non-Motile Green Algae	Elakatothrix viridis	0	14	0	2	
Non-Motile Green Algae	Selenastrum sp.	0	0	0	0	
Non-Motile Green Algae	Staurastrum sp.	0	0	1	0	
Non-Motile Green Algae	Crucigenia tetrapedia	0	0	20	0	
Non-Motile Green Algae	Crucigenia quadrata	0	0	0	57	
Non-Motile Green Algae	Lagerheimia sp.	0	0	0	0	
Non-Motile Green Algae	Micractinium pusillum	0	0	0	0	
Non-Motile Green Algae	Tetraedron minimum	0	0	0	0	
Non-Motile Green Algae	Tetraedron spp.	0	0	0	0	
Non-Motile Green Algae	Golenkinia radiata	0	0	0	0	
Non-Motile Green Algae	Coelastrum microporum	0	0	0	0	
Non-Motile Green Algae	Closterium aciculare	0	0	0	0	
Non-Motile Green Algae	Unidentified green algae	0	0	173	0	
Total Non-Motile Green Algae		**57**	**153**	**740**	**247**	
Unidentified Algae		1130	1740	530	3345	
Total Algae		**9715**	**12640**	**28034**	**68060**	

Table 5. Yearly Algae Metrics Analysis[#]

	1979	1989	1997	1998
Species Count	27	22	96	87
Total Count	7368	557237	252967	1418302
Percent Blue-Green	91.99%	99.00%	63.33%	95.39%
Percent AAM*	80.37%	0.35%	5.13%	2.67%
Percent Diatoms	9.22%	0.09%	10.86%	0.51%
Percent Pennate Diatoms	7.10%	0.08%	6.88%	0.33%
Percent Centric Diatoms	2.12%	0.01%	3.98%	0.19%
Percent Green Algae	2.65%	0.55%	6.79%	0.27%
Percent Colonial Green	3%	0.50%	3.62%	0.37%
Percent Chrysophytes	0.49%	0.00%	9.96%	0.29%
Percent Euglenophytes	0.00%	0.00%	0.26%	0.00%
Percent Dinoflagellates	0.08%	0.00%	0.035	0.01%
Shannon (10) Diversity	0.754	0.632	1.901	0.958
Shannon (2) Diversity[##]	2.50	2.1	6.31	3.18
Shannon Evennes	0.53	0.47	0.96	0.49
Equally Abundant Species	5.68	4.29	79.57	9.07
Simpson Diversity	0.669	0.681	0.961	0.800
Simpson Evenness	0.69	0.71	0.97	0.81
Simpson Dominance	0.331	0.319	0.039	0.200
TSI(B)**	52.99	61.03	78.65	94.10
Nitrogen Fixer Index (C)***	4.685	0.342	3.671	65.296
Preferred Indicator Species	P	P	P	P
Clean Water Index	2	1	62	84
Palmer Index[###]	8	9	30	30

Metrics generated by combining all algae samples and stations by year from the lake

Shannon (2) Diversity: Values <2.00-considerable environmental stress, 2.00-3.00-average diversity, >3.00-above average diversity.

Palmer Index: Values>19 indicate increased eutrophication

* Percent Anabaena, Aphanizomenon and Microcystis

** Trophic State Index (Biovolume)

*** Nitrogen Fixer Index (cells/mL)

Table 6. Algae Species List.

Achnanthes sp.
Actinastrum sp.
Amphora sp.
Anabaena circinalis
Anabaena flos-aquae
Anabaena planctonica
Anabaena sp.
Anabaena spiroides
Ankistrodesmus convolutus
Ankistrodesmus falcatus
Ankistrodesmus sp.
Aphanizomenon flos-aquae
Aphanocapsa elachista
Aphanocapsa elachista v.conferta
Aphanocapsa pulchra
Aphanocapsa sp.
Aphanothece sp.
Asterionella formosa
Botryococcus braunii
Botryococcus sudeticus
Ceratium hirundinella
Chlamydomonas sp.
Chroococcus cohaerens
Chroococcus pallidus
Chroococcus sp.
Chroomonas sp.
Chrysochromulina parva
Chrysococcus amphora
Chrysococcus sp.
Closterium aciculare
Closterium sp.
Coelastrum microporum
Coelosphaerium naegelianum
Coelosphaerium sp.
Crucigenia quadrata
Crucigenia tetrapedia
Cryptomonas sp.
Cyclotella comta
Cyclotella ocellata
Cyclotella sp.
Cymbella sp.
Dictyosphaerium ehrenbergianum
Dictyosphaerium pulchellum
Dictyosphaerium sp.
Dinobryon bavaricum
Dinobryon cylindricum
Dinobryon sertularia
Dinobryon sociale
Dinobryon sp.
Echinosphaerella limnetica
Elakatothrix sp.
Elakatothrix viridis
Euglena gracilis
Euglena sp.
Fragilaria crotonensis
Glenodinium gymnodinium
Glenodinium quadridens
Glenodinium sp.
Golenkinia radiata
Gomphosphaeria aponina
Gomphosphaeria lacustris
Gomphosphaeria sp.
Gomphosphaeria wichurae
Gyrosigma sp.
Kirchneriella sp.
Lagerheimia (Chodatella)
Lyngbya birgei
Lyngbya subtilis
Mallomonas acaroides
Mallomonas alpina
Mallomonas caudata
Mallomonas pseudocoronata
Mallomonas sp.
Mallomonas tonsurata
Melosira granulata
Melosira granulata v. angustissima
Melosira sp.
Merismopedia glauca
Merismopedia punctata
Merismopedia sp.

Micractinium pusillum
Microcystis aeruginosa
Microcystis incerta
Microcystis sp.
Navicula sp.
Nitzschia acicularis
Nitzschia sp.
Ochromonas sp.
Oocystis sp.
Oscillatoria sp.
Pediastrum boryanum
Pediastrum duplex
Pediastrum simplex v. duodenarium
Pediastrum sp.
Peridinium sp.
Peridinium willei
Phacus pseudonordstedtii
Phacus sp.
Phormidium mucicola
Polycystis sp.
Rhizosolenia eriensis
Rhizosolenia sp.
Scenedesmus bijuga
Scenedesmus quadricauda
Scenedesmus sp.
Schroederia setigera
Selenastrum sp.
Sphaerocystis schroeteri
Staurastrum sp.
Stephanodiscus hantzschii
Stephanodiscus niagarae
Stephanodiscus sp.
Surirella sp.
Synedra acus
Synedra radians
Synedra sp.
Tabellaria fenestrata
Tetraedron minimum
Tetraedron sp.
Trachelomonas sp.
Trachelomonas volvocina
Unidentified algae
Unidentified centric diatoms
Unidentified euglenoid flagellates
Unidentified flagellates
Unidentified green algae
Unidentified pennate diatoms

Specie Count: 127

APPENDIX F

Water Quality Data

Site	Depth	Date	Time	Air Temp	pH	Secchi Depth	Water Temp	Dissolved Oxygen	Alkalinity Total	Total Solids
				°C	su	m	°C	mg/L	mg/L	mg/L
ESL1	Surface	08/26/1996	1000	21	8.73	1.20	22.00	7.60	189	266
ESL1	Bottom	08/26/1996	1000		8.73	1.20	21.00	7.00	189	266
ESL1	Surface	09/16/1996	1115	17	8.56	1.51	19.00	8.50	194	274
ESL1	Bottom	09/16/1996	1115	17	8.99	1.51	18.00	8.00	193	284
ESL1	Surface	10/15/1996	1025	10	8.99	1.62	12.60	9.40	195	253
ESL1	Bottom	10/15/1996	1025	10	8.99	1.62	12.00	9.20	193	259
ESL1	Surface	02/25/1997	1215	0	8.50		0.00	12.20	219	283
ESL1	Surface	03/26/1997	905	9	8.45		1.00	11.00	217	278
ESL1	Surface	05/06/1997	1000	13.5	7.99	1.80	9.00	10.60	189	248
ESL1	Bottom	05/06/1997	1000	13.5	7.93	1.80	8.50	10.60	190	248
ESL1	Surface	06/11/1997	1000	21.5	8.32	4.27	19.20	8.80	198	257
ESL1	Bottom	06/11/1997	1000	21.5	8.14	4.27	18.00	8.10	198	261
ESL1	Surface	07/08/1997	930	19	8.56	1.22	19.50	8.20	200	263
ESL1	Bottom	07/08/1997	930	19	8.45	1.22	18.80	5.30	196	268
ESL1	Surface	08/12/1997	1000	24	8.64	1.13	21.50	6.00	195	270
ESL1	Bottom	08/12/1997	1000	24	8.62	1.13	21.50	5.40	194	281
ESL1	Surface	09/15/1997	1030	22	8.56	1.62	20.00	8.30	195	264
ESL1	Bottom	09/15/1997	1030	22	8.49	1.62	19.50	6.80	196	267
ESL1	Surface	04/22/1998	1115	17	8.18	3.32	10.00	10.90	197	269
ESL1	Bottom	04/22/1998	1115	17	8.10	3.32	10.00	10.90	198	266

Site	Depth	Date	Time	Unionized Ammonia mg/L	Nitrate mg/L	TKN mg/L	Total Phosphorus mg/L	Total Dissolved Phosphorus mg/L	Fecal Coliform Colonies / 100ml	Vol Susp Sol mg
ESL1	Surface	08/26/1996	1000	0.00198	0.1	0.86	0.037		5	0.
ESL1	Bottom	08/26/1996	1000	0.00187	0.1	0.80	0.044	0.004	5	
ESL1	Surface	09/16/1996	1115	0.00118	0.1	0.79	0.023	0.010	10	
ESL1	Bottom	09/16/1996	1115	0.00251	0.1	0.79	0.029	0.010	5	
ESL1	Surface	10/15/1996	1025	0.00182	0.1	0.88	0.020	0.010	5	
ESL1	Bottom	10/15/1996	1025	0.00175	0.1	0.78	0.023	0.008	5	
ESL1	Surface	02/25/1997	1215	0.00153	0.05	0.85	0.014	0.016	5	
ESL1	Surface	03/26/1997	905	0.00025	0.1	0.84	0.014	0.012	5	
ESL1	Surface	05/06/1997	1000	0.00017	0.2	0.34	0.023	0.006	5	
ESL1	Bottom	05/06/1997	1000	0.00014	0.2	0.35	0.476	0.003	5	
ESL1	Surface	06/11/1997	1000	0.00073	0.05	0.79	0.011	0.005	5	
ESL1	Bottom	06/11/1997	1000	0.00090	0.05	0.82	0.022	0.006	5	
ESL1	Surface	07/08/1997	930	0.00122	0.05	0.88	0.025	0.005	5	[illegible]
ESL1	Bottom	07/08/1997	930	0.00093	0.05	0.86	0.028	0.006	5	[illegible]
ESL1	Surface	08/12/1997	1000	0.00162	0.05	0.43	0.033	0.004	5	1
ESL1	Bottom	08/12/1997	1000	0.00156	0.05	0.68	0.036	0.005	5	
ESL1	Surface	09/15/1997	1030	0.00126	0.05	0.60	0.025	0.008	5	
ESL1	Bottom	09/15/1997	1030	0.00106	0.05	0.80	0.035	0.007	5	
ESL1	Surface	04/22/1998	1115	0.00027	0.1	0.64	0.013	0.004	5	
ESL1	Bottom	04/22/1998	1115	0.00023	0.1	0.62	0.016	0.009	5	

Site	Depth	Date	Time	Air Temp	pH	Secchi Depth	Water Temp	Dissolved Oxygen	Alkalinity Total	Total Solids	Su S
				^{o}C	su	m	^{o}C	mg/L	mg/L	mg/L	
ESL2	Surface	08/26/1996	1100		8.73	1.28	22.00	7.80	190	270	
ESL2	Bottom	08/26/1996	1100		8.73	1.28	22.00	7.40	188	270	
ESL2	Surface	09/16/1996	1030	17	8.90	1.39	19.00	7.70	192	270	
ESL2	Bottom	09/16/1996	1035	17	8.90	1.39	19.00	6.90	192	285	
ESL2	Surface	10/15/1996	1045	11	8.83	1.77	12.50	10.10	197	251	
ESL2	Bottom	10/15/1996	1045	11	8.83	1.77	12.00	9.80	194	252	
ESL2	Surface	02/25/1997	1110	0.5	8.39		0.50	12.60	221	291	
ESL2	Surface	03/26/1997	1040	1100	8.39		1.00	11.40	187	276	
ESL2	Surface	05/06/1997	1030	13.5	7.85	2.53	8.50	11.50	188	245	
ESL2	Bottom	05/06/1997	1030	13.5	7.86	2.53	8.00	11.30	190	241	
ESL2	Surface	06/11/1997	930	22.2	8.25	3.75	19.00	9.00	195	254	
ESL2	Bottom	06/11/1997	930	22.2	8.13	3.75	17.00	8.40	196	254	
ESL2	Surface	07/08/1997	950	20	8.56	1.71	19.80	9.00	198	262	
ESL2	Bottom	07/08/1997	950	20	8.46	1.71	19.00	7.00	202	267	
ESL2	Surface	08/12/1997	1035	22.5	8.65	1.45	22.20	6.40	193	266	
ESL2	Bottom	08/12/1997	1035	22.5	8.63	1.45	22.00	6.20	196	258	
ESL2	Surface	09/15/1997	1000	21	8.62	1.62	20.00	8.40	193	256	
ESL2	Bottom	09/15/1997	1000	21	8.62	1.62	19.80	7.40	193	259	
ESL2	Surface	02/23/1998	1130	2	8.39	1.62	0.50	12.80	196	251	
ESL2	Surface	03/18/1998	1130	-2	8.28	1.62	0.00	15.10	204	272	
ESL2	Surface	04/22/1998	1000	17	8.13	3.89	9.00	11.00	195	265	
ESL2	Bottom	04/22/1998	1000	17	8.13	3.89	8.00	11.70	195	266	
ESL2	Surface	05/27/1998	930	18	8.63	2.56	18.50	9.30	193	255	
ESL2	Bottom	05/27/1998	930	18	8.53	2.56	18.50	9.20	194	249	
ESL2	Surface	06/24/1998	1045	32	8.48	1.83	21.00	8.60	198	272	
ESL2	Bottom	06/24/1998	1045	32	8.42	1.83	19.50	8.80	198	270	
ESL2	Surface	07/15/1998	930	22.5	8.35	1.23	26.00	7.10	195	195	
ESL2	Bottom	07/15/1998	930	22.5	8.10	1.23	23.50	4.40	200	266	
ESL2	Surface	08/24/1998	1045	24	8.58	1.22	24.00	7.80	187	261	
ESL2	Bottom	08/24/1998	1045	24	8.51	1.22	24.00	7.60	187	263	

Site	Depth	Date	Time	Unionized Ammonia mg/L	Nitrate mg/L	TKN mg/L	Total Phosphorus mg/L	Total Dissolved Phosphorus mg/L	Fecal Coliform Colonies / 100ml	Volatile Suspended Solids mg/L	BOI mg/
ESL2	Surface	08/26/1996	1100	0.00198	0.1	0.84	0.037	0.023	5		
ESL2	Bottom	08/26/1996	1100	0.00198	0.1	1.09	0.027	0.004	5		
ESL2	Surface	09/16/1996	1030	0.00227	0.1	1.06	0.030	0.010	5		
ESL2	Bottom	09/16/1996	1035	0.00227	0.1	0.91	0.034	0.007	5		
ESL2	Surface	10/15/1996	1045	0.00133	0.1	0.74	0.027	0.013	5		
ESL2	Bottom	10/15/1996	1045	0.00128	0.1	0.85	0.020	0.010	5		
ESL2	Surface	02/25/1997	1110	0.00145	0.1	0.64	0.014		5	0.542	
ESL2	Surface	03/26/1997	1040	0.00497	0.6	6.19	0.225	0.213	5		
ESL2	Surface	05/06/1997	1030	0.00012	0.2	0.51	0.013	0.004	5		
ESL2	Bottom	05/06/1997	1030	0.00011	0.2	0.38	0.015	0.003	5		
ESL2	Surface	06/11/1997	930	0.00062	0.1	0.62	0.013	0.005	5		
ESL2	Bottom	06/11/1997	930	0.00123	0.1	0.78	0.016	0.006	5		
ESL2	Surface	07/08/1997	950	0.00124	0.05	0.58	0.024	0.005	5	5	1
ESL2	Bottom	07/08/1997	950	0.00096	0.05	0.73	0.032	0.004	5	3	0.5
ESL2	Surface	08/12/1997	1035	0.00172	0.05	0.62	0.026	0.005	5		
ESL2	Bottom	08/12/1997	1035	0.00164	0.05	0.62	0.029	0.006	5		
ESL2	Surface	09/15/1997	1000	0.00142	0.05	0.81	0.027	0.007	5		
ESL2	Bottom	09/15/1997	1000	0.00140	0.05	0.59	0.029	0.007	5		
ESL2	Surface	02/23/1998	1130	0.00021	0.1		0.014	0.010	5		
ESL2	Surface	03/18/1998	1130	0.00016	0.1	0.71	0.011	0.006	5		
ESL2	Surface	04/22/1998	1000	0.00023	0.2	0.63	0.018	0.008	5		
ESL2	Bottom	04/22/1998	1000	0.00021	0.2	0.66	0.015	0.004	5		
ESL2	Surface	05/27/1998	930	0.00132	0.05	0.67	0.019	0.010	5		
ESL2	Bottom	05/27/1998	930	0.00108	0.05	0.82	0.022	0.010	5		
ESL2	Surface	06/24/1998	1045	0.00114	0.05	0.51	0.018	0.018	5		
ESL2	Bottom	06/24/1998	1045	0.00092	0.05	0.56	0.036	0.018	5		
ESL2	Surface	07/15/1998	930	0.00120	0.05	0.76	0.036	0.008	5		
ESL2	Bottom	07/15/1998	930	0.00061	0.05	0.74	0.037	0.010	5		
ESL2	Surface	08/24/1998	1045	0.00168	0.05	0.56	0.026	0.013	5		
ESL2	Bottom	08/24/1998	1045	0.00146	0.05	0.70	0.026	0.013	5		

Site	Depth	Date	Time	Air Temp ^{o}C	pH su	Secchi Depth m	Water Temp ^{o}C	Dissolved Oxygen mg/L	Alkalinity Total mg/L	Total Solids mg/L	Su
ESL-C	Surface	07/08/1997	1035	20	8.57	1.68	19.80	9.20	197	255	
ESL-T	Surface	07/08/1997	1025	20	8.47	1.62	19.50	9.40	199	261	
ESL-C	Surface	08/12/1997	1200	24.5	8.64	1.31	22.50	7.30	191	256	
ESL-T	Surface	08/12/1997	1130	24.5	8.64	1.31	22.50	7.70	192	266	
ESL-C	Surface	09/15/1997	1200	24	8.59	1.62	20.20	9.00	191	257	
ESL-T	Surface	09/15/1997	1145	24	8.57	1.46	20.20	8.70	192	257	
ESL-C	Surface	07/15/1998	1010	25.5	8.33	1.05	26.00	6.40	268	268	
ESL-T	Surface	07/15/1998	1000	25.5	8.36	1.17	26.00	7.10	193	252	

Site	Depth	Date	Time	Unionized Ammonia mg/L	Nitrate mg/L	TKN mg/L	Total Phosphorus mg/L	Total Dissolved Phosphorus mg/L	Fecal Coliform Colonies / 100ml	Volatile Suspended Solids mg/L
ESL-C	Surface	07/08/1997	1035	0.00127	0.05	0.92	0.023	0.007	5	4
ESL-T	Surface	07/08/1997	1025	0.00102	0.05	0.83	0.017	0.007	5	4
ESL-C	Surface	08/12/1997	1200	0.00172	0.05	0.63	0.023	0.004	5	
ESL-T	Surface	08/12/1997	1130	0.00172	0.05	0.66	0.039	0.005	5	
ESL-C	Surface	09/15/1997	1200	0.00136	0.05	0.62	0.023	0.007	5	
ESL-T	Surface	09/15/1997	1145	0.00130	0.05	0.77	0.026	0.008	5	
ESL-C	Surface	07/15/1998	1010	0.00115	0.05	0.92	0.039	0.008	5	
ESL-T	Surface	07/15/1998	1000	0.00123	0.05	0.89	0.033	0.008	5	

Site	Depth	Date	Time	Air Temp °C	pH su	Secchi Depth m	Water Temp °C	Dissolved Oxygen mg/L	Alkalinity Total mg/L	Total Solids mg/L	Total
ESL3 (Outlet)	Surface	06/11/1997	905	22.2	8.01		18.80	8.80	194	261	
ESL3 (Outlet)	Surface	07/08/1997	1010	20	7.84		19.00	9.20	196	259	
ESL3 (Outlet)	Surface	08/12/1997	1115	24.5	8.69		22.20	8.00	193	258	
ESL3 (Outlet)	Surface	09/15/1997	1135	24	8.62		20.00	8.70	191	257	
ESL4 (Inlet)	Surface	07/08/1997	910	19	7.76		17.00	3.10	290	364	
ESL4 (Inlet)	Surface	08/12/1997	945	24	7.94		18.00	6.60	317	417	
ESL4 (Inlet)	Surface	09/15/1997	1100	22	7.75		18.50	3.00	339	426	
Animal Feeding Area	Surface	02/24/1998	1100		7.86		1.00		359	915	
Animal Feeding Area	Surface	04/01/1997	1500		7.96		1.00		228	581	

Site	Depth	Date	Time	Unionized Ammonia mg/L	Nitrate mg/L	TKN mg/L	Total Phosphorus mg/L	Total Dissolved Phosphorus mg/L	Fecal Coliform Colonies / 100ml	Volatile Suspended Solids mg/L
ESL3 (Outlet)	Surface	06/11/1997	905	0.00036	0.1	0.62	0.018	0.005	10	
ESL3 (Outlet)	Surface	07/08/1997	1010	0.00025	0.05	0.71	0.023	0.007	5	5
ESL3 (Outlet)	Surface	08/12/1997	1115	0.00186	0.05	0.66	0.024	0.005	10	
ESL3 (Outlet)	Surface	09/15/1997	1135	0.00142	0.05	0.92	0.034	0.007	30	
ESL4 (Inlet)	Surface	07/08/1997	910	0.00018	0.05	0.45	0.023	0.015	180	0.5
ESL4 (Inlet)	Surface	08/12/1997	945	0.00029	0.05	0.90	0.024	0.013	170	4
ESL4 (Inlet)	Surface	09/15/1997	1100	0.00020	0.1	0.71	0.027	0.015	2,300	1
Animal Feeding Area	Surface	02/24/1998	1100	0.21941	0.3	57.70	5.290		55,000	
Animal Feeding Area	Surface	04/01/1997	1500	0.19523	0.2	39.40	4.440	3.490	3,200	

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