DIAGNOSTIC/FEASIBILTY STUDY REPORT
BEAVER LAKE/BEAVER CREEK WATERSHED
YANKTON COUNTY, SOUTH DAKOTA

SOUTH DAKOTA CLEAN LAKES PROGRAM
DIVISION OF WATER RESOURCES MANAGEMENT
SOUTH DAKOTA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOUCES
DECEMBER 1991

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Prepared By

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STUDY SUMMARY

Beaver Lake, locally known as State Lake, is a 72-acre reservoir constructed by the South Dakota Department of Game Fish and Parks (SD GF&P) in 1926. Beaver Creek, a tributary of the James River, was dammed to create Beaver Lake. The Beaver Creek watershed is approximately 91,120 acres of primarily agricultural land. The watershed holds many sink holes which capture 16,640 acres of run off, and the remaining 74,480 acres drain into Beaver Creek. The subwatershed which enters the lake totals 59,720 acres. And there are 14,760 acres located between the Beaver Lake spillway and the James River.

In October 1989, the South Dakota Department of Environment and Natural Resources (SD DENR) began a Diagnostic/Feasibility Study (D/F Study) at the request of local residents. The cooperating sponsors in the study were the Yankton Conservation District and the Yankton County Soil Conservation Service (SCS).

The purpose of the study was to assess the general condition of the lake, tributaries, and watershed. In addition, the study was to identify sources causing the lakes degradation, and propose feasible restoration alternatives to improve water quality in the lake and watershed.

The study included water quality monitoring and the use of the Agricultural Non-Point Source model (AGNPS). The lake was sampled monthly and the tributaries were sampled during run off events. Samples were collected by a local resident and sent to the South Dakota State Health Laboratory for analysis. AGNPS was developed by the U.S. Department of Agriculture to evaluate the sediment and nutrient input from watersheds. Information needed for AGNPS was compiled by the local resident responsible for water sampling, the Yankton Conservation District, and the Yankton SCS. The information gathered was sent to SD DENR personnel who reported the results.

The results of the in-lake sampling showed Beaver Lake to be a hyper-eutrophic lake. Hyper-eutrophic is a term which means that the lake has an over abundance of nutrients. Nutrients, such as nitrogen and phosphorus, are used by algae and macrophytes for growth and reproduction. Macrophytes are the "aquatic weeds" which grow up from the lake bed. Due to its shallow depths, Beaver Lake has nuisance growth of macrophytes. Algal blooms occur when the conditions are optimum for growth and reproduction. Many times blue-green algae will form floating green "mats" on the surface of the water. These large blooms significantly reduce the recreational uses of the lake and can cause odor problems. The large amounts of nutrients which are present in the lake are directly responsible for algal blooms. Turbidity, the dirty appearance of the water, could be explained by the shallow depths of the lake and the suspension of bottom sediments due to wave action. One fecal coliform sample taken from the lake on July 17, 1990, exceeded the State Water Quality Standard. The State Standard is 400 counts per 100 mg/L, the sample recorded 430 counts per 100 mg/L. Fecal coliform bacteria are disease causing organisms which live in the digestive tracts of warm blooded animals. Possible sources of the bacteria could be domestic livestock in the watershed, or a failing/insufficient sewage system. No other human health problem was observed during the D/F Study.

Through the duration of the study, a severe drought limited the number of tributary samples that could be taken. When samples were taken extremely large concentrations of nutrients and sediments were present. Fecal coliform bacteria concentrations were also extremely high in the tributary sampling. As stated earlier, the presence of fecal coliform reveals a problem with animal or human waste. The concentrations of nitrogen and phosphorus were also extremely high. The amount of phosphorus recorded from the samples was over 10 x's the minimal amount needed for algal growth. The sources for the nutrient inputs could be from feedlot run off, fertilizer run off, erosion, and/or decaying organic matter.

The AGNPS model supports the data from the tributary sampling. The model predicts loadings of sediment, nitrogen, and phosphorus into tributaries during a 5-year, 24 hour storm event. AGNPS sugguested significant amounts of nutrients may enter Beaver Lake and the James River. AGNPS estimated 37,858 tons of sediment would enter Beaver Lake in a single storm event. The model also predicted 27,617 tons of the sediment could be captured and settle in the lake basin. This would be an approximately 11% of the reservoirs capacity. During the same storm event 23,282 tons of sediment may enter the James River. Nutrient levels entering Beaver Lake are also substantial. The model estimates 102 tons of nitrogen and 39.6 tons of phosphorus entering Beaver Lake during a 5-year, 24 hour storm event. The model also predicts 91.2 tons of nitrogen and 31.3 tons of phosphorus would enter the James River. Although the model only makes predictions and estimations, it is obvious that the watershed is contributing extremely large amounts of sediment and nutrients to both the James River and Beaver Lake.

The dam of Beaver Lake, constructed in 1926, is also in need of repair. Erosion on both the upstream and downstream side of the embankment should to be controlled. The trees growing on the embankment need to be removed, and some repair is needed on the spillway itself.

The recommendations which were made for the improvement of the Beaver Lake/Beaver Creek watershed are as follows:

1) A minimum of three years work should be concentrated in the watershed. Work applied should include grassing all fields with inclines greater that 9%, no-till or ridge till

fields with slopes from 3% - 9%, injection of fertilizer on slopes from 3% - 9%. Feedlot run off near surface waters should also be controlled.

2) When the work in the watershed is completed the lake and the tributaries should again be sampled to see what kind of improvements have been made. If significant improvements have been made, the sponsor should continue with in-lake restoration below #3). If no significant improvements have been made, the sponsor may consider to either continue working in the watershed, to try applying different agricultural management practices, or to allow SD GF&P to manage the area for waterfowl/wildlife production.

It would not be practical or cost effective to attempt in-lake restoration without first controlling the watershed areas causing the problems.

3) If significant work is completed in the watershed the lake should be de-watered by placing culverts in the embankment. The primary goal for dewatering is to make the lake accessible for sediment removal of land based equipment. Equipment from the city or county could be used to remove as much sediment as desired. Other benefits of dewatering include flushing the system of its high nutrient waters, temporarily controlling the macrophytes, and consolidating the bottom sediments.

4) While the lake is dry a qualified contractor should be contacted to begin work on the dam. Riprap should be placed on the embankments, trees on the embankments should be removed and backfilled with impervious material, and the scaling and cracking of the spillway structure itself should be repaired.

The local sponsors may select any of the restoration alternatives listed in the main report or choose any of there own. The recommendations mentioned above are the ones the State feels best can solve the problems addressed in this report.

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BEAVER LAKE AND THE BEAVER CREEK WATERSHED DIAGNOSTIC / FEASIBILITY STUDY REPORT

ABSTRACT

Beaver Lake, locally known as State Lake, is a 72-acre reservoir constructed by the South Dakota Department of Game Fish and Parks in 1926. Beaver Lake has experienced dense algal blooms and nuisance growth of aquatic macrophytes. The purpose of the study was to assess the general water quality and condition of the lake, tributaries, and watershed. In addition,identify sources causing the lakes degradation, and propose feasible restoration alternatives to improve water quality in the lake and watershed.

On October 1989, the South Dakota Department of Environment and Natural Resources began a Diagnostic/Feasibility Study with the cooperation of the Yankton Conservation District and the Yankton County Soil Conservation Service.

The study included monitoring the water quality of the lake and tributaries. The Agricultural Non-Point Source model, developed by the United States Department of Agriculture, was used to evaluate sediment and nutrient input from the watershed. A severe drought occurred during the duration of the study which limited tributary sampling. Loadings to Beaver Lake and Beaver Creek were calculated from the Agricultural Non-Point Source model.

Results of the study indicate the tributaries are carrying extremely large amounts of nutrients and sediment to Beaver Lake and the James River. These loadings are the cause of the degradation of Beaver Lake. The primary sources of the nutrient and sediment loadings in the watershed were feedlots and agricultural land.

Recommendations for improvements in the watershed include 1) grassing all slopes greater than 9%, 2) no-till or ridge till and 3) injecting fertilizer in the subsoil. Once the work in the watershed is completed, the recommended lake restoration activities included 1) dam repair, 2) dewatering the lake, and 3) removal of sediment by land based equipment.

INTRODUCTION

The purpose of this report is to provide information gathered from a Diagnostic/Feasibility Study of Beaver Lake and its watershed. The study was conducted from October, 1989, to May, 1991. The parties to this cooperative study were the State of South Dakota Department of Environment and Natural Resources (SD DENR), the Yankton County Conservation District, and the Yankton County Soil Conservation Service.

The study was initiated, at local request, to assess the current status of the lake and its watershed, to determine water quality problems, to identify pollution sources and develop specific restoration alternatives. This report presents the results of the analyzed data, and the recommendations for restoration.

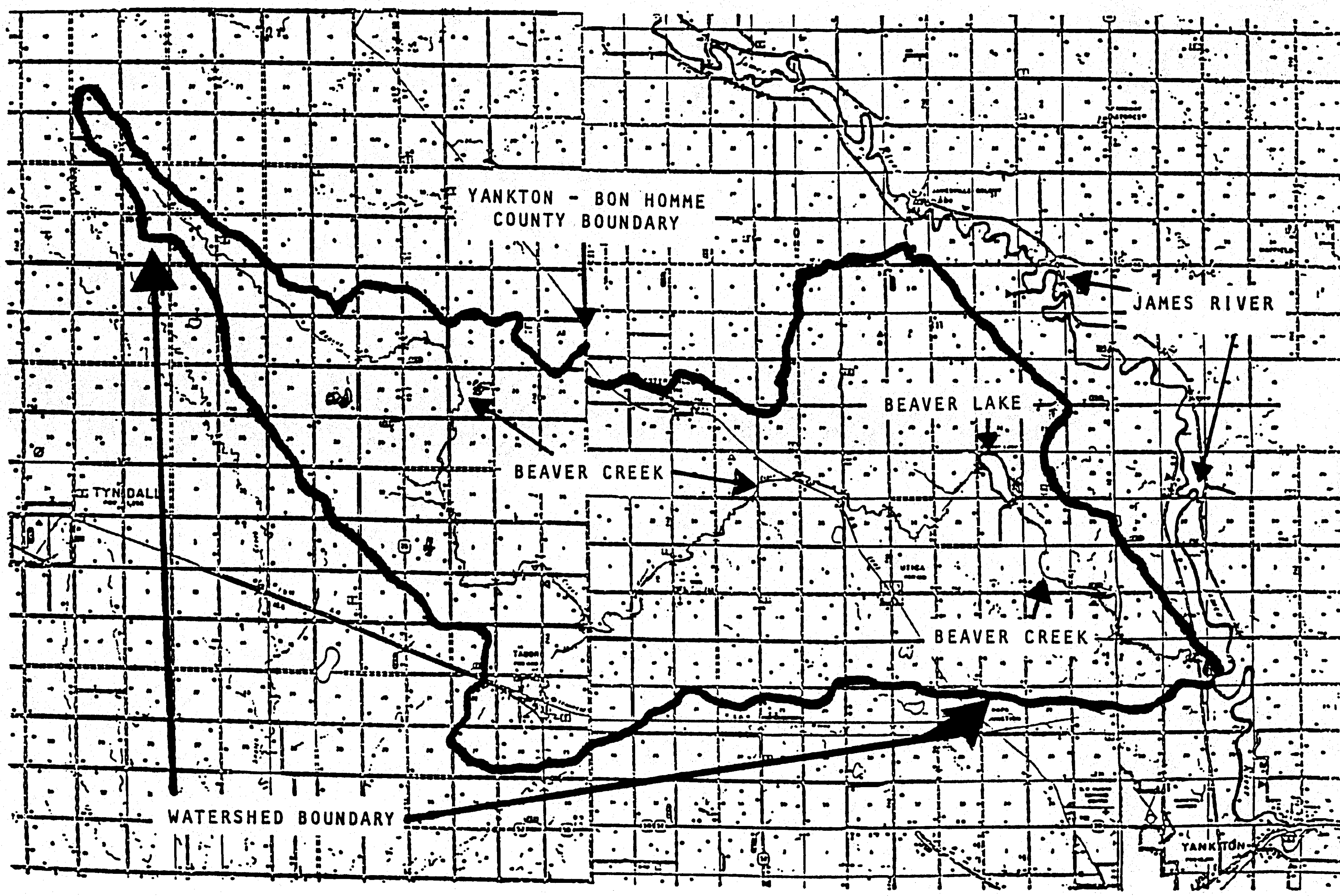
STUDY SITE DESCRIPTION

The Beaver Lake/Beaver Creek watershed is approximately 91,120 acres of primarily agricultural land. A total of 74,480 acres from the Beaver Lake/Beaver Creek watershed discharge into the James River. The remaining 16,640 acres is captured by sink holes and sealed basins. Figure 1 shows the Beaver Lake watershed located in Bon Homme and Yankton Counties in southeastern South Dakota. Beaver Lake is located 6 miles north and 2.25 miles west of Yankton, South Dakota. It has a surface area of 72 acres, a mean depth of approximately 2.5 feet and a maximum depth of 4.5 feet. The total shoreline length is 2 miles with its fetch measuring 0.8 miles. The long axis of Beaver Lake lies in a northwest to southeast orientation. Beaver Creek is the main tributary discharging into Beaver Lake. The climate is dry to semi arid. The area receives an average of 25 inches of rain each year. Water loss due to lake evaporation is greatest in the summer months and averages 38 inches a year. The average temperature is 47^{o}F and ranges from -36 to 109^{o}F from winter to summer respectively (USGS, 1986). The average wind speed is 14 miles per hour and is greatest in the spring (SCS, 1979). In 1981 the population, in a 80 kilometer radius of the lake, was 217,565 (Census Data Center, Brookings South Dakota, 1991).

WATERSHED

The Beaver Lake/Beaver Creek watershed lies at the western margin of the Central Lowlands physiographic province. The geomorphic province is split between the James River lowlands in the northwest part of the watershed and the James River highlands in the southeast region of the watershed. The boundary splitting the two minor provinces is almost parallel to the Yankton and Bon Homme county border. The Pleistocene glaciation left glacial, alluvial, and eolian deposits generally covering the upland regions. Holocene alluvium and colluvium deposits lie in and are limited to the stream valleys. The major bedrock formations are the Carlile Shale and Niobrara Formation which are generally located >100 feet below the surface. Glacial till, which dominates the watershed, consists of gentle rises, steep rolling hills, and flatlands which correspond with the general topography of the Central Lowlands (USGS, 1986). Beaver Lake is located in the James Ridge, a small 150 - 400 feet coteau, however, the average topographical relief is less than five feet (SCS, 1979).

Figure 1. The Beaver Lake/Beaver Creek Watershed



Beaver Creek travels east-southeast to the James Ridge, which it has eroded through, then it turns south and flows into the James River. Outwash lenses can be found throughout the watershed but are mainly concentrated in valleys and streams (USGS, 1986). The Beaver Creek outwash and alluvial deposits are hydraulically connected with underlying Lesterville and Lower James-Missouri aquifers. Beaver Creek may receive or lose water from the underlying areas depending on the water level of the aquifers with respect to the water level of Beaver Creek (USGS, 1986).

BACKGROUND/HISTORICAL INFORMATION

In 1926, an earthen dam was constructed on Beaver Creek by the South Dakota Department of Game Fish and Parks (SD GF&P) to create Beaver Lake (South Dakota Dept. Environmental Protection, 1973). Since 1926, Beaver Lake has severely filled with silt. In 1972, the SD GF&P completed a management study which addressed many of the same problems which prompted this Diagnostic/Feasibility Study. The SD GF&P study was initiated to help SD GF&P develop a fisheries management plan. The results of the study are summarized below. At the time of the study the lake had a maximum depth of 7.5 feet and an average depth of 5.5 feet. The littoral area cover was 100% of the lake. Plant coverage was 3% emergent and 70% submergent. The bottom sediments were 100% soft sediment. Public access was reported to be good for shoreline fishing and fair for boat launching. Results of the trap-nets set fish are included in Table 1.

Table 1. Fish Netting Summary Sheet - June 1971

SPECIES	TOTAL CATCH				AVERAGE SIZE	
	Number	(%)	Weight	(%)	Inches	Pounds
Black Bullhead	250	54.5	52.5	10.7	7.0	0.21
Carp	100	21.8	95.0	19.5	12.5	0.95
Northern Pike	80	17.4	338.4	69.4	25.7	4.23
Green Sunfish	29	6.3	1.7	0.4	4.2	0.06

Spawning conditions in the lake were excellent for black bullhead and panfish, good for largemouth bass and roughfish, fair for northern pike, and poor for walleye. Fish kills were documented in the winter of 1958-1959; a partial winter kill occurred in 1969; and a severe winterkill occurred in the winter of 1971-1972. The recommendations for management was to stock Northern pike, yellow perch, and bullhead as necessary, following winterkills.

Another study was completed by the South Dakota Department of Environmental Protection in 1973 in response to a petition received. The study addressed the points that pollution from animal and domestic sources might enter the lake by examining the fecal coliforms concentrations of samples. A copy of this document is attached (Appendix A). The general conclusions from the 1973 study indicated a need for improvements of the domestic waste systems on the lake, and also the animal feedlot systems in the watershed.

The South Dakota GF&P took dissolved oxygen (DO) samples in the winters of 1974 and 1979. Both samples showed low DO concentrations (below 2.0 mg/L). In 1980 a request was made by Representative Francis Thieman to the SD GF&P to dredge Beaver Lake. The SD GF&P denied the request because the nutrient and sediment inflow to the lake would shortly nullify the dredge's success. Beaver Lake has not been stocked since 1982 due to the shallow conditions that exist and its inability to support fish life in winter.

Since the dam was built in 1926, Beaver Lake has functioned as a reservoir and sediment basin for Beaver Creek. Until around 1971 it could support a game fish population (Table 1). The lake has now reached the point were its shallow depths and hypereutrophic conditions can not support a game fish population.

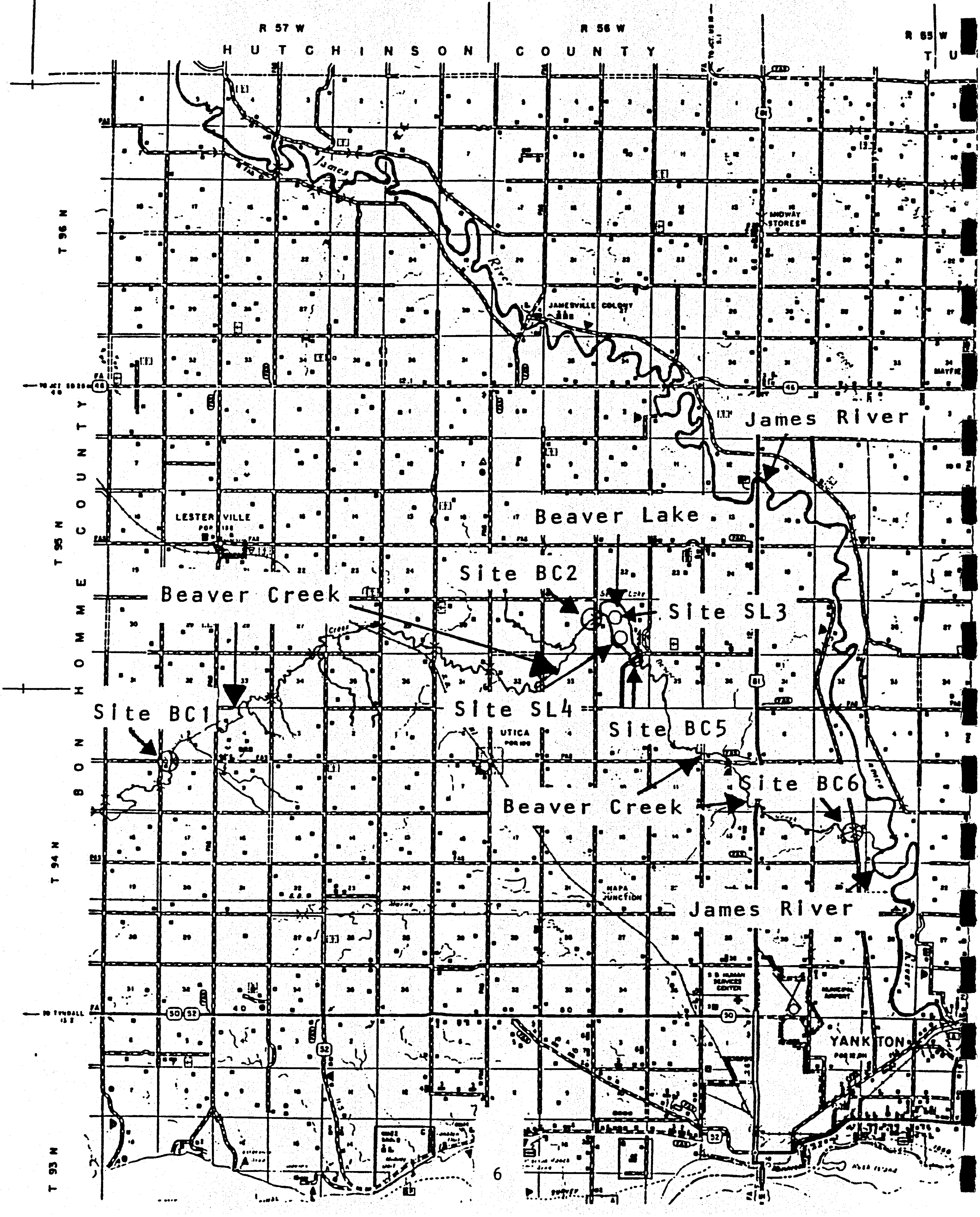
METHODS AND MATERIALS

Two methods were used assess the general condition of Beaver Lake and the Beaver Creek watershed. The first - water quality monitoring - was designed to determine sediment and nutrient loads to the lake. A hydrologic budget could then be calculated using the inflow and outflow data. This monitoring system also could help locate areas of high nutrient input by placing monitoring stations strategically throughout the watershed. Water quality monitoring is extremely effective in the above mentioned capacity; however, it can neither pinpoint problems without excessive cost and time, nor can it suggest changes to improve problems. The second method used - Agricultural Non-Point Source Pollution Model (AGNPS) - identifies areas in a watershed that have a potentially high level of nutrient runoff. The model also permits the user to apply different Best Management Practices (BMPs) to the problem cells. The model then calculates the decreased sediment and nutrient loads each BMP will provide an individual cell or the total watershed. Together, the two methods provide a good overview of the happenings in the watershed. An explanation of AGNPS can be found in Appendix B.

Water Quality Monitoring

Water quality samples were collected at 6 different sites in the watershed. Figure 2 is a map of the sampling sites for the study. Sites BC1 and BC2 were located upstream from the lake. Sites SL3 and SL4 were inlake sites. Site BC5 was located at the spillway and site BC6 was located close to the mouth of Beaver

Figure 2. Beaver Lake/Beaver Creek Water Quality Monitoring Sites



Creek, before it enters the James River. The Location of each site is as follows:

Site BC1 - Located 5.8 miles west of Utica on the northeast side of a road bridge. The site is representative of the water quality as it leaves Bon Homme County and enters Yankton County.

Site BC2 - Located 2 miles east and 2.7 miles north of Utica on the northeast side of a gravel road bridge. This site is representative of the Beaver Creek watershed before it enters Beaver Lake.

Site SL3 - Located in the middle of the lake 1/3 of the way into the lake from the north. This portion of the lake provided data for the north half of Beaver Lake.

Site SL4 - Located in the middle of the lake 2/3 of the way from the north end of the lake. This portion of the lake provided data for the south half of Beaver Lake.

Site BC5 - Located approximately 3 miles east and 2 miles north of Utica at the spillway of Beaver Lake. This site provides the outflow data for Beaver Lake.

Site BC6 - Located approximately 2 miles east and 2.6 miles north of the north boundary of the city of Yankton. This site provides data for the Beaver Creek watershed after it leaves the lake and before it enters the James River.

As listed in the following table (Table 2), the sampling period for the study extended from January 29, 1990 through May 21, 1991. During this period a total of 43 samples were collected from the 6 sites.

Table 2. Sampling Period and Number of Samples

SITE #	SAMPLE PERIOD FROM:		TO:	# OF SAMPLES
BC1	5/09/90	-	5/21/91	4
BC2	3/20/90	-	5/21/91	7
SL3	1/29/90	-	5/21/91	14
SL4	1/29/90	-	5/21/91	14
BC5	1/29/90	-	5/21/91	0
BC6	5/09/90	-	5/23/90	4
			Total Samples	43

The schedule for sample collection was set for once per month. This schedule was adhered to as closely as possible throughout the the project period. Due to drought conditions in 1990, only a small number of samples were collected. Site BC5, located at the spillway, did not have a sample collected because of the drought conditions and the fact that water was seeping underneath the dam. No water went over the spillway. The other watershed sites received minimal runoff events and were sampled whenever possible. The in-lake sites were sampled monthly except during unsafe ice conditions. Under normal condition the samples are collected at the surface and at the bottom of the lake; however, because of the relatively shallow depth of Beaver Lake only surface samples were taken. The surface samples were grab samples taken approximately 0.5 feet beneath the water surface.

The laboratory analyses were conducted by the South Dakota State Health Laboratory in Pierre, South Dakota. Field sample collection and analyses were conducted by a local resident.

The raw data were compiled by the South Dakota Department of Environment and Natural Resources, Division of Water and Resources Management. Water quality parameters were loaded into the computer and analyzed. A minimum, maximum, mean, and median were calculated for each of the parameters.

The water quality parameters that were tested at all of the sampling sites are shown in Table 3. A description of each parameter may be found in Appendix C.

A sediment survey will be completed in the winter of 1991 - 1992. Sediment depth information will be gathered from test holes drilled through the ice, spaced at set intervals. After the field data has been gathered, a topographic map of the sediment depths will be drawn, and estimates of sediment volume will be calculated.

Table 3. Water Quality Parameters

Parameters	
Water Temperature	Total Solids
Air Temperature	Total Dissolved Solids
Secchi Disk	Total Suspended Solids
Dissolved Oxygen	Ammonia
Field pH	Nitrates & Nitrites
Fecal Coliform Bacteria	Total Kjeldahl Nitrogen
Laboratory pH	Total Phosphorus
Total Alkalinity	Orthophosphate
Un-ionized Ammonia	

WATER QUALITY STANDARDS

The surface water quality standards for the State of South Dakota are based on the highest ranking criteria assigned to a body of water. The beneficial use assigned to Beaver Lake containing the highest criteria is warmwater marginal fish propagation. Other beneficial uses assigned to Beaver Lake are immersion recreation, limited contact recreation, and wildlife propagation and stock watering. The water quality standards for Beaver Lake are listed in Table 4.

Table 4. Beaver Lake Water Quality Standards

Parameter	Standard
Total Chlorine Residual	<0.02 mg/L
Un-Ionized Ammonia	<0.05 mg/L
Total Cyanide	<0.02 mg/L
Free Cyanide	<0.005 mg/L
Dissolved Oxygen	>5.0 mg/L
Undissassociated Hydrogen Sulfide	<0.002 mg/L
pH	>6.5 & <8.3 units
Suspended Solids	<150 mg/L
Temperature	<90^{o} F
Polychlorinated Biphenyls	<0.000001 mg/L
Fecal Coliform Organisms	<200 per 100 ml
Total Alkalinity	<750 mg/L
Total Dissolved Solids	<2500 mg/L
Conductivity	<4000 micromhos/cm
Nitrates	<50 mg/L
Sodium absorption ratio	<10:1

The beneficial uses for Beaver Creek have been split between; 1) the source of the creek to Beaver Lake and, 2) the Beaver Lake spillway to the James River. The portion of Beaver Creek from Beaver Lake to the James River is classified for the benefits of warmwater marginal fish propagation, limited contact recreation, irrigation, and wildlife propagation and stock watering. Site BC6 is the only sampling site which is given these standards. The waters from the source of Beaver Creek to the lake are classified for the beneficial uses of irrigation and wildlife and stock watering. The two sites which are regulated by these standards are BC1 and BC2. The water quality standards for Beaver Creek before it reaches Beaver Lake are listed in Table 5. Table 6 contains the information for the portion of Beaver Creek from the spillway of Beaver Lake to the James River.

Table 5. Beaver Creek Water Quality Standards
(Source of Beaver Creek to Beaver Lake)

Parameter	Standard
Total Alkalinity (calcium carb.)	<750 mg/L
Total Dissolved Solids	<2500 mg/L
Conductivity	<4000 micromhos/cm
Nitrates	<50 mg/L
pH	>6.0 & <9.5 units
Sodium absorption ratio	<10:1

TABLE 6. - BEAVER CREEK WATER QUALITY STANDARDS
(Beaver Lake Spillway to James River)

Parameter	Standard
Total Chlorine Residual	<0.02 mg/L
Un-Ionized Ammonia	<0.05 mg/L
Total Cyanide	<0.02 mg/L
Free Cyanide	<0.005 mg/L
Dissolved Oxygen	>5.0 mg/L
Undissassociated Hydrogen Sulfide	<0.002 mg/L
pH	>6.0 & <9.0 units
Suspended Solids	<150 mg/L
Temperature	<90° F
Polychlorinated Biphenyls	<0.000001 mg/L
Fecal Coliform Organisms	<1000 /100 ml
Total Alkalinity	<750 mg/L
Total Dissolved Solids	<2500 mg/L
Conductivity	<4000 micromhos/cm
Nitrates	<50 mg/L
Sodium absorption ratio	<10:1

RESULTS AND DISCUSSION OF WATER QUALITY MONITORING

IN-LAKE

With a few exceptions, the concentration of the parameters tested were within the legal limits of the Surface Water Quality Standard set by the State of South Dakota. However, parameters such as total nitrogen and total phosphorus are not included in the State standards. Therefore, using only the Water Quality Standards to judge water quality can be misleading. The parameters chosen for discussion in the following paragraphs have been chosen based on data evaluation. Each one of the parameters exhibits either violations of existing standards and/or may be responsible for limitations on beneficial uses. Table 7 contains all the in-lake data for both in-lake sites. Graphs comparing the two in-lake sites can be found in Appendix D.

Dissolved Oxygen

The dissolved oxygen standard was not met on at least three occasions during the sampling period at each of the in-lake sites. As noted on Table 4, the standard for dissolved oxygen is 5 mg/L. On July 17, 1991, the dissolved oxygen was 0.1 mg/L. On September 25 and October 16, 1991, the dissolved oxygen was 0.2 mg/L. Depletion in oxygen levels can be attributed to plant and animal respiration, but mostly to bacterial decomposition of organic matter. As the oxygen levels decline near the sediment interface, phosphorus and other nutrients have a higher potential to be released from the sediments into the water column (Wetzel, 1983). This process, called internal loading, can cause many water quality problems resulting in reduced beneficial use. Low oxygen levels are also responsible for fish kills. Most game

Table 7. Beaver Lake In-lake Sample Data 1990 - 1991

SAMPLE DATA FOR BEAVER LAKE FOR 1990 - 1991 - SITE SL3

DATE	TIME	SAMP	DEPTH Feet	WTEMP C	ATEMP C	SDISK Feet	DISOX mg/L	FPH units	FECAL COL. /100ml	LABPH units	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	AMMON mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TOTAL-N mg/L	TPO4 mg/L	OPO4 mg/L	NITR. PHOS. RATIO
01/29/90	1000	GRAB	1.0	0.56	0.00	0.5	8.0	8.7	10	8.06	223	3938	3814	124	1.71	0.0712	0.1	5.39	5.49	0.800	0.096	6.86
02/12/90	1030	GRAB	1.5	0.56	11.11	0.5	6.7	8.9	10	7.70	34	691	667	24	0.28	0.0180	0.1	1.71	1.81	0.176	0.005	10.28
03/20/90	1020	GRAB	3.0	6.11	10.00	1.0	7.8	8.6	10	8.28	229	986	934	52	0.05	0.0026	0.1	0.78	0.88	0.210	0.005	4.19
04/24/90	930	GRAB	3.0	15.56	21.11	0.6	9.0	8.4	110	8.06	280	1475	1331	144	0.14	0.0094	0.1	0.81	0.91	0.559	0.022	1.63
05/21/90	930	GRAB	3.5	11.67	13.33	0.6	10.9	8.5	340	8.16	210	1275	1215	60	0.03	0.0019	0.1	0.81	0.91	0.244	0.005	3.73
06/19/90	1000	GRAB	5.5	21.11	24.44	0.5	10.0	8.5	330	7.25	115	516	464	52	0.50	0.0589	0.1	2.09	2.19	1.320	0.954	1.66
07/17/90	1000	GRAB	6.0	22.22	26.67	1.0	0.1	8.4	430	8.18	233	796	758	38	0.03	0.0031	0.7	1.19	1.89	0.478	0.047	3.95
08/21/90	1030	GRAB	3.5	20.00	22.22	0.5	17.0	10.1	10	7.91	206	1235	1143	92	0.26	0.2167	0.1	1.86	1.96	0.522	0.027	3.75
09/25/90	900	GRAB	5.0	15.56	17.78	0.3	0.2	8.5	50	7.99	159	1565	1479	86	0.02	0.0017	0.1	1.58	1.68	0.447	0.005	3.76
10/16/90	930	GRAB	4.0	10.00	15.56	4.0	0.2	8.9	200	8.06	177	1677	1529	148	0.02	0.0026	0.1	1.35	1.45	0.475	0.007	3.05
02/05/91	1000	GRAB	3.0	0.56	4.44	0.2	22.0	8.3	10	7.26	190	2624	2576	48	0.87	0.0148	0.2	5.18	5.38	0.437	0.031	12.31
03/19/91	900	GRAB	4.0	3.33	4.44	0.6	22.0	9.5	2	8.90	100	1443	1393	50	0.05	0.0128	0.1	2.68	2.78	0.319	0.005	8.71
04/23/91	1000	GRAB	5.0	10.00	3.89	0.5	23.0	7.5	28	7.99	251	1213	1155	58	0.06	0.0004	0.1	1.27	1.37	0.288	0.005	4.76
05/21/91	1000	GRAB	3.5	20.00	21.11	1.0	26.0	7.4	10	8.30	145	1717	1681	36	0.03	0.0003	0.1	2.31	2.41	0.437	0.011	5.51
SL3 - 14 SAMPLES		MIN.	1.0	0.56	0.00	0.2	0.1	7.4	2	7.25	34	516	464	24	0.02	0.0003	0.1	0.78	0.88	0.176	0.005	1.63
		MAX.	6.0	22.22	26.67	4.0	26.0	10.1	430	8.90	280	3938	3814	148	1.71	0.2167	0.7	5.39	5.49	1.320	0.954	12.31
		MEAN	3.7	11.23	14.01	0.8	11.6	8.6	111	8.01	182	1611	1439	72	0.29	0.0251	0.2	2.07	2.22	0.479	0.088	5.30
		MEDIAN	3.5	10.83	14.44	0.5	9.5	8.5	19	8.06	198	1359	1273	55	0.06	0.0063	0.10	1.65	1.85	0.442	0.009	4.07
#######	#####	#####	#####	#####	#####	#####	#####	#####	######	#####	######	#####	#####	#####	#####	#######	#####	#####	######	######	#####	#####

SAMPLE DATA FOR STATE LAKE FOR 1990 - 1991 - SITE SL4

DATE	TIME	SAMP	DEPTH Feet	WTEMP C	ATEMP C	SDISK Feet	DISOX mg/L	FPH units	FECAL COL. /100ml	LABPH units	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	AMMON mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TOTAL-N mg/L	TPO4 mg/L	OPO4 mg/L	NITR. PHOS. RATIO
01/29/90	930	GRAB	1.0	0.56	0.00	0.5	8.0	8.7	10	8.15	186	3130	3118	12	1.61	0.0670	0.1	4.87	4.97	0.376	0.081	13.22
02/12/90	930	GRAB	1.5	0.56	11.11	0.5	6.7	8.9	10	6.92	107	486	468	18	0.14	0.0080	0.1	1.49	1.59	0.146	0.005	10.89
03/20/90	1100	GRAB	3.0	6.11	10.00	1.0	7.8	8.6	10	8.27	231	982	922	60	0.03	0.0015	0.1	1.01	1.11	0.203	0.005	5.47
04/24/90	1000	GRAB	3.0	15.56	22.22	0.5	9.2	8.4	70	7.84	115	2706	2562	144	0.07	0.0047	0.1	4.36	4.46	1.040	0.024	4.29
05/21/90	930	GRAB	4.0	11.67	13.33	1.0	11.0	8.8	20	8.05	139	2512	2428	84	0.08	0.0094	0.1	3.94	4.04	0.749	0.008	5.39
06/19/90	930	GRAB	6.5	15.56	22.78	1.5	9.4	8.4	70	8.03	178	1729	1705	24	0.09	0.0080	0.1	2.41	2.51	0.712	0.290	3.53
07/17/90	900	GRAB	6.0	22.22	25.56	1.0	0.1	8.4	150	7.92	202	3909	3889	20	0.03	0.0031	0.1	2.00	2.10	0.834	0.494	2.52
08/21/90	900	GRAB	4.0	20.00	21.11	0.5	15.0	9.1	10	8.76	131	1601	1592	9	0.05	0.0167	0.1	4.04	4.14	0.428	0.055	9.67
09/24/90	1000	GRAB	5.0	15.56	18.89	0.3	0.2	8.4	300	7.83	158	1554	1474	80	0.02	0.0013	0.1	1.57	1.67	0.565	0.005	2.95
10/16/90	1000	GRAB	4.0	10.00	15.56	4.0	0.2	8.9	150	8.02	183	1714	1518	196	0.03	0.0039	0.1	1.52	1.62	0.468	0.005	3.46
02/05/91	1030	GRAB	3.5	0.56	0.00	0.2	20.0	8.3	10	7.27	189	2721	2655	66	0.88	0.0150	0.2	5.00	5.20	0.509	0.016	10.22
03/19/91	930	GRAB	4.0	3.33	4.44	0.5	19.0	9.6	2	8.84	102	1436	1394	42	0.03	0.0091	0.1	2.65	2.75	0.271	0.005	10.15
04/23/91	900	GRAB	4.5	10.00	3.89	0.5	23.0	8.2	2	8.18	115	1666	1602	64	0.04	0.0011	0.1	2.60	2.70	0.298	0.005	9.06
05/21/91	900	GRAB	4.3	20.00	21.11	1.0	25.0	7.7	10	8.20	147	1735	1693	42	0.02	0.0004	0.0	2.22	2.23	0.607	0.008	3.67
SL4 - 14 SAMPLES		MIN.	1.0	0.56	0.00	0.2	0.1	7.7	2	6.92	102	486	468	9	0.02	0.0004	0.01	1.01	1.11	0.146	0.005	2.52
		MAX.	6.0	22.22	25.56	4.0	25.0	9.6	300	8.84	231	3909	3889	196	1.61	0.0670	0.20	5.00	5.20	1.040	0.494	13.22
		MEAN	3.8	11.62	14.62	0.9	11.0	8.6	59	8.02	157	1982	1930	62	0.22	0.0106	0.10	2.83	2.94	0.615	0.072	6.75
		MEDIAN	4.0	10.83	14.44	0.5	9.3	8.5	10	8.04	153	1722	1648	51	0.05	0.0054	0.10	2.51	2.61	0.489	0.007	5.43

fish can not survive in water where oxygen levels are lower than 3.5 mg/L (Cole, 1983).

Fecal Coliform Bacteria

Fecal coliform bacteria inhabit the digestive systems of warm-blooded animals. The presence of fecal coliform bacteria in water is evidence of human or animal waste in the water supply. Sources for these organisms include wild mammals or birds, domestic livestock near the lake or in the watershed, or failing/insufficient sewage systems. High concentrations of these bacteria generally coincide with high concentration of nutrients such as phosphorus and nitrogen. High fecal coliform bacteria concentrations also create a high oxygen demand, resulting in a lower levels of dissolved oxygen which support aquatic life (MPCA, 1989). One sample taken for this project did exceed the state standards. A count of 430 fecal coliform bacteria per 100 mL was collected July 17, 1991, at site SL3. Other high counts of bacteria did occur during sampling, however, those counts were not above the 400 per 100 mL standard limit. The majority of the samples taken recorded higher bacteria counts closer to the inlet (SL3) suggesting the fecal problem is entering the lake from the watershed.

pH

The pH standard between 6.5 - 8.3 units was exceeded 11 out of the 14 samples taken at each site. The maximum concentration was 10.1 at site SL3, August 21, 1990. The samples did not exceed the lower limit. The field pH measurements were taken with an Orion "pen" pH meter. A second pH reading was taken at the State Health Laboratory. The Health Laboratory tested a sample from site SL3 taken March 19, 1991 which recorded 8.90 units and did not meet the State standard. Site SL4 exceeded the standard at the State Health Lab on August 21, 1990 and March 19, 1991. The values recorded were 8.76 and 8.84 units respectively. High and low pH values are dependant on many variables including geology of the land (hardness of water), temperature, photosynthesis, and decomposition. Hard waters act as a buffer to pH, however photosynthesis may counteract the buffer and be responsible for high pH levels (Vallentyne, 1974).

Un-ionized Ammonia

The un-ionized ammonia standard for Beaver Lake is 0.05 mg/L. This standard was surpassed twice during the sampling period on June 17, 1990 and August 21, 1991 on site SL3. Recorded levels were 0.0599 mg/L and 0.2167 mg/L respectively. Site SL4 exceeded the standard on January 29, 1991, of 0.067 mg/L. Un-ionized ammonia is a calculated fraction of total ammonia whose rise and fall in concentration parallels increases or decreases in pH and water temperature.

Phosphorus

The State of South Dakota does not include phosphorus in the water quality standards. However, the in-lake samples taken revealed concentrations of 0.146 mg/L as a minimum. The average concentrations for total phosphorus were 0.479 mg/L and 0.5148 mg/L for sites SL3 and SL4 respectively. The high phosphorus concentrations classify the lake as hypereutrophic. A hypereutrophic lake has an over abundance of nutrients which can cause nuisance algae blooms. The minimum concentration of 0.146 mg/L experienced in Beaver Lake is more than seven times the 0.02 mg/L of phosphorus needed for optimum growth of many algae species (Wetzel, 1983). Sources of phosphorus in a lake may be from animal or human waste, fertilizer, detergent, run off from land (sediments), internal loading from the sediments, and aquatic plants themselves.

Limiting Nutrient

The limiting nutrient concept, in reference to algae, states that the production of algae will be determined by the abundance of the substance, needed for survival, which is least abundant in the environment. According to the concept, if you control the limiting nutrient for algae, you can control the production of the organism and the rate of growth (Wetzel, 1983). In Beaver Lake the limiting nutrient is nitrogen except in periods where the lake is covered with thick ice and snow. During this time, usually in February, phosphorus is the limiting nutrient.

TRIBUTARY

The main reasons for tributary sampling is to locate problem areas in the watershed and also to calculate nutrient loads to the lake. To estimate nutrient loads a hydrologic budget must be established. During the sampling period no water was collected running over the spillway. Water was observed seeping underneath the dam so no accurate outflow information could be calculated. Inflow computations to the lake were constantly hampered by beaver dams and the fact that the site acted much like an extended part of the lake. Due to these uncontrollable circumstances an accurate and defendable hydrologic budget was impossible to calculate. In addition to the difficulty figuring the hydrologic budget, the watershed and surrounding areas were subject to drought which limited the number of samples. During the 18 month sampling period only seven samples were collected on site BC2, four samples each on sites BC1 and BC6, and no samples on site BC5 (Figure 2). The parameters tested at the tributary sites are the same as the lake sites (Table 3). The analysis of the lab results did reveal nutrient problems in the watershed which will be explained below. Later in the report the nutrient and sediment loadings to Beaver Lake will be discussed using the AGNPS model.

Table 8. Tributary Samples for Beaver Creek 1990 - 1991

SAMPLE DATA FOR STATE LAKE FOR 1990 - 1991

DATE	TIME	SITE	SAMP	DEPTH Ft	WTEMP C	ATEMP C	SDISK Ft	DISOX mg/L	FPH units	FECAL COLIFORM per 100mL	LABPH units	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L	OPO4 mg/L
05/09/90	800	BC1	GRAB	1.0	10.0	4.4	2.0	5.3	8.2	38,000,000	8.13	542	4,529	4,069	460	10.80	0.30978	8.40	41.50	18.800	7.080
05/23/90	730	BC1	GRAB	2.0	14.4	11.7	1.0	9.2	8.6	650,000	7.61	81	3,996	147	3,849	1.40	0.13249	2.60	4.31	3.880	1.390
05/23/90	800	BC1	GRAB	1.5	15.6	13.3	0.1	9.0	8.5	810,000	7.90	120	1,614	314	1,300	0.55	0.04556	2.00	3.11	2.530	1.040
05/21/91	930	BC1	GRAB	1.5	15.6	18.3	0.2	36.0	7.5	700,000	7.88	735	3,963	2,913	1,050	21.35	0.19109	0.01	32.40	12.100	4.770
BC1 - 4 SAMPLES			MIN.	1	10.0	4.4	0.1	5.3	7.5	650,000	7.61	81	1,614	147	460	0.55	0.04556	0.01	3.11	2.530	1.040
			MAX.	2	15.6	18.3	2.0	36.0	8.6	38,000,000	8.13	735	4,529	4,069	3,849	21.35	0.30978	8.40	41.50	18.800	7.080
			MEAN	1.5	13.9	11.9	0.8	14.9	8.2	10,040,000	7.88	369	3,526	1,861	1,665	8.53	0.16973	3.25	20.33	9.328	3.570
			MEDIAN	1.5	15.0	12.5	0.6	9.1	8.6	755,000	7.89	331	3,980	1,613	1,175	6.10	0.16180	2.30	18.36	7.990	3.080

DATE	TIME	SITE	SAMP	DEPTH Ft	WTEM C	ATEMP C	SDISK Ft	DISOX mg/L	FPH units	FECAL COLIFORM per 100ml	LABPH units	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	AMMONI mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L	OPO4 mg/L
03/20/90	930	BC2	GRAB	3.3	6.1	7.2	1.3	8.1	8.7	10	8.24	227	981	937	44	0.04	0.00257	0.10	0.75	0.203	0.012
05/09/90	930	BC2	GRAB	2.5	12.2	12.2	0.8	7.0	8.3	360	8.04	220	1,359	1,279	80	0.03	0.00127	0.20	0.86	0.366	0.012
05/14/90	1030	BC2	GRAB	3.0	14.4	13.3	1.9	9.0	8.5	620	8.18	214	1,290	1,238	52	0.05	0.00383	0.10	0.96	0.261	0.005
05/21/90	1000	BC2	GRAB	3.0	11.7	13.3	0.1	9.0	8.8	250	8.16	210	1,277	1,227	50	0.02	0.00236	0.10	0.74	0.261	0.006
05/23/90	930	BC2	GRAB	3.0	14.4	16.7		7.4	8.3	7,900	8.13	117	846	786	60	0.02	0.00100	0.10	0.51	0.329	0.090
04/30/91	930	BC2	GRAB	4.0	10.0	7.2	0.5	23.0	8.1	110	4.14	253	1,152	1,136	16	0.02	0.00046	0.10	0.84	0.193	0.080
05/21/91	930	BC2	GRAB		18.9	21.1	1.0	16.0	8.4	1,200	8.05	251	1,247	1,191	56	0.03	0.00253	0.10	1.10	0.096	0.017
BC2 - 7 SAMPLES			MIN.	2.5	6.1	7.2	0.1	7.0	8.1	10	4.14	117	846	786	16	0.02	0.00046	0.10	0.51	0.096	0.005
			MAX.	4.0	18.9	21.1	1.9	23.0	8.8	7,900	8.24	253	1,359	1,279	80	0.05	0.00383	0.20	1.10	0.366	0.090
			MEAN	3.1	12.5	13.0	0.9	11.4	8.4	1,493	7.56	213	1,165	1,113	51	0.03	0.00200	0.11	0.82	0.244	0.032
			MEDIAN	3.0	12.2	13.3	0.9	9.0	8.4	360	8.13	220	1,247	1,191	52	0.03	0.00236	0.10	0.84	0.261	0.030

DATE	TIME	SITE	SAMP	DEPTH Ft	WTEM C	ATEMP C	SDISK Ft	DISOX mg/L	FPH units	FECAL COLIFORM per 100mL	LABPH units	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	AMMONI mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L	OPO4 mg/L
05/09/90	830	BC6	GRAB	0.8	12.2	8.9	1.0	9.4	8.0	1,300	7.69	287	927	909	18	0.08	0.00173	0.30	0.72	0.105	0.028
05/14/90	900	BC6	GRAB	0.8	10.0	13.3	1.0	11.0	8.0	1,500	7.62	394	1,216	1,212	4	0.07	0.00128	0.10	0.55	0.064	0.011
05/21/90	1030	BC6	GRAB	0.5	11.7	13.3	1.5	9.2	7.7	150	7.56	394	1,441	1,431	10	0.02	0.00021	0.40	0.67	0.081	0.025
05/23/90	1030	BC6	GRAB	2.0	15.6	16.7		10.0	8.1	200,000	7.64	117	2,039	219	1,820	0.31	0.01076	0.80	2.13	0.763	0.393
BC6 - 4 SAMPLES			MIN.	0.5	10.0	8.9	1.0	9.2	7.7	150	7.56	117	927	219	4	0.02	0.00021	0.10	0.55	0.064	0.011
			MAX.	2.0	15.6	16.7	1.5	11.0	8.1	200,000	7.69	394	2,039	1,431	1,820	0.31	0.01076	0.80	2.13	0.763	0.393
			MEAN	1.0	12.4	13.1	1.2	9.9	8.0	50,738	7.63	298	1,406	943	463	0.12	0.00350	0.35	1.02	0.253	0.114
			MEDIAN	0.7	12.0	13.3	1.0	9.7	8.0	1,400	7.63	340	1,329	1,061	14	0.08	0.00151	0.35	0.70	0.093	0.077

As stated earlier Beaver Creek is subject to two separate beneficial uses and thus two different water quality standards; 1) from the source of Beaver Creek to Beaver Lake (Table 5), and 2) from Beaver Lake to the mouth of Beaver Creek at the James River (Table 6). A site by site analysis of the lab data follows to explain the conditions of the watershed. All of the actual data for each of the tributary sites it located on Table 8.

Site BC1

Site BC1 is the furthermost site upstream from Beaver Lake. No water quality standards (Table 5) were exceeded during the sample period. It is not accurate to concluding that the water quality is good because the standards were not surpassed. Good quality streams usually have fecal coliform counts below 200 colonies per 100 mL of water. The minimum fecal coliform bacteria count per 100 mL of water sampled was 650,000. Bacterial counts of this magnitude reveal a definite problem either in feedlot or domestic waste control. Many feedlots reside near Beaver Creek, upstream of where the samples were taken, and may be responsible for the high concentration. Since fecal coliform indicates some form of warm blooded animal excretion, other nutrients increase with increasing fecal counts. All the nitrogen forms; ammonia, unionized ammonia, nitrate-nitrite, and kjeldahl nitrogen, have extremely high concentrations (Table 8) compared to a good quality stream or even the lake itself. The total phosphorus concentrations, all above 2.5 mg/L, are 100 times the concentration needed for minimal algal growth. The results of the samples taken from site BC1 exhibit inordinate amounts of nutrients. The condition of the watershed upstream of site BC1 appears to have major problems which need to be addressed.

Site BC2

Site BC2 is the inlet to Beaver Lake (Figure 2). None of the seven samples taken from March 20, 1991, to May 21, 1991, exceeded the State of South Dakota Water Quality Standards (Table 5). The data show the immoderate concentrations found at site BC1 were diluted before reaching site BC2. Even though the fecal coliform counts were reduced significantly, in most cases the counts were higher than levels which should be entering a lake. The suspended solid levels (all particulate solids) which average in the thousands of mg/L for BC1 were reduced to an average of 51 mg/L for BC2. However the dissolved solids remained relatively the same. This suggests that the flow of the river may have subsided and the particulates settled to the bottom. Particles carrying fecal coliform may have dropped out of the water column which would explain the drop in concentration at site SL2. Review of the data also showed decline in the concentration of other nutrients as well, between BC1 and BC2. This indicates that the suspended solids carry the bulk of the nutrient load.

Site BC6

Site BC6 was installed to collect data on the segment of Beaver Creek between the spillway of Beaver Lake and the James River. This portion of Beaver Creek is subject to different water quality standards than the section of Beaver Creek above the lake (Table 6). There was one violation of water quality standards during the sampling period. On May 23, 1990 the suspended solid concentration reached 1,820 mg/L. The concentration standard for suspended solids is 150 mg/L. As found with site BC2, there was an increase in fecal coliform bacteria corresponding to the increase in suspended solids. Although there is no standard for fecal coliform bacteria, the level reached on May 23, 1990 (200,000 colonies per 100 mL) was extremely high. The highest concentrations of all the other nutrients was also reached on this day.

As the water from Beaver Creek enters Beaver Lake, sediments are dropped as the flow is decreased. Because nitrogen is water soluble, increases or decreases in the concentration of nitrogen depend on the amount of nitrogen present in the system. If the sediments, in contact with the water, are nitrogen rich, the water will release the nitrogen from the sediments increasing the nitrogen dissolved concentration. Due to the amount of nitrogen in the sediments and in the water, the chances of nitrogen levels decreasing as they pass through the lake are small (Saull, 1990). Sediments containing phosphorus, on the other hand, will not easily release phosphorus molecules. In fact, phosphorus will sorb on to sediments when oxygen is available (Vallentyne, 1974). As the sediments reach enter the lake they drop out of the water column with the attached phosphorus. These characteristics, along with the fact that the subwatershed is smaller for site BC6 than BC2, explain why site BC6 has generally better water quality. This is not to say that the subwatershed for BC6 is not in need of improvement. The domestic or animal waste input between the lake and the James River which need to be addressed.

RESULTS AND DISCUSSION OF AGRICULTURAL NON-POINT SOURCE MODEL

The complete Agricultural Non-Point Source Model (AGNPS) report is attached on Appendix B. Table 2A of the AGNPS report lists the inlets to the lake, the spillway, and the inlet to the James River by reference of a cell number. Cell numbers 882, 1093, and 2065 correspond to sites BC2, BC5, and BC6 respectively. The AGNPS model is extremely useful in that it predicts sediment and nutrient loadings to the lake for a 5-year 24 hour storm. The ensuing paragraphs will give an overview of the conclusions of the AGNPS report with respect to loading and water quality.

Sedimentation

In Table 2A of Appendix B, the three cells referred to as inlets are #741, #742, and #882. Cells #741 and #742 are relatively small in loading, while cell #882, the Beaver Creek inlet, is the recipient of 54,000 acres of drainage. The most striking conclusion drawn from the model is that the combined inlets discharge 37,858 tons of sediment into the lake. This amount sediment loading roughly corresponds to 34 acre-feet of sediment or 5 1/2 inches of sediment per rainfall event over the 72 acre Beaver Lake. During the project no water left the lake over the spillway, it must be assumed that the sediment is being deposited in the inlet and the lake. Considering a normal year when there is more water entering the lake than seeping underneath the dam or evaporating, the AGNPS model estimates most of the sediment, 25 acre-feet, being discharged from the lake due to the reduced storage capacity of the lake. The resulting net input of sediment to the lake would be 1 1/2 inches per storm event. This aspect of the model can be supported when considering the life of Beaver Lake.

When Beaver Lake was formed in 1926 it had an estimated average depth of 10 feet (storage capacity = 720 acre-feet). In 1972 the South Dakota GF&P estimated the average depth of Beaver Lake at 5.5 feet (storage capacity = 396 acre-feet), an average loss of nearly 1 1/4 inches per year. From 1972 to 1990 the average depth lost was approximately 2.5 feet, leaving a storage capacity of 216 acre-feet. The average amount of sediment added to the lake between 1972 and 1990 was 1 2/3 inches per year. The increase in sedimentation in the later years can be explained by the fact that the land in the watershed was not intensely farmed until World War II (SCS, 1941). During the life of the lake there may have been years of drought as well as years with 50 year floods. What ever the case, the lake has lost an average of 1 1/3 inches of depth a year since the lake was established. The fact that the AGNPS models estimated sedimentation rate and the average loss of depth per year are similar is only coincidental. More importantly, both of the scenarios show substantial loads of sediments have entered Beaver Lake. The area of watershed from the Beaver Lake spillway to the James River also has a high sedimentation rate. The water which leaves Beaver Lake during a 5-year, 24 hour storm is carrying 10,241 tons of sediment. On its route to the James River after leaving Beaver Lake an additional 13,041 tons of sediment are accumulated. According to the model, approximately 23,282 tons (30 acre-feet) of sediment are entering the James River, during the same storm event. When looking at subwatersheds, the drainage from Beaver Lake to the James River is only 13,160 acres, giving a sediment delivery rate of approximately 0.99 tons/acre. Compared to the sediment delivery rate of 0.63 tons/acre average from the land that flows into Beaver Lake, there is an average of 57% more sediment coming off every acre below the spillway. The sediments entering Beaver Lake and the James River could be coming from many sources. Common causes of sedimentation are excessive tillage, steep slopes, and bank erosion. Considering the extensive farming in the Beaver Creek watershed, agriculture is the prominent cause.

Nutrients

The sample concentrations established that the inputs of phosphorus and nitrogen into the lake were extremely large. The AGNPS model reinforced these claims through its nutrient load estimation. The inflow in tons/acre for phosphorus and nitrogen to Beaver Lake from the watershed averaged 0.0006 and 0.0017 tons/acre respectively. According to the model Beaver Lake's trapping efficiency for phosphorus is 52.8% and for nitrogen it is approximately 40%. The reason for the higher trapping efficiency for phosphorus may be that, as stated earlier, phosphorus sorbs to sediment particles and settles more readily than the water soluble nitrogen. The estimated net accumulation of phosphorus into Beaver Lake during a 5-year, 24 hour storm is estimated at 20.9 tons. During the same storm 41.3 tons of nitrogen are also said to be collected. These excessive amounts of nutrients are increasing the eutrophication and sedimentation of the lake by increasing productivity of aquatic plants. The portion of the watershed from Beaver Lake to the James River which has a greater soil erosion rate, also has a higher average tons/acre loss for phosphorus and nitrogen. The average loss for phosphorus above Beaver Lake is approximately 0.0006 tons/acre, the average loss below Beaver Lake is approximately 0.00095 tons/acre, an increase of 58%. The average amount of nitrogen lost above Beaver Lake is estimated at 0.0017 tons/acre, below the lake there is an increase of 35% to 0.0023 tons/acre of nitrogen added to Beaver Creek. Steeper slopes closer to the James River may be responsible for the increases in sediment and nutrient loads. Whatever the case, both subwatersheds of Beaver Creek (above and below Beaver Lake) have water quality problems.

DISCUSSION OF THE DAM

A complete inspection report of the Beaver Lake dam on June 6, 1989, by the SD DENR is attached (Appendix E). In short, the report states that erosion is occurring on the upstream slope of the dam which does not have adequate grass cover and riprap. Trees are also growing on the slope and next to the dam and may be causing the seepage through decayed root systems. Erosion is also occurring on the downstream slope due to inadequate grass cover and cattle grazing. Finally, due to weathering, the spillway has cracking, scaling, undercutting, and missing joint material.

CONCLUSIONS

Beaver Lake has succumbed to the fate of most man made lakes built in or around the 1930's. The typical practice was to build a dam across a stream of a usually large watershed to be sure of a sufficient water supply. Since its establishment in 1926, Beaver Lake has acted as a sediment basin for Beaver Creek. The large agricultural watershed draining into Beaver Lake's relatively small basin is the primary cause for the accelerated eutrophication. The nutrients flowing into the lake are at levels which can easily propagate nuisance algae blooms. The shallowness of Beaver Lake encourages excessive macrophyte growth, and makes it difficult to support a stable fish population. Beaver Creek, which is the primary source to Beaver Lake also empties into the James River, The watershed is primarily agricultural ground. The potential agricultural influence on these two water bodies has been shown through the AGNPS model and the water quality sample data. Both reveal inordinate amounts of nutrients and sediments entering Beaver Lake and the James River.

As with natural succession in all lakes, Beaver Lake is moving from a lake to dry ground. However, at its accelerated rate of eutrophication, Beaver Lake's life expectancy has been shortened. If the depth of Beaver Lake continues to decrease, emergent macrophytes may replace the open water, the lake will take on more characteristics of a marsh. As the carrying capacity of the lake decreases so will its ability to filter the water before it reaches the James River. As a result the James River may receive what is now entering Beaver Lake.

Before restoration on Beaver Lake is contemplated, problems causing the sedimentation and eutrophication in the watershed should be addressed and corrected. The dam also should be repaired. Any benefits caused by inlake work completed before controls in the watershed are established would be short lived. It must be noted that even if everything possible is done to correct the problems in the watershed, Beaver Lake will probably remain eutrophic to hypereutrophic. The benefits received by the alternatives listed below will shorten the duration and intensities of algae blooms, control some of the macrophyte problem, and improve the fishery by reducing the chance of fishkills.

RESTORATION ALTERNATIVES

There are many ways to correct problems in watersheds and increase recreational benefits in lakes. However, every lake has different problems so not all restoration alternatives can be considered viable corrective measures. The alternatives considered for restoration of the Beaver Creek watershed and

Beaver Lake have been chosen because of their effectiveness, cost, and their ability to be accomplished. The alternatives chosen include the following:

1. No action
2. Watershed controls suggested by the AGNPS model
3. Dam repair
4. Dredging
5. Dewatering of lake
6. Land based removal of sediment

<u>No Action</u>

If the "No action" alternative is selected, the lake's condition will not improve. The large concentration of nutrients currently in the lake will continue to cycle through the system. The lake will continue to degrade and algae or emergent macrophytes may take over the lake. The lake will continue to lose depth and odor problems may occur due to decaying organic material. Traditional lake recreations will be increasingly impaired. In general, the lake may cease being a lake and become a productive wetland. The is not completely negative. Wetland are vital to the production of wildlife, especially waterfowl. If land adjacent to the lake could be purchased or leased to the SD GF&P, it could be managed as wildlife production area. The benefits for contact recreation would be limited but hunting and other wildlife benefits would improve.

<u>Watershed controls suggested by the AGNPS Model</u>

Five Best Management Practices were recommended by AGNPS to obtain best results:

1. No-till or ridge till on slopes from 3% to 9%.

2. Contouring all 3% to 6% slopes.

3. Grassing all slopes with inclines greater the 9%.

4. Subsurface injection of fertilizer (knifing or banding).

5. Establishment of soil testing with the goal of reducing the amount of applied fertilizer.

6. Application of fertilizer to seed rows only.

These options were selected by the Yankton Conservation District, Soil Conservation Service, and SD DENR on the basis of effectiveness and ability to sell these practices to the land owners in the watershed. The amounts of sediment and nutrient reduction for the above treatments are given in the complete AGNPS document (Appendix B).

Dam Repair

On June 7, 1989, the Beaver Lake dam was inspected by the SD DENR. The report (Appendix E) states three main areas for repair or maintenance. The first, trees and shrubs should be removed from the embankment and the holes which are left should be backfilled with impervious materials. The trees and shrubs may be causing the seepage through decayed root systems. Second, control erosion on both the upstream and down stream slopes. Controls suggested are riprapping, grassing slopes, and controlling cattle grazing on the down stream slopes. Finally the spillway is in need of repair. The cracking, scaling, erosion, undercutting, missing joint material, and displaced joints should be repaired to correct existing deficiencies and prevent further deterioration. A cost estimate for the work needed may be acquired from a qualified consultant.

Dredging

If the sediment is removed from lake basin, several improvements will be evident. Fish habitat can be enhanced and the threat of summer and winter fishkills is usually reduced. There can be better control of macrophytes in deeper areas. The water is generally clearer because the deeper depths help keep waves from suspending solids in the water column. Selective dredging is less expensive and less time consuming than whole lake dredging. Fewer sediment disposal ponds will be needed. The negative difference is that you do not remove as much nutrient rich sediment. Suspended solids may still be a problem. Areas not dredged will still have a macrophyte problem. Both whole lake and selective dredging would be beneficial to the lake. The total amount of sediment and the location of the greatest sediment concentrations is going to be calculated by a sediment survey in the 1991-1992 winter. A rough calculation of sediment is between 600,000 to 800,000 cubic yards. The average cost of an eight inch dredge for a year is $200,000. An eight inch dredge has removed a average of 63,000 cubic yards of sediment during the 1988-1990 dredging seasons. The total cost for whole lake dredging is estimated at $2,000,000 over 10 years.

Dewatering the Lake

If dewatering is selected, the removal of water from the lake could be accomplished by placing a culvert or two in the embankment to the side of the spillway. A engineering design would have to be drawn to ensure proper placement and installation of the culvert. A pump could also be placed in the lake basin, however, because of Beaver Creek, the water inflow may never stop and the pump may have to run constantly. Several benefits will occur by the use of this alternative. By exposing the bottom of the lake, the sediments will consolidate and the lake volume will increase slightly. The consolidation of sediment is considered to be permanent and the material will not suspend again. By oxidizing the rich organic surface of the sediments the nutrient release from the sediments is reduced. Aquatic macrophytes may be controlled. Any subsurface pollution sources may be detected and corrected when the lake level is down. The work needed to repair the dam embankment and the spillway may also be accomplished at this time (Cooke, 1986 and Wisconsin DNR, 1975).

There are several potentially negative factors involved with this alternative. Potential failure of the reservoir to promptly refill is one risk of dewatering the lake. This problem may be magnified by drought which is always a potential problem in South Dakota. Although macrophytes may be temporarily controlled algae bloom do reoccur. The lake basin may be taken over by noxious weeds during draw down (this is a short term problem). A soft, flocculent sediment crust may make it hazardous to people attempting to walk across the "dried" lake basin. As stated above, the lake may never completely dry if the Beaver Creek watershed experiences a wet year.

Land Based Removal of Sediment

If the dewatering alternative is chosen, land based removal of the sediment is a possibility. The end result of land based removal would be similar to that of selective dredging. The advantage of land based removal is that is can be accomplished with conventional equipment such as draglines, bulldozers, or scrapers. The dry sediment can be transported and disposed of immediately by trucks. The sediment can be removed after it dries or in the winter. In addition to the sediment removal, fish structures such as rock piles, ditches, or walls can be constructed.

RECOMMENDATIONS

Based on the information collected during the course of this study and the evaluation of the historical data, the Water Resource Management Division of the SD DENR recommends the following activities for the improvement of the Beaver Creek watershed and Beaver Lake.

First, due to the condition of the watershed, for a minimum of three years, all money and man power should be concentrated to reduce sediment and nutrient loadings to Beaver Creek/Beaver Lake. This can be accomplished by using the alternatives suggested by the AGNPS model in Appendix B. The final recommendations of the model suggest best results can be obtained by a combination of three treatments including 1) grassing all waterways wit inclines greater than 9%, 2) no-till or ridge till on slopes from 3% to 9% and 3) injection of fertilizer on slopes from 3% to 9%. Soil testing for proper fertilizer amount and using ridge till for row crops and applying fertilizer only to seed rows was also recommended, however the benefits are not as significant as the first three recommendations. Along with the changes in farming practices suggested by AGNPS, feedlot run off near surface water must also be controlled. If after three years, significant work has been applied in the watershed, the inlet to the Beaver Lake and the James River should be sampled again to document the expected decreases in sediment and nutrient loadings. Basically two scenarios will exist once the samples have been evaluated. One, no significant decrease in sediment or nutrient loadings can be detected. Secondly, considerable improvements in the watershed have taken place. If the first scenario is true the supporters of the project have limited options. It will be the recommendation of the SD DENR that, if feasible, work in the watershed continue, or the local sponsor may consider the "No Action" alternative and allow the SD GF&P to manage the lake and surrounding area for waterfowl/wildlife production. It would not be feasible or cost effective to attempt restoration activities without controlling the input loadings from the watershed. If considerable improvements in sediment and nutrient loads were evident after the first three years, options to restore the lake could now be considered. Work in the watershed should continue until the increasing water quality of the inlets to the lake and the river stabilizes.

Of all the inlake restoration alternatives listed in the previous section, dewatering the reservoir and using land based equipment for sediment removal would be the most cost effective and beneficial. The primary goal of dewatering is to make the lake available for land based removal of sediment. An advantage of dewatering is that it will also assist in other restoration activities. Dewatering will allow the flushing of the high nutrient concentrated waters much quicker than natural flushing. The macrophytes in the lake would be temporarily controlled. Bank stabilization and the maintenance work on the dam embankment and the spillway would be easier, and thus less expensive. Rough fish which now inhabit the lake could be removed.

Land based removal of sediment was selected to increase depth, improve fish habitat and reduce the the threat of fishkill. Conventional equipment owned by the county or the city can be used to remove as much sediment as desired. The State would like to see fish structures such a deep pools, rock piles, points, and walls constructed to increase the lakes recreational fishing. It may take more than one year of sediment removal to achieve the desired results. Two or even three years of dewatering and sediment removal may be needed. A more accurate time table will be available when the sediment survey is complete.

Before the lake is refilled, all of the dam repair and maintenance recommendations should be addressed. As stated in the dam summary report (Appendix E) the trees growing next to the spillway and on the embankment must be removed and backfilled with impervious material. The erosion on the upstream side of the sloped embankment which appears to have been caused by wave and ice action should be riprapped and the grassed above the riprap. The downstream embankment has eroded due to grazing. Reseeding the slope and prohibiting grazing on the embankment can correct the downstream embankment erosion problems. Repairs to the scaling, erosion, undercutting, missing joint material, and displaced joints should be completed to correct existing deficiencies and prevent further deterioration of the primary spillway structure. Estimates on the costs and how the repairs could best be completed should come from a qualified consultant. As with the watershed work, repairs to the dam and spillway are an integral part of the complete lake restoration project.

The local sponsors may select any of the restoration alternatives listed and described in this report or choose to take another plan of action. The recommendations mentioned above are those which the State feels best can solve the problems addressed in this report.

APPENDIX A. ENVIRONMENTAL HEALTH SURVEY - 1973

REPORT
on
BEAVER LAKE (State Lake)
Yankton County

ENVIRONMENTAL HEALTH SURVEY

SOUTH DAKOTA STATE DEPARTMENT OF ENVIRONMENTAL PROTECTION

August, 1973

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I. INTRODUCTION

Beaver Lake, located in Section 27, T 95 N, R 56 W, Yankton County, is situated 9 miles north and 2 1/2 miles west of Yankton. The lake covers about 100 surface acres, has a maximum depth of 7 1/2 feet and an average depth of about 5 1/2 feet.

Beaver Lake was developed as the result of construction of a dam by the Department of Game, Fish and Parks in 1926. The dam and lake is one of that Department's early projects of this type.

The South Dakota Board of Environmental Protection has adopted Water Quality Standards for the Surface Waters of South Dakota. These Standards designate Beaver Lake for the beneficial uses of immersion sports, warm water marginal fish life propagation, limited contact recreation, wildlife propagation and stock watering.

The field survey was conducted on July 31 and August 1, 1973, in response to a petition received by the Department of Environmental Protection on July 9, 1973.

II. SCOPE OF SURVEY

The survey was restricted to determining those points where pollution from animal and domestic sources may enter the lake.

Water samples were collected from Beaver Lake and analyzed for fecal coliform which is an indicator of fecal pollution of water. The normal habitat of these organisms is generally the intestine of man and animals, therefore, fecal coliform determinations are of particular value in determining the source of pollution of a lake or stream.

III. SURVEY CRITERIA

For the purpose of this survey, the following criteria were utilized:

1. Satisfactory wastewater disposal facility or privy exists:

   a. When toilet or sink wastewater does not flow directly into the lake or onto the ground;

   b. When wastewater does not rise to the ground surface;

   c. When located at least 100 feet from the lake;

   d. When the privy is fly-tight, rodent resistant and of good physical construction with self-closing doors and seat covers.

2. Satisfactory livestock enterprises exist:

a. When the number of cattle confined in a feedlot does not exceed 500 animal units or a comparable combination of other livestock; or the proposed or existing livestock enterprise, regardless of number or kinds of animals, is not a water pollution source;

b. When the livestock enterprise does not contribute to a body of water or a watercourse draining more than 3,200 acres of land above the enterprise and/or the distance to the nearest point on the body of water or watercourse is more than 2 feet per head of cattle or equivalent livestock in the enterprise;

c. When the runoff water from the enterprise, or overflow from a lagoon or liquid manure storage tank, does not flow into a tile line or other buried conduit, drainage well, pumped well, abandoned well, or sinkhole.

3. Satisfactory water for immersion sports exists when fecal coliform organisms do not exceed a concentration of 200/100 ml as a monthly average; nor to exceed this value in more than 20% of the samples examined in any one day during the recreation season.

IV. SUMMARY OF COLLECTED DATA

Surveys of 10 cabins on the east side of Beaver Lake were conducted by personnel from the Department of Environmental Protection. Those interviewed to obtain information on the wastewater facility included the dwelling owner, occupant, neighbor, or relative. When lot owners or neighbors could not be contacted, survey personnel filled in obvious information to the best of their ability and included it as a part of this report. The survey data is shown in Table 1 as follows:

TABLE I

LOCATION OF WASTEWATER
DISPOSAL FACILITIES IN RELATION TO LAKE SHORE

Number of Facilities*	Distance to lake shore (in feet) 0-49	50-99	100-over	Unsatisfactory
9	4	5	0	9

* One cabin did not have a disposal facility.

On the west side of Beaver Creek, there is a public access which has one outdoor privy.

The City of Lesterville, 7 miles west and 2 miles north of Beaver Lake, has a population of 181 and a 1.7 acre two-level bottom stabilization pond constructed in July, 1972. The pond has a good algal growth and appeared to have been recently drawn down for mowing of the dikes around the pond. The pond was not overflowing at the time of the survey; however, when it does overflow it discharges to a tributary of Beaver Creek. The pond is located nine creek miles from Beaver Lake. A gate in the effluent manhole was leaking at the time of the survey.

The disposal of livestock waste was investigated as a part of this survey and those operators with a pollution problem were advised by letter of the facilities necessary to comply with the South Dakota livestock waste regulations. The survey data is shown in Table II as follows:

TABLE II

LIVESTOCK ENTERPRISES

Number Visited	Problem	Not a problem
13	8	5

During the survey, the water in Beaver Lake was suitable for swimming as indicated by the analysis in Table III.

TABLE III

BACTERIOLOGICAL ANALYSIS FOR BEAVER LAKE (8-3-73)

Sampling Point in Lake	Fecal Coliform/100 ml
South	40
West	120
Outlet	3
Middle	190
West Shoreline	30
Beaver Creek Bridge	40

V. RECOMMENDATIONS

1. That if residential and recreational development around Beaver Lake continues, a centralized water and wastewater system be established when the development exceeds 15 homes and/or cabins.

2. That all individual water supply systems be properly constructed and maintained. Bacteriological samples should be submitted to the Department of Health Laboratory in Pierre at least once each year.

3. That the outdoor privy located on the west side of the lake be properly abandoned.

4. It is recommended that bacteriological samples be collected at the swimming beaches at least once each week during the swimming season and submitted to the Department of Health Laboratory for determination of bacteriological quality of the water.

5. That livestock enterprises which contribute pollutants to Beaver Lake or its tributaries construct water pollution control facilities.

6. That all residents be made aware of the fact that as of July 10, 1973, the South Dakota Air Pollution Control Regulations provide that no open burning activities shall be conducted unless certain conditions are met.

7. All existing and new homes and/or cabins should install new waste disposal systems. These systems should comply with the following:

   a. Privies, septic tanks and underground disposal systems should be located not less than 100 feet, measured horizontally from the high water level of the lake. The soil must prove satisfactory by the percolation test when underground disposal is used.

      b. The percolation rate (the time required for water to fall 1 inch) can be calculated and the size of the tile disposal system determined from Tables IV and V. In the event that the absorption rate is less than 1 inch per 60 minutes, the above-ground or Nodak disposal system or other shallow type disposal system should be installed. At least two percolation tests in separate test holes should be made per lot.

TABLE IV

THE TILE LENGTH FOR EACH 100 GALLONS OF WASTEWATER PER DAY

Time in Minutes for 1-inch Drop	Tile Length for Trench Widths of 1-foot	2-feet	3-feet
1	25	13	9
2	30	15	10
3	35	18	12
5	42	21	14
10	59	30	20
15	74	37	25
20	91	46	31
25	105	53	35
30	125	63	42

TABLE V

ABSORPTION AREA REQUIREMENTS FOR PRIVATE RESIDENCES (PROVIDES FOR GARBAGE GRINDER AND AUTOMATIC WASHING MACHINES)

Time in minutes* required for water to drop 1 inch	Required absorption area, in square feet per bedroom* standard trench+
1 or less	70
2	85
3	100
4	115
5	125
10	165
15	190
30	250
45	300
60++	330

* In every case, sufficient area should be provided for at least 3 bedrooms.

+ Absorption area for standard trench is figured as trench bottom area.

++ Unsuitable for absorption systems if over 60.

c. The thickness of the permeable soil below the point of percolation test should be determined. The bottom of the tile field should be at least 4 feet above the highest annual ground water elevation and 5 feet above rock formations or impervious soil strata.

d. The usable liquid capacity of all septic tanks should conform to the occupant load or the number of plumbing fixture units, as shown in Table VI. However, the minimum usable septic tank size should be 1000 gallons.

TABLE VI

CAPACITY OF SEPTIC TANKS*

Single family dwelling-number of bedrooms	Other uses; maximum fixture units served	Minimum usable septic tank capacity in gallons
1-3	20	1000
4	25	1200
5 or 6	33	1500
7 or 8	45	2000
	55	2250
	60	2500
	70	2750
	80	3000
	90	3250
	100	3500

Extra bedroom 150 gallons each.

Note: Septic tank sizes in this table include sludge storage capacity and the connection of domestic food waste disposal units without further volume increase.

e. A distribution box is optional.

f. Maximum depths of seepage pits should be not more than 4 feet.

g. Seepage pits which penetrate groundwater should be prohibited.

h. Absorption trenches should be designed and constructed on the basis of the required effective percolation area. Maximum depths of absorption trenches should be no more than 4 feet.

i. The filter material should cover the tile and extend the full width of the trench and shall be not less than 6 inches deep beneath the bottom of the tile, and 2 inches above the top of the tile. The filter material may be washed gravel, crushed stone, slag, or clean bank-run gravel ranging in size from 1/2 to 2 1/2 inches.

j. The size and minimum spacing requirements for absorption fields should conform to those given in Table VIII.

TABLE VII

SIZE AND SPACING FOR DISPOSAL FIELDS

Width of trench at bottom (inches)	Depth of trench (inches)	Spacing tile lines s 1/ (feet)	Effective Absorptio[n] area per lineal feet of trench [2/] (square feet)
18	18 to 30	6.0	1.5
24	18 to 30	6.0	2.0
30	18 to 36	7.6	2.5
36	24 to 36	9.0	3.0

1/ A greater spacing is desirable where available area permits.

2/ Maximum length 100 feet.

k. Absorption lines should be constructed of 4 inch pipe of open jointed or horizontally split or perforated clay tile, perforated asbestos cement, perforated bituminized fiber or perforated plastic pipe conforming to Commercial Standard CS 228-61 as defined by ASTM D-2852-69T and Federal Specification #LP-001221; or open jointed cast iron soil pipe. In the case of clay tile or open jointed cast iron soil pipe, the sections should be spaced not more than 1/2 inch, and the upper half of the joint should be protected by asphalt-treated paper while the piping is being covered.

i. The trench bottom should be uniformly graded to slope from a minimum of 2 inches to a maximum of 4 inches per 100 feet.

APPENDIX B: SUMMARY AND RESULTS OF THE AGNPS MODEL

The Agricultural Non-Point Source Pollution Model (AGNPS)

Background

The Agricultural Non-Point Source Pollution Model (AGNPS) developed by Dr. Robert A. Young at the Agriculture Research Service Laboratory (ARS) in Morris, Minnesota, is being used by DENR to evaluate watershed management options. The AGNPS computer simulation model has the capability to predict the effect of BMP implementation on the sediment, phosphorus, and nitrogen output of a watershed. The model simulates nutrient and sediment runoff during a single storm event under prevailing land management practices and the physical characteristics of the land area in question, (e.g. a 40-acre square cell). All watershed characteristics and inputs are expressed at the cell level. Twenty-one cell parameters are required to quantitatively describe each watershed cell for the input data file of the model. Critical land areas may then be selected for data management (simulation of the application of BMP's) based on their nutrient and sediment output obtained on execution of the initial computer run.

The model output predicts watershed runoff volume and peak runoff rate with estimates of upland/channel erosion and delivered sediment as well as nutrient and chemical oxygen demand (COD) transport for any cell or the entire watershed. Estimates of dissolved and sediment-associated phosphorus and nitrogen are given in units of concentration (ppm) and mass (lb/acre).

Following this evaluation, coordination with State and Federal agricultural agencies is solicited to verify the critical nature of the identified land areas and the efficacy of selected control methods such as fertilizer/ animal waste management and conservation tillage among others. For those acreages targeted as critical, the owner/operators are contacted to request their voluntary participation in the control program.

The topography of the Beaver Creek/State Lake watershed is gently rolling with steeper grades occurring in a relatively narrow region running northwest and southeast of State Lake. Surface soils are predominantly silt loam and silt clay loam in texture. Corn, small grains, soybeans, and hay or pasture are principal crops grown.

Procedure

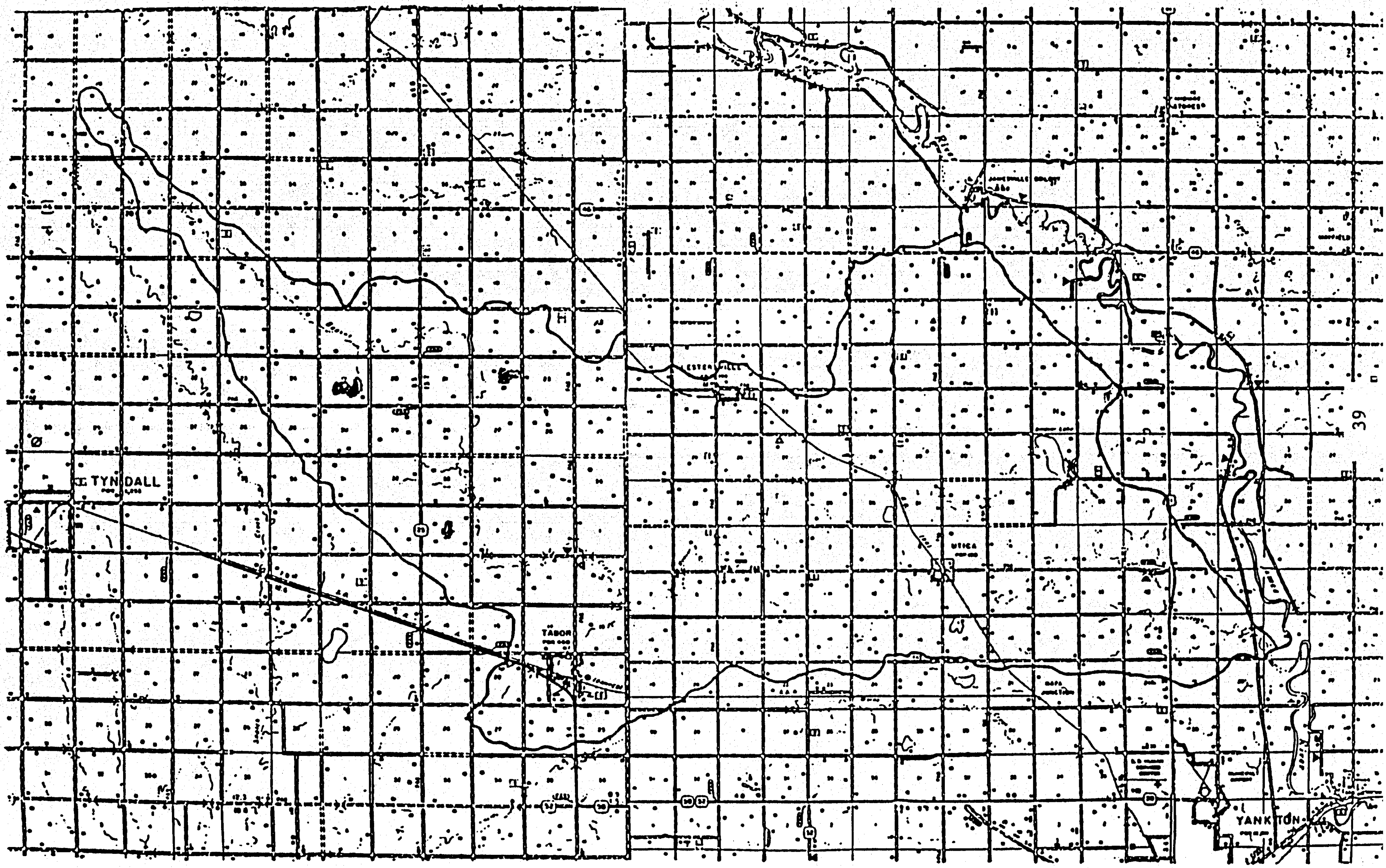
Analysis of appropriate U.S. Geological Survey (USGS) topographic maps indicated the Beaver Creek/State Lake basin totals 91,120 acres (Figure 1A) of which 74,480 acres (82%) contributes runoff to the James River. Approximately 45 small lakes, ponds, and marshy areas in the watershed catch and store runoff flow.

The Beaver Creek/State Lake watershed was divided into 2278 square 40-acre cells by drawing a grid onto the combined USGS topographic maps (scale 1:2400) as specified by the AGNPS manual (Young et al 1986). The 40-acre squares were numbered in single lines progressing across the watershed-west to east, north to south. Execution of the AGNPS computer model (version 3.60 PC) required collection of 21 field parameters for each cell that described the major physical features (soil types, topography, hydrology) and land-use of each designated acreage.

The drainage pattern of the watershed was charted by delineating the major direction of waterflow through each 40-acre cell, beginning with the uppermost cell in the northwestern corner of the watershed (cell #1), progressing east-southeast to State Lake and eventually to the particular cell (#2065) where Beaver Creek drains into the James River, approximately two miles north of Yankton, South Dakota (Figure 1A). For the purposes of the model, cell #2065 represented the sole watershed outlet for the Beaver Creek drainage. The net sediment and nutrient contribution of the entire watershed to the James River was calculated at this location by the computer program for a previously chosen rainstorm event.

The type of storm event selected for this computer simulation was based on estimates of average annual soil losses in the watershed as previously determined by SCS. The storm event selected was a 5-year, 24 hour rainstorm with a rainfall of 3.4 inches and a storm energy intensity (EI) of 125 to reflect average annual

Figure 1A. The Beaver Creek/State Lake Watershed.



erosion rates. Moderate soil moisture conditions were assumed to exist when the precipitation event would occur in mid to late May when new crops were being planted.

Sources of information for cell parameters (field data) included SCS personnel, farmer interviews, topographic maps, visual observations, ASCS records, county survey maps, and reference tables contained in Young et al (1986) and SCS Technical Guides for South Dakota.

An examination of AGNPS results from other watershed evaluations suggested that some modification of the present data file would be needed to more realistically describe land conditions in the Beaver Creek drainage as they relate to water erosion and the export of sediment and nutrients. Problems arose in the process of choosing the most suitable land-use parameter values to be used in the computer input file. Due to the now commonly employed practice of crop rotation by producers, the land conditions observed and quantified from a large watershed during the time of field data collection, can change significantly before results of a lengthy AGNPS computer simulation program can be obtained and recommendations based thereon can be distributed. Mitigation procedures suitable for acreages utilized for row crops may not be appropriate for the same lands given over to small grains or pasture the following growing season. Therefore, to arrive at base parameters that better related to the sequence of crops grown on an acreage, the entire cycle of crop rotation, usually 5 years in length, must be considered. Parameter values (averages) should be derived that adequately fit the range of land conditions (with regard to runoff curve numbers, surface condition constants and other parameters) that may be present during a crop rotation cycle. The cropping factor(C) need not be averaged since its tabular value is based on cropping sequence.

However, to evaluate a 5-year cropping history for all the cells in a large watershed, such as the Beaver Creek drainage, would be extremely time consuming. Therefore, as an acceptable alternative, a sufficient number of randomly selected cells was chosen to represent the cropping practices prevalent in the entire watershed. An attempt was made to include in the sample the various land slopes found in the drainage. Based on this sampling, the following five crop rotations were found to be utilized within the Beaver Creek drainage with the percentage of watershed cropland in each rotation:

CROP SEQUENCE AND TILLAGE	ACREAGE
1. Beans after Corn with Spring Disk	40%
2. Small Grains after Corn with Fall Chisel & Spring Disk	20%
3. Beans after Corn after Alfalfa with Spring Disk	20%
4. Continuous Corn with Fall Chisel & Spring Disk	10%
5. Continuous Beans with Fall Chisel & Spring Disk	10%

The related AGNPS land-use parameters were then determined for each crop rotation and tillage category. It was found that rotations 2 and 3 could be combined in the computer model because their parameters were essentially the same.

Four alternative land treatments (BMP's) were selected for data manipulation to estimate by means of the model their relative effectiveness in reducing sediment and nutrient losses in the Beaver Creek watershed. The application of each land treatment involved a number of changes in the values of previously determined base land-use parameters stored in the input data file. The selected land treatments were the following:

1. Use of No-Till or Ridge-Till on fields with 3% to 9% slopes.
2. Use of Contouring on all fields with 3% to 6% slopes.

3. Planting Permanent Grass Cover on fields with slopes greater than 9%.

4. In addition, the effect of subsurface fertilizer application (knifing or banding) was tested on land treatments 1 and 2 to estimate potential reductions in soluble nutrient export from cells with surface applied fertilization.

To estimate the potential benefits of implementing the above recommended practices, treatments were run in computer simulation, singly and in combination, to test their relative efficacy in reducing watershed sediment and nutrient output and resulting inflow of these pollutants into State Lake and the James River.

Results

The output file of the initial computer run, which utilized descriptive data of recent land conditions in the Beaver Creek/State Lake drainage, is shown in Table 1A. The mass and concentration of sediment and nutrients represent loadings that can be expected to occur on roughly an annual basis, at the cell (#2065) where Beaver Creek flows into the James River (Figure 1A). Considerable loads of sediment and nutrients entering the James River are indicated by the table even though State Lake acts as a sediment trap, which also serves to remove nutrients, particularly phosphorus, that are bound to soil particles. However, this sediment/nutrient trapping capacity may have become greatly diminished in recent years due to sediment accumulations filling the reservoir basin.

Nutrient and sediment inputs to State Lake appear in Table 2A. Also shown is the discharge of sediment and nutrients at the reservoir spillway (cell #1093) along with the contribution of the downstream portion of the watershed (20%of the area of the entire contributing watershed) at the James River confluence (cell #2065).

Table 2A indicates that State Lake may be experiencing considerable sedimentation over an average annual cycle of rainfall. The sediment loading of 37,858 tons roughly corresponds to a volume of nearly 34 acre-feet. At a reservoir capacity of 216 acre-feet (assuming an area of 72 acres and an average depth of 3 feet) this loading represents an annual sediment volume in excess of 15% of reservoir capacity; a rate of filling which makes for an unacceptably short reservoir life span. Moreover, as the sediment-settling capacity of State Lake further diminishes, increasing sediment and nutrient loads from the watershed can be expected to be transported to the James River during runoff events. Therefore it is essential that conservative land

Table 1A. AGNPS output for runoff, erosion, sediment, nitrogen and phosphorus discharge in the untreated Beaver Creek/State Lake watershed for a simulated 3.4-inch rainfall.

Watershed Summary

Watershed Studied	BEAVER CREEK\STATE LAKE
The area of the watershed is	74480 acres
The area of each cell is	40.00 acres
The characteristic storm precipitation is	3.40 inches
The storm energy-intensity value is	125

Values at the Watershed Outlet

Cell number	2065 000
Runoff volume	1.3
Peak runoff rate	9728 cfs
Total Nitrogen in sediment	1.25 lbs/acre
Total Nitrogen in sediment	1.20 lbs/acre

Soluble Nitrogen concentration in runoff	4.05 ppm
Total Phosphorus in sediment	0.62 lbs/acre
Total soluble Phosphorus in runoff	0.22 lbs/acre
Soluble Phosphorus concentration in runoff	0.75 ppm
Total soluble chemical oxygen demand	42.51 lbs/acre
Soluble chemical oxygen demand concentration in runoff	144 ppm

Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.23	0.00	72	10	1108.29	0.16	12174.5
SILT	0.36	0.00	12	2	303.29	0.04	3331.6
SAGG	2.25	0.00	5	1	701.60	0.10	7707.0
LAGG	1.40	0.00	0	0	5.07	0.00	55.7
SAND	0.28	0.00	0	0	1.25	0.00	13.8
=====	=====	=====	====	====	=====	=====	=====
TOTAL	4.51	0.00	7	1	2119.50	0.31	23282.6

Table 2A. Sediment yield and nutrient mass/concentration at State Lake's tributary inlets (cells #741, #742, #882), lake spillway (#1093) and Beaver Creek confluence with James River (#2065).

Condensed Soil Loss

	RUNOFF					SEDIMENT			
	Drainage		Generated	Peak	Cell	Generated			
Cell	Area	Volume	Above	Rate	Erosion	Above	Within	Yield	Depo
Num Div	(acres)	(in.)							
741 000	3800	1.56	98.8	1458	8.87	3894.81	354.80	3945.08	7
742 000	1920	0.70	98.9	1236	1.28	2047.01	51.10	1922.22	8
882*000	54000	0.70	100.0	9775	2.21	32361.31	88.36	31991.23	1
1093 000	61320	0.70	100.0	8543	0.23	10242.99	9.15	10240.61	0
2065 000	74480	0.70	100.0	9728	0.46	23706.40	18.40	23282.58	2

*Beaver Creek tributary inlet.

Nutrient Analysis

NITROGEN

Cell Num Div	Drainage Area (acres)	Sediment Within Cell (lbs.a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
741 000	3800	18.14	3.26	1.24	1.27	4
742 000	1920	3.85	3.17	0.14	1.30	4
882 000	54000	5.96	2.08	0.14	1.22	4
1093 000	61320	0.97	0.76	0.14	1.22	4
2065 000	74480	1.70	1.25	0.14	1.20	4

Nutrient Analysis

PHOSPHORUS

Cell Num Div	Drainage Area (acres)	Sediment Within Cell (lbs.a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
741 000	3800	9.07	1.63	0.22	0.23	1
742 000	1920	1.92	1.58	0.01	0.24	1
882 000	54000	2.98	1.04	0.01	0.23	1
1093 000	61320	0.49	0.38	0.01	0.23	1
2065 000	74480	0.85	0.62	0.01	0.22	1

management procedures be implemented in the Beaver Creek/State Lake drainage that significantly reduce soil loss in the watershed and decrease substantially the impact of transported sediments/nutrients on State Lake and the James River.

The effect of selected land treatments applied on the watershed in simulation is presented in Table 3A. The table shows that the largest sediment and nutrient reductions (30% and 19%) of any single treatment application were obtained with Treatment 3. This treatment involved planting permanent grass cover on steep fields with slopes greater than 9%. Treatment 3 affected 77 watershed cells or 3080 acres - by far the smallest land area of any of the treatments considered.

The next highest reductions of sediments were obtained by simulating application of Treatment 1: No-till or ridge-till on fields with slopes of 3% to 9%. Treatments 1 and 2 (contouring all fields with 3% to 6%

slopes) appeared to be similarly effective in reducing nutrient export (Table 3A).

Treatment 4: Subsurface fertilizer application (knifing or banding) can also be recommended for reducing nutrient loss from croplands. It is particularly effective when used in conjunction with Treatment (No-till).

Implementation of contour tillage (Treatment 2) on fields with 3% to 6% slopes produced smaller but still significant reduction, particularly in nutrients. It has the moderate advantage of involving a smaller area of watershed land (by 5320) acres) than no-till treatment.

Maximum reduction of both pollutant species was obtained with a combination of treatments. The best combination tested was comprised of Treatments 1, 4, and 3 (Table 3A): No-till or ridge till farming with subsurface fertilizer injection (Treatments 1 and 4) and planting of permanent grass cover on fields with slopes greater than 9%.

Reduced tillage (no-till or ridge-till) has proven in recent experience both an economical and productive

Table 3A. Estimated sediment and nutrient yields from a 5-year, 24 hour storm before and after application of selected best management practices (treatments)

Watershed Sediment (Sed.) and Nutrient (N & P) Yield in Tons

Monitoring Locations	Untreated			Treat. 1			Yield Reduction & % Red.		
	Sed.	N	P	Sed.	N	P	Sed.	N	P
Lake Inflow* (Drainage Area - 59720 acres)	37858	102.0	39.6	29600	90.4	33.7	8258 (22%)	11.6 (11%)	5.9 (15%)
Lake Outflow (Drainage Area - 61320 acres)	10241	60.7	18.7	8003	56.4	16.6	2238 (22%)	4.3 (7%)	2.1 (11%)
James R. Confluence (Drainage Area-74480 acres)	23282	91.2	31.3	19161	84.5	27.9	4121 (18%)	6.7 (7%)	3.4 (11%)

	Untreated			Treat. 1 & 4			Yield Reduction & % Red.		
	Sed.	N	P	Sed.	N	P	Sed.	N	P
Lake Inflow* (Drainage Area - 59720 acres)	37858	102.0	39.6	29600	79.4	31.3	8258 (22%)	22.6 (22%)	8.3 (21%)
Lake Outflow (Drainage Area - 61320 acres)	10241	60.7	18.7	8003	45.1	13.8	2238 (22%)	15.6 (26%)	4.9 (26%)
James R. Confluence (Drainage Area-74480 acres)	23282	91.2	31.3	19161	71.1	25.0	4121 (18%)	20.1 (22%)	6.3 (20%)

	Untreated			Treat. 1 & 4 & 3			Yield Reduction & % Red.		
	Sed.	N	P	Sed.	N	P	Sed.	N	P
Lake Inflow* (Drainage Area - 59720 acres)	37858	102.0	39.6	20905	65.1	24.4	16953 (45%)	36.9 (36%)	15.2 (38%)
Lake Outflow (Drainage Area - 61320 acres)	10241	60.7	18.7	6218	40.8	12.0	4023 (39%)	19.9 (33%)	6.7 (36%)
James R. Confluence (Drainage Area-74480 acres)	23282	91.2	31.3	12128	57.3	18.6	11154 (48%)	33.9 (37%)	12.7 (40%)

	Untreated			Treat. 2			Yield Reduction & % Red.		
	Sed.	N	P	Sed.	N	P	Sed.	N	P
Lake Inflow* (Drainage Area - 59720 acres)	37858	102.0	39.6	33317	92.5	35.5	4541 (12%)	9.5 (9%)	4.1 (10%)
Lake Outflow (Drainage Area - 61320 acres)	10241	60.7	18.7	9036	54.9	16.6	1205 (12%)	5.8 (10%)	2.1 (11%)
James R. Confluence (Drainage Area-74480 acres)	23282	91.2	31.3	20967	83.4	28.7	2315 (10%)	7.8 (9%)	2.6 (8%)

Table 3A. Continued

	Untreated			Treat. 2 & 4			Yield Reduction & % Red.		
	Sed.	N	P	Sed.	N	P	Sed.	N	P
Lake Inflow* (Drainage Area - 59720 acres)	37858	102.0	39.6	33317	85.9	34.3	4541 (12%)	16.1 (16%)	5.3 (13%)
Lake Outflow (Drainage Area - 61320 acres)	10241	60.7	18.7	9036	48.4	15.5	1205 (12%)	12.3 (20%)	3.4 (18%)
James R. Confluence (Drainage Area-74480 acres	23282	91.2	31.3	20967	75.6	26.8	2315 (10%)	15.6 (17%)	4.5 (14%)

	Untreated			Treat. 2 & 4 & 3			Yield Reduction & % Red.		
	Sed.	N	P	Sed.	N	P	Sed.	N	P
Lake Inflow* (Drainage Area - 59720 acres)	37858	102.0	39.6	24703	70.5	27.4	13155 (35%)	31.5 (31%)	12.2 (31%)
Lake Outflow (Drainage Area - 61320 acres)	10241	60.7	18.7	7262	42.0	13.2	2979 (29%)	18.7 (31%)	5.5 (29%)
James R. Confluence (Drainage Area-74480 acres	23282	91.2	31.3	139911	60.3	20.5	9291 (40%)	30.9 (34%)	10.8 (34%)

	Untreated			Treat. 3			Yield Reduction & % Red.		
	Sed.	N	P	Sed.	N	P	Sed.	N	P
Lake Inflow* (Drainage Area - 59720 acres)	37858	102.0	39.6	29114	88.6	33.1	8744 (23%)	11.6 (13%)	6.5 (16%)
Lake Outflow (Drainage Area - 61320 acres)	10241	60.7	18.7	8450	56.4	16.6	1791 (17%)	4.3 (7%)	2.1 (11%)
James R. Confluence (Drainage Area-74480 acres	23282	91.2	31.3	16232	78.2	25.3	7050 (30%)	13.0 (14%)	6.0 (19%)

* Consists of 3 State Lake tributaries: Beaver Creek (drains 72% of contributing watershed) and 2 smaller temporary streams.

Treatment 1: No-till or ridge till on 3% to 9% slopes.
Treatment 2: Contouring 3% to 6% slopes.
Treatment 3: Grassing slopes steeper than 9%.
Treatment 4: Subsurface injection of fertilizer (knifing or banding).

system of farming as well as one with a reduced impact on the environment. Conservation tillage has been demonstrated to be a safe and sound system to reduce sediment, nutrient, and pesticide pollution. According to SCS estimates, as much as 90% of cropland erosion can be eliminated in some instances with a no-till system. No-till requires less horsepower and less equipment. No-till requires approximately 120 horsepower primarily for knifing in fertilizers. Most conventional planters can be economically adapted to no-till whereas some planters require no adaptation to plant no-till.

High concentrations of water soluble nutrients exported from the watershed (Table 1A) suggest that management of fertilizer levels could be advantageous to further reduce nutrient export from croplands. This may be done by establishing a schedule of field soil testing to determine natural soil fertility and nutrient carryover. If soil nitrogen and phosphorus levels are sufficiently high and near the requirements of desired crop yields, smaller quantities of fertilizers can be applied without risk of decreased yield.

Utilization of ridge till for row crops offers unique advantages for the reduction of applied nitrogen and phosphorus fertilizer levels. When fertilizers are applied to the seed rows rather than the entire field, smaller quantities of fertilizer are required. For example, applied nitrogen fertilizer can be reduced by half from the average current use of approximately 130 lb/ac. to from 60 to 75 lb per acre.

A fact sheet on soil nitrogen (a much more mobile nutrient than phosphorus) is available from the SDSU Extension Service, Brookings, S.D. Topics covered include soil tests, nitrate leaching, nitrogen requirements of crops, and nitrogen fertilizer management.

Recommendations

Best results obtained with the present AGNPS simulation in terms of nutrient and sediment reduction were from the following watershed treatments:

1.) Treatment 3: Grassing all watershed slopes with inclines greater than 9%.

2.) Treatment 1 & 4: No-till or ridge till with subsurface fertilizer injection on fields with slopes from 3% to 9%.

3.) A combination of Treatments 1, 4 and 3.

4.) Establishment of soil testing with the goal of reducing the amount of applied fertilizer.

5.) Utilization of ridgetill for row crops and application of fertilizer to seed rows only.

APPENDIX C. DESCRIPTION OF WATER QUALITY PARAMETERS

WATER QUALITY PARAMETERS

1. **Laboratory Analysis:**

a. Fecal Coliform (organisms/100 mL) can indicate fecal contamination and thus potential human health hazards. Fecal coliform bacteria are bacteria which live in the digestive tract of warm-blooded animals. These bacteria are considered to be an indicator of sewage pollution or livestock manure. Fecal coliform bacteria are not found in the digestive tract of cold-blooded animals such as fish, amphibians or from the material of wild animals or birds.

b. Laboratory pH (su) is a measure of the hydrogen ion activity which directly affects the toxicity (solubility) of heavy metals in water, among other items. The pH scale is a number range between 1 and 14, with 7 being neutral. Any value less than 7 is considered acidic an any value greater than 7 is considered basic. The pH range for most natural lakes is between the 6 and 9. Deviation, from the neutral pH 7, is a result of the decomposition of salts as they reacted with water. Gases such as carbon dioxide, hydrogen sulfide, and ammonia have a significant effect on pH. The pH of a lake is directly related to the geography of the surrounding area.

c. Total Alkalinity (mg/L) refer to the quantity of different compounds that shift the pH to the alkaline side of neutrality. Alkalinity generally the result of bicarbonates but is expressed as a sum of hydroxide, carbonate, and bicarbonate. Carbonate and bicarbonate are common in water because carbonate minerals are common in nature. The contribution to alkalinity by hydroxides is rare in nature. Thus alkalinity is directly related to geography. Expected total alkalinities in nature range from 20 to 200 mg/L.

d. Total Solids (mg/L) are all the materials, suspended and dissolved, present in water. These are the materials left after the raw water has evaporated off.

e. Total Dissolved Solids (mg/L) include salts and organic residue which pass through a filtered water sample. Total dissolved solids can also be determined by subtracting the total solids by the suspended solids.

f. Total Suspended Solids (mg/L) include organic and inorganic materials that are not dissolved. This parameter can indicate the sediment load into a body of water and possible problems to the biological community. Suspended solids does not include a measure of larger particles that are moved along the stream bed during high flows.

g. Ammonia-Nitrogen (mg/L) is generated by bacteria as a primary end product of decomposition of organic matter. Ammonia is the form of nitrogen directly available to plants as a nutrient for growth. High ammonia concentrations can be used to demonstrate organic pollution.

h. Unionized Ammonia (mg/L) is a portion of ammonia-nitrogen which is highly toxic to many organisms, especially fish. Unionized ammonia is derived from a calculation and is dependant on temperature and pH.

i. Nitrate-Nitrogen (mg/L) is often the most abundant inorganic form of nitrogen. Nitrate constitutes the inorganic form of nitrogen assimilated by algae and larger hydrophytes. In natural waters the concentrations are usually low, around 0.1 mg/L. Some sources for inorganic nitrogen are agricultural activities, sewage, and atmospheric pollution by man.

j. Total Kjeldahl Nitrogen (mg/L) is used to measure both total nitrogen and organic nitrogen. Ammonia is subtracted from total kjeldahl nitrogen to acquire the amount of organic nitrogen present. Organic forms of nitrogen can be broken down into different compounds which are then used by phytoplankton. Organic nitrogen can be released from living macrophytes and large quantities can also be released from decaying macrophytes.

k. Total Nitrogen (mg/L) is the sum of nitrate-nitrate nitrogen plus total kjeldahl nitrogen. Total nitrogen to total phosphorus ratios are used to identify which nutrient is limiting to algae growth in lake waters. A lake is usually defined as phosphorus limited if the total nitrogen/total phosphorus ratio is greater than 10:1.

l. Total Phosphorus (mg/L) represents all of the phosphorus found in the water sample. Phosphorus is an element which is essential to all life. Not all of the phosphorus is immediately available to aquatic plants and algae. Soil can sorb to phosphorus which is released when dissolved oxygen levels are depleted. When concentrations are high, nuisance growth of aquatic plants or algae may result. Sources of phosphorus are from agriculture, sewage, and from the decomposition of organic matter.

m. Ortho-Phosphorus (mg/L) is a form of phosphorus which is readily available for uptake by plants.

2. **Field Analysis:**

a. Water Temperature (^{o}C) is taken since it has a considerable effect on the chemical process in a lake. Also, temperature is important to fish life and other aquatic species.

b. Field pH (su) is a measure of the hydrogen ion activity which directly effects the toxicity (solubility) of heavy metals in water, among other items. The pH scale is a number range between 1 and 14, with 7 being neutral. Any value less than 7 is considered acidic and any value greater than 7 is considered basic.

c. Dissolved Oxygen (mg/L) the dissolved oxygen content of water results from (1) the activities of growth and decomposition in the lake system; and (2) the air-water interface and the distribution by wind driven mixing. Oxygen levels less than 3.0 mg/L are stressful to aquatic vertebrates and most other aquatic life.

d. Climate Conditions - wind, precipitation, air, and temperature (^{o}C).

e. Visual Observations - septic conditions, odor, water color, turbidity, or anything unusual (e.g. dead fish.

f. Water Depth in tributaries it is taken to assist in calculating flow measurements. Water depth in lakes are used as reference points and to notice changes in lake elevation.

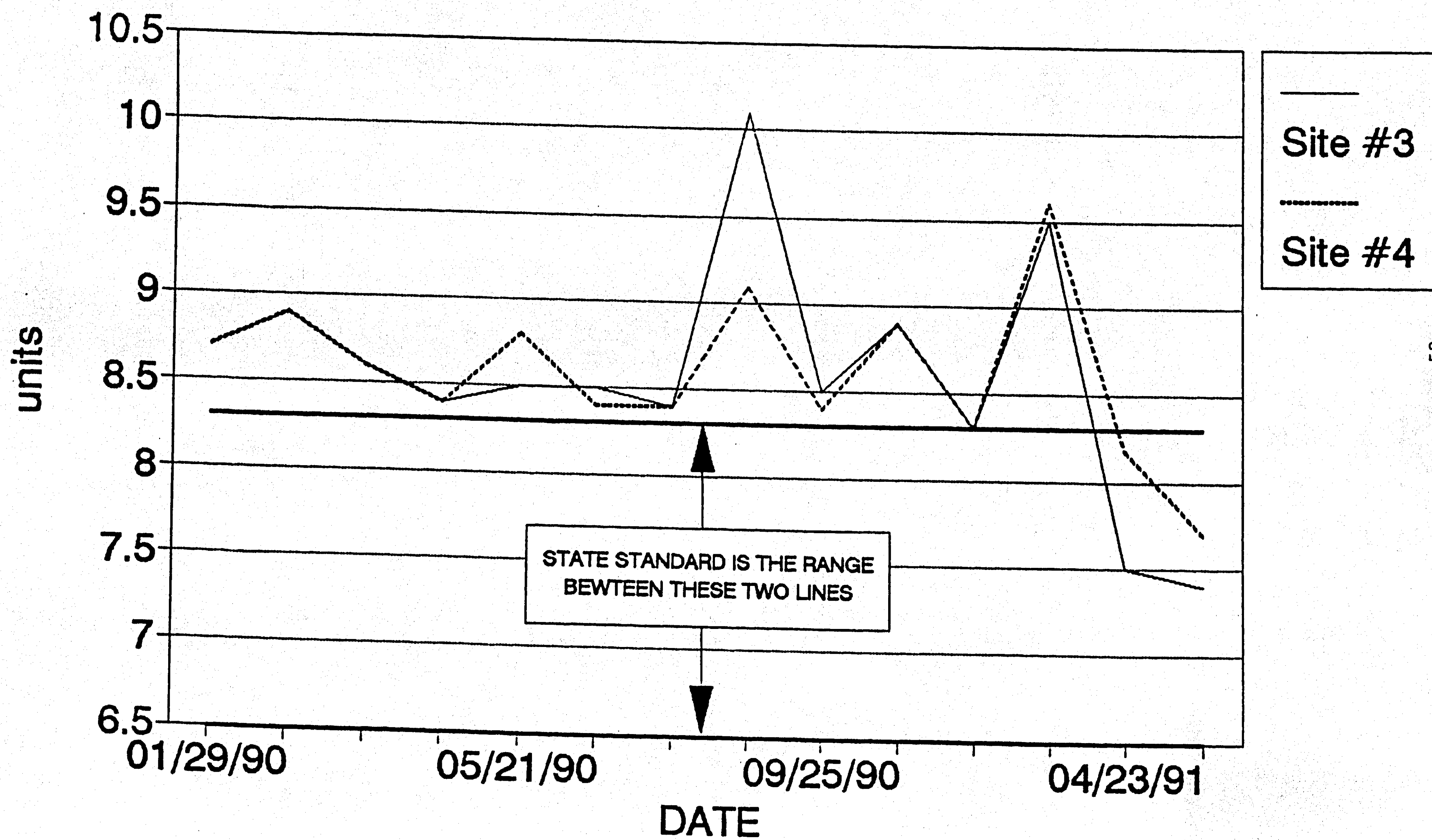
g. Secchi Disk is taken for a comparison of water clarity.

3. **In-lake Sediment Sampling**

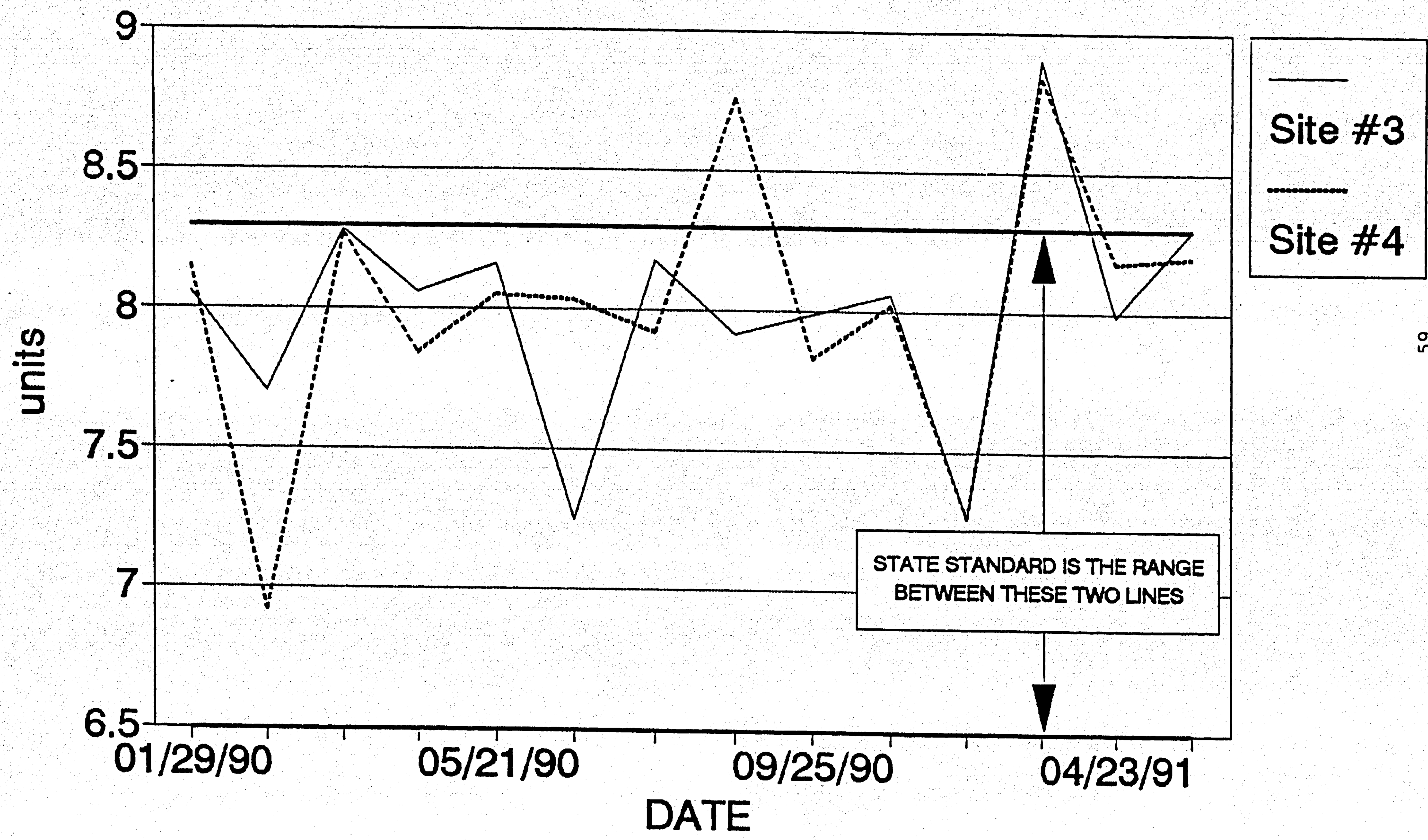
a. Sediment Surveys are conducted and topographic maps are made to determine sediment volumes and concentrations in the lake.

APPENDIX D: GRAPHS COMPARING PARAMETERS OF THE THE IN-LAKE SITES

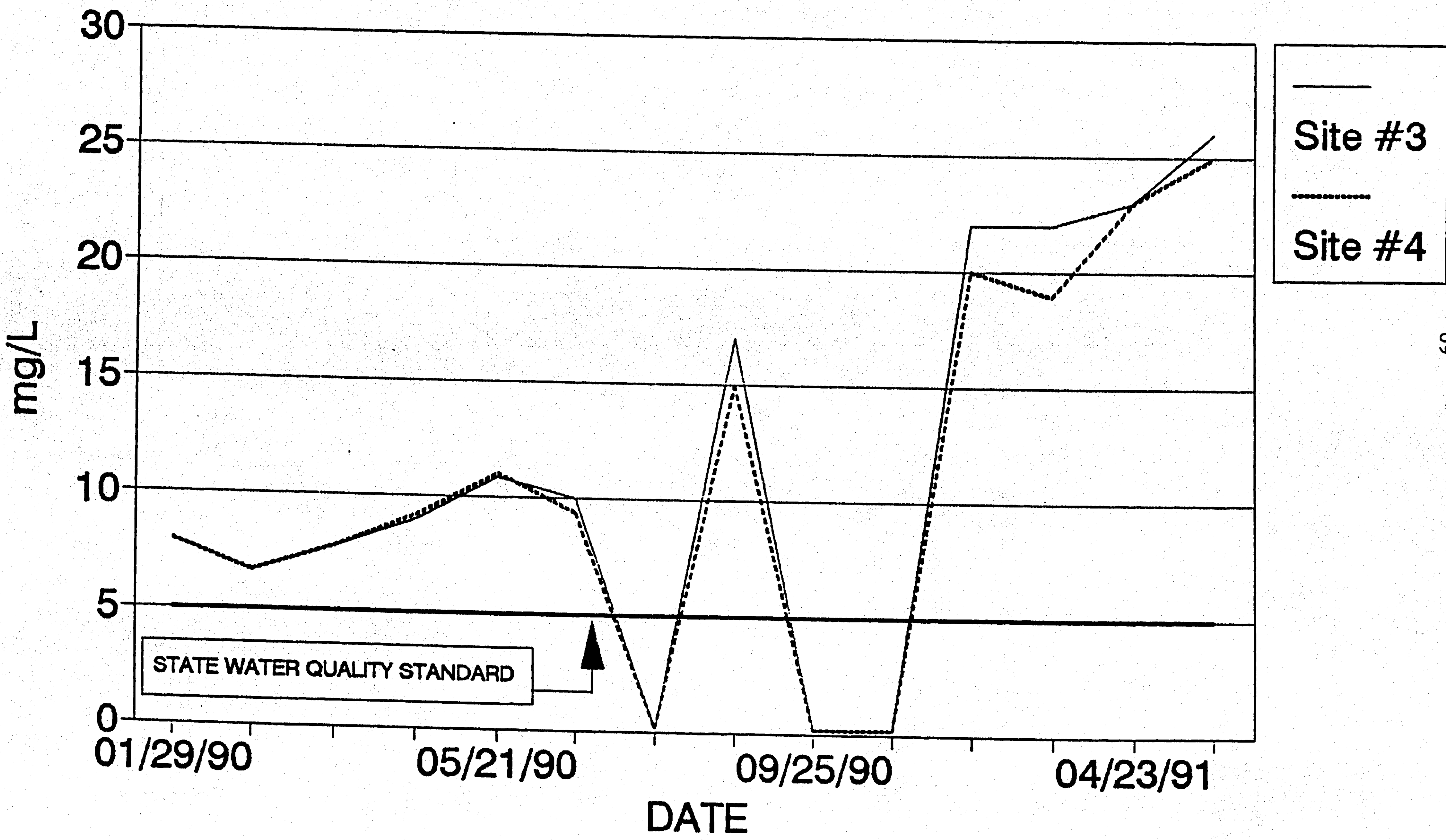
FIELD pH FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4



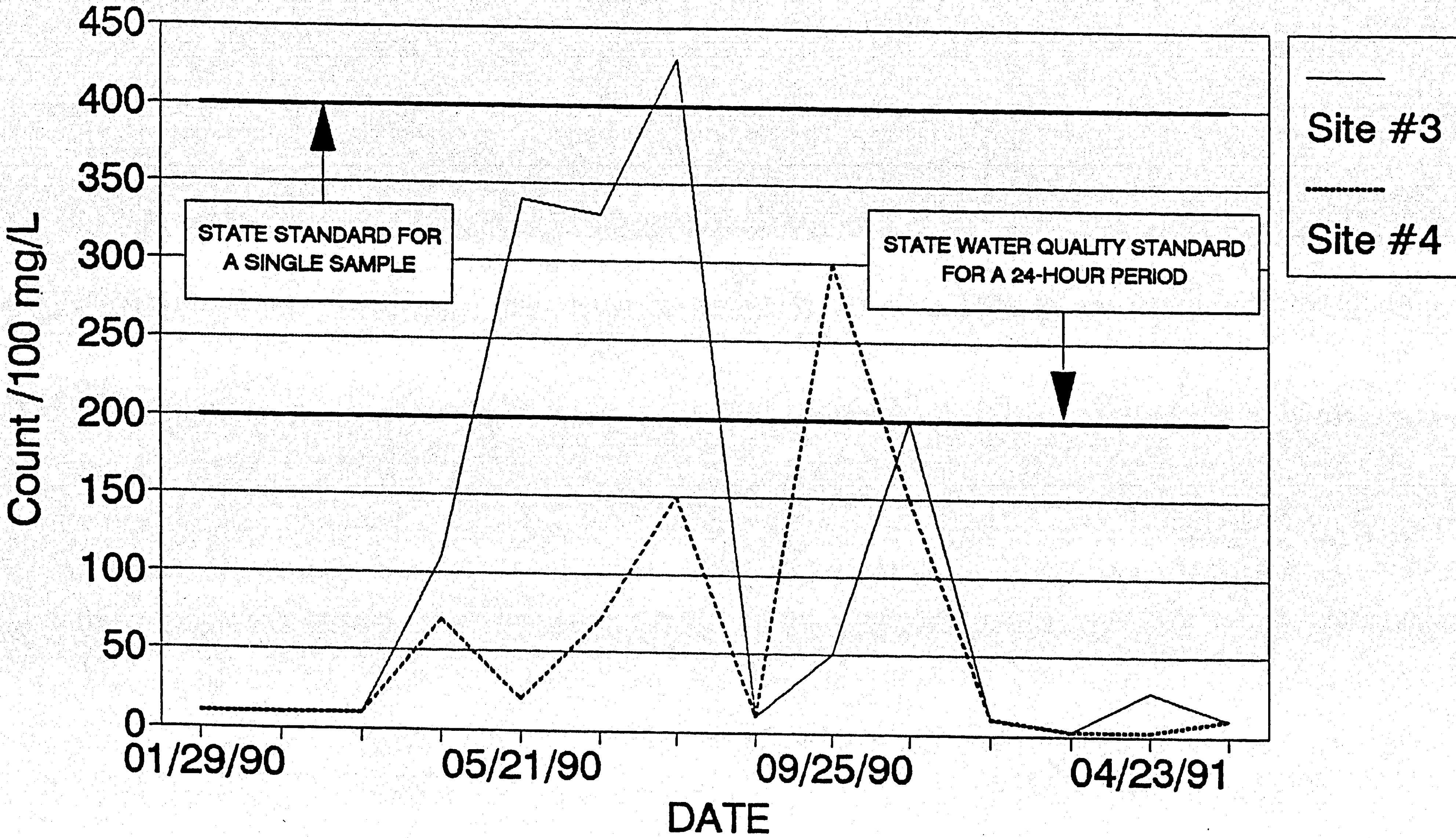
LABORATORY pH FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4



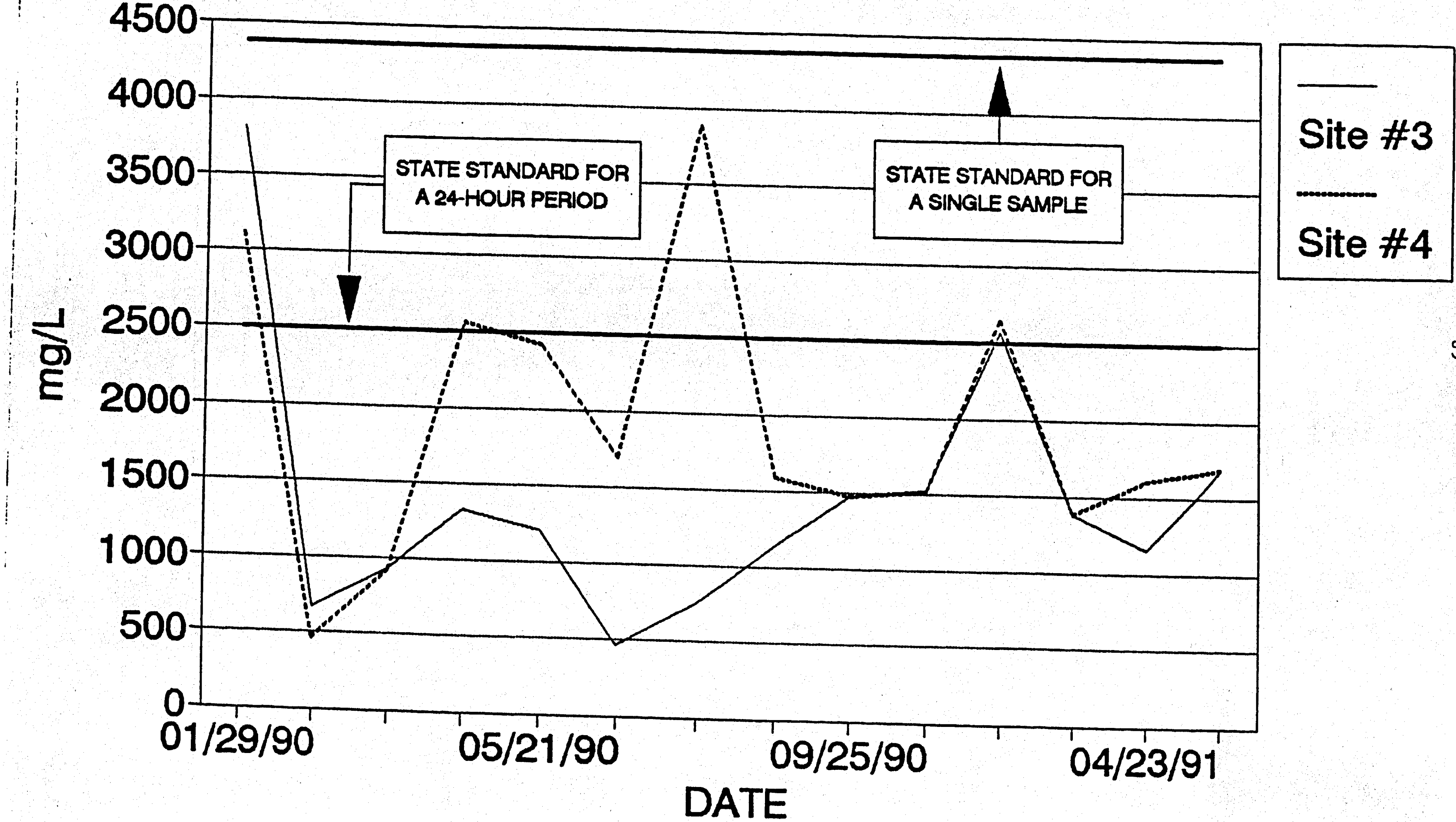
DISSOLVED OXYGEN FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4



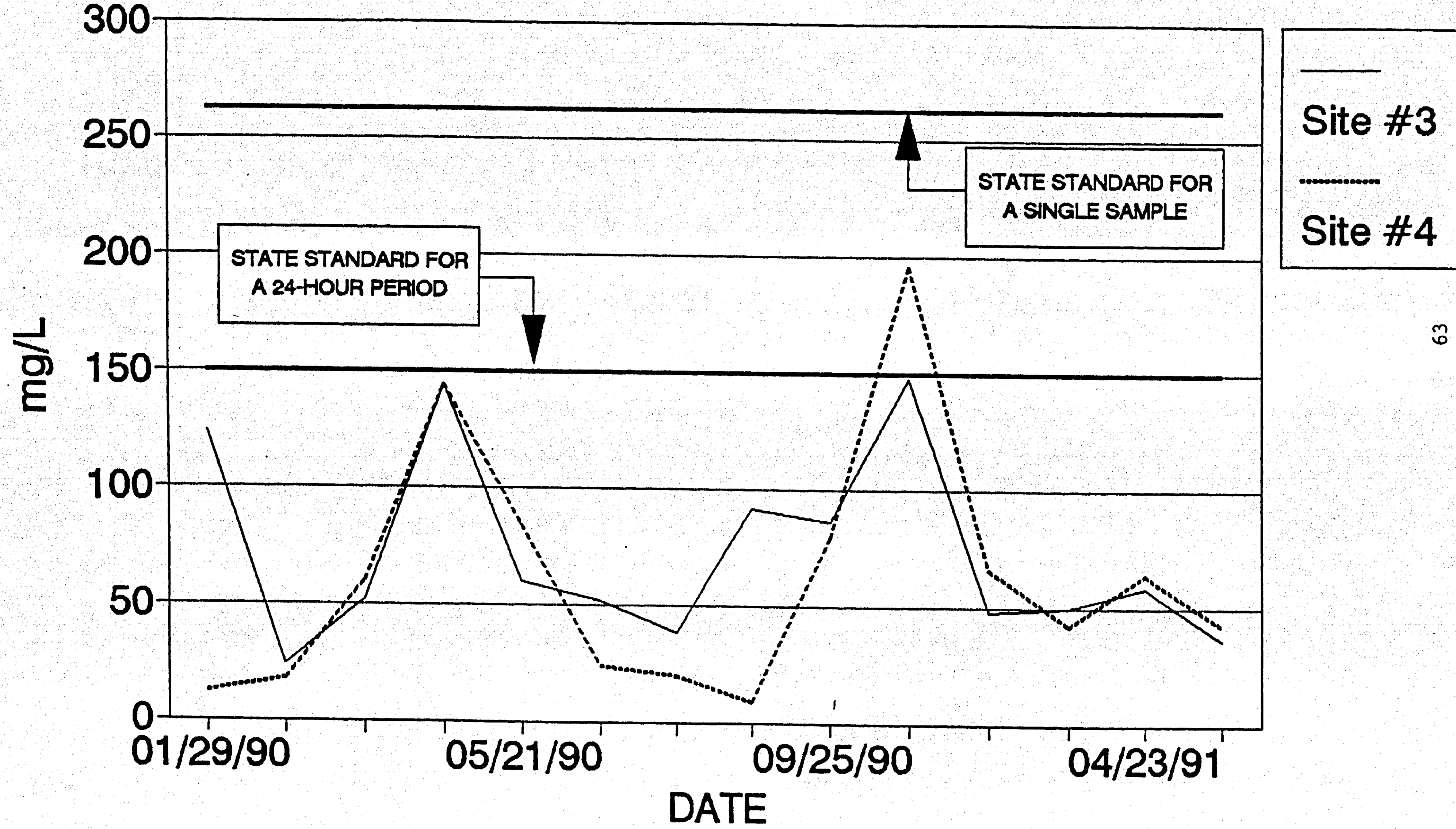
FECAL COLIFORM FOR BEAVER LAKE
1990 - SITE #3 & SITE #4

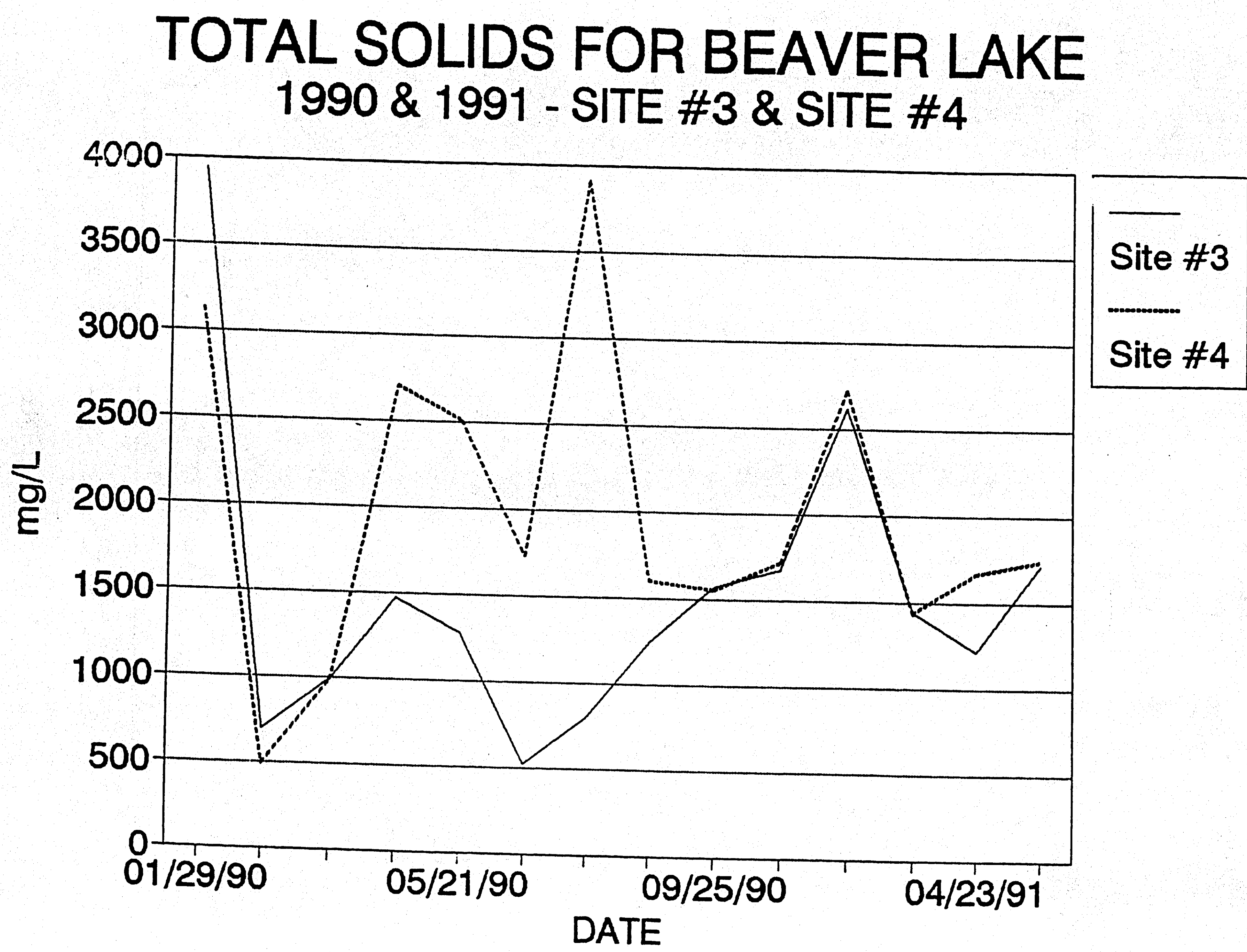


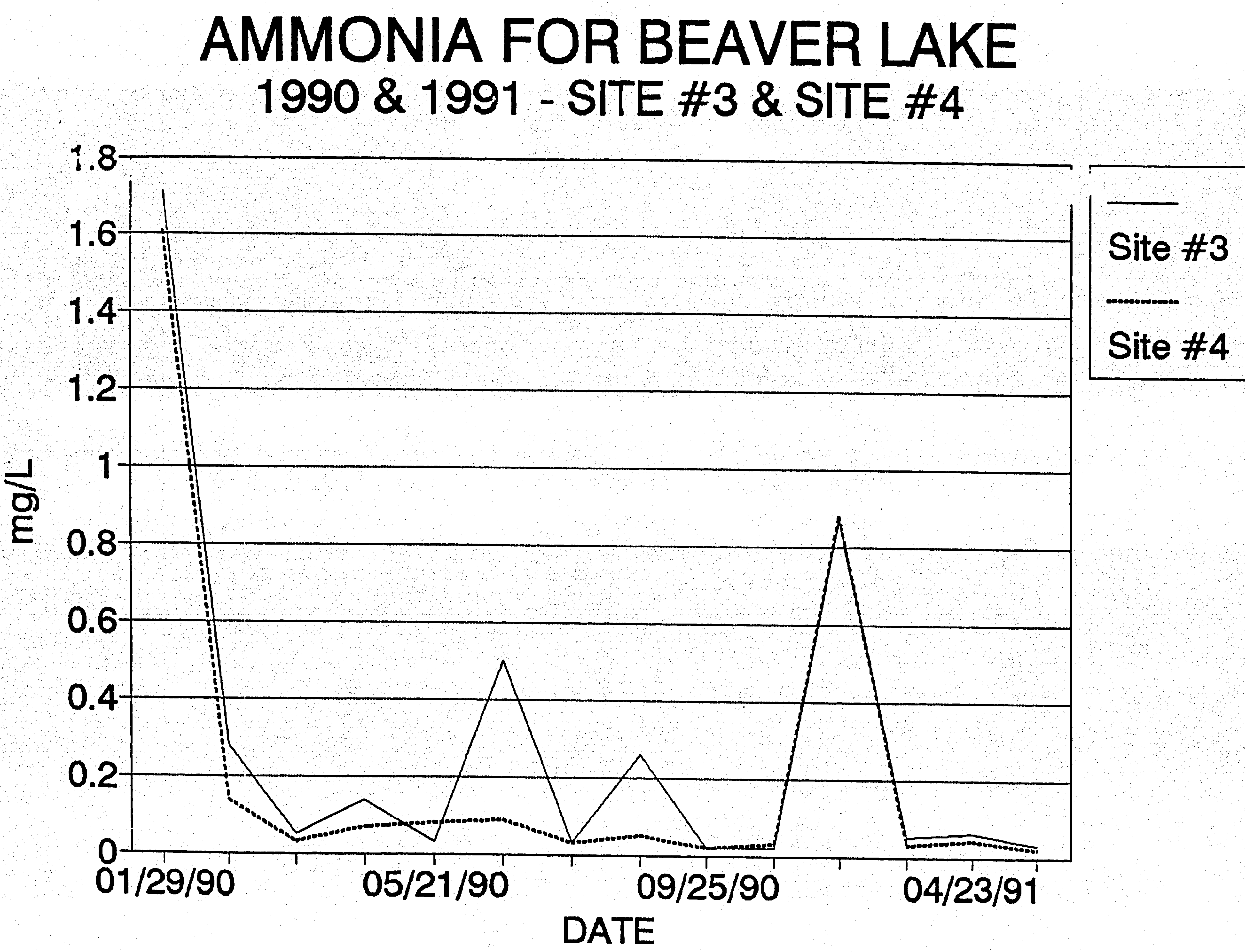
TOTAL DISSOLVED SOLIDS FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4

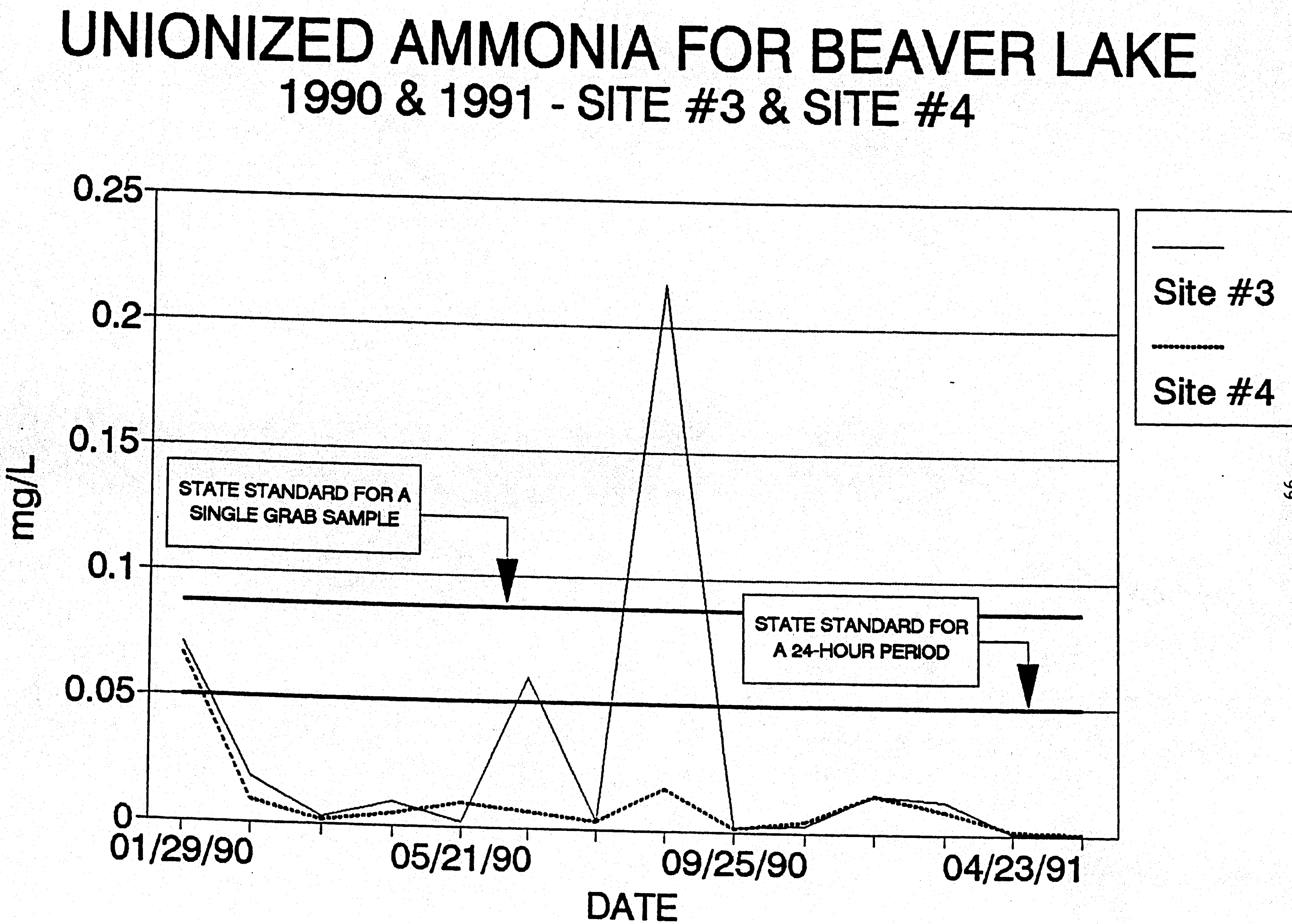


TOTAL SUSPENDED SOLIDS FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4

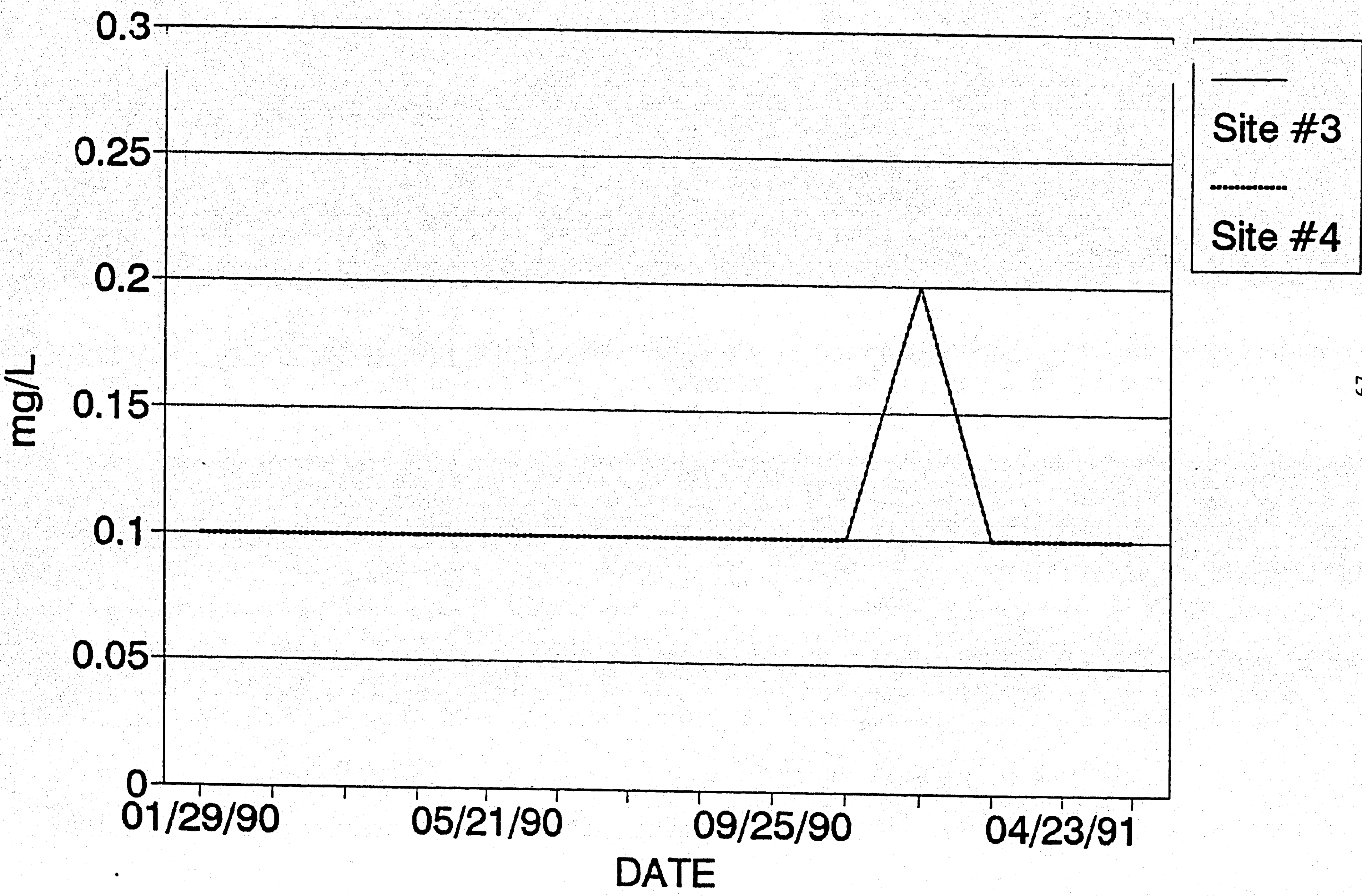


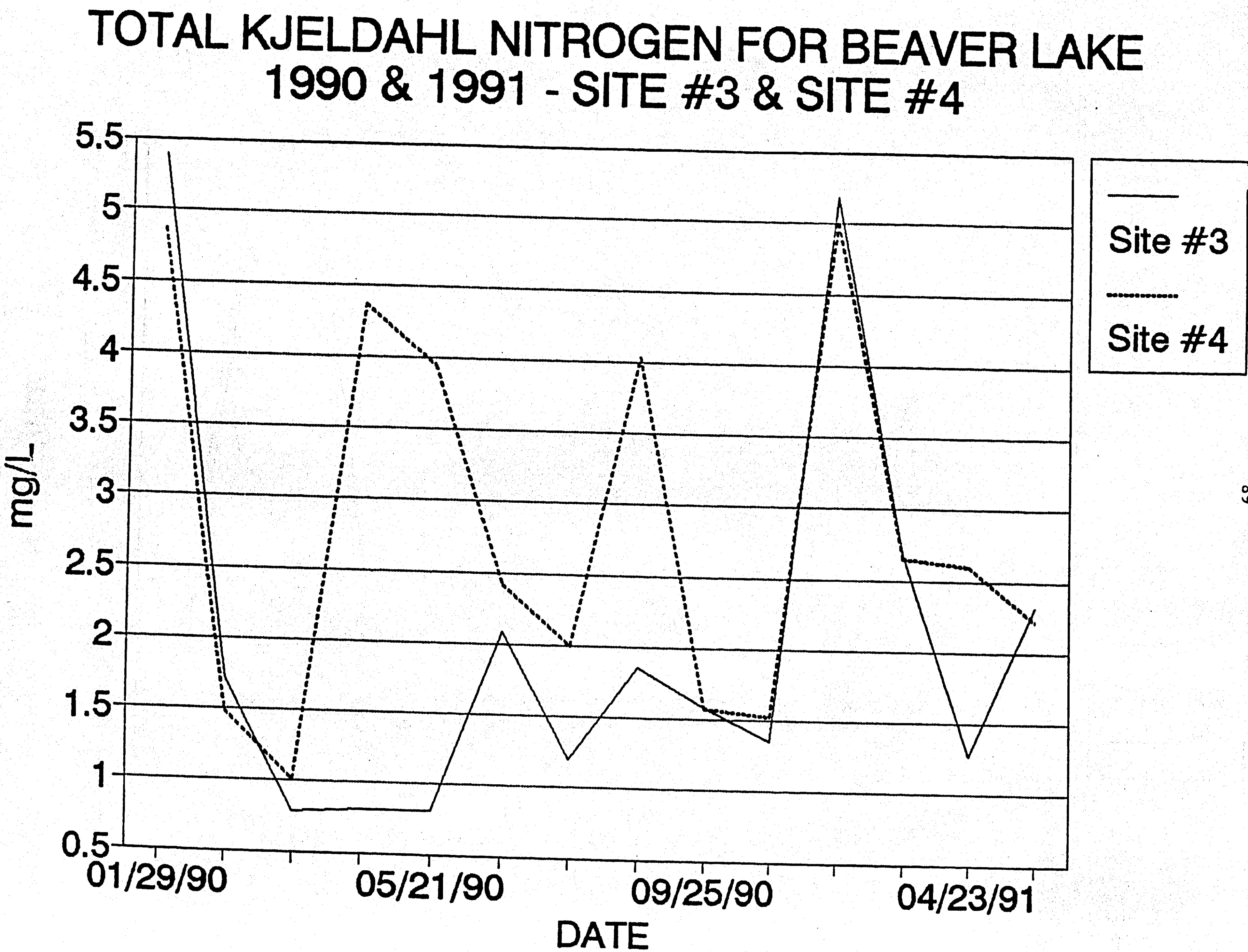

TOTAL SOLIDS FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4
4000
3500
3000
2500
2000
1500
1000
500
0
mg/L
01/29/90
05/21/90
09/25/90
04/23/91
DATE
Site #3
Site #4

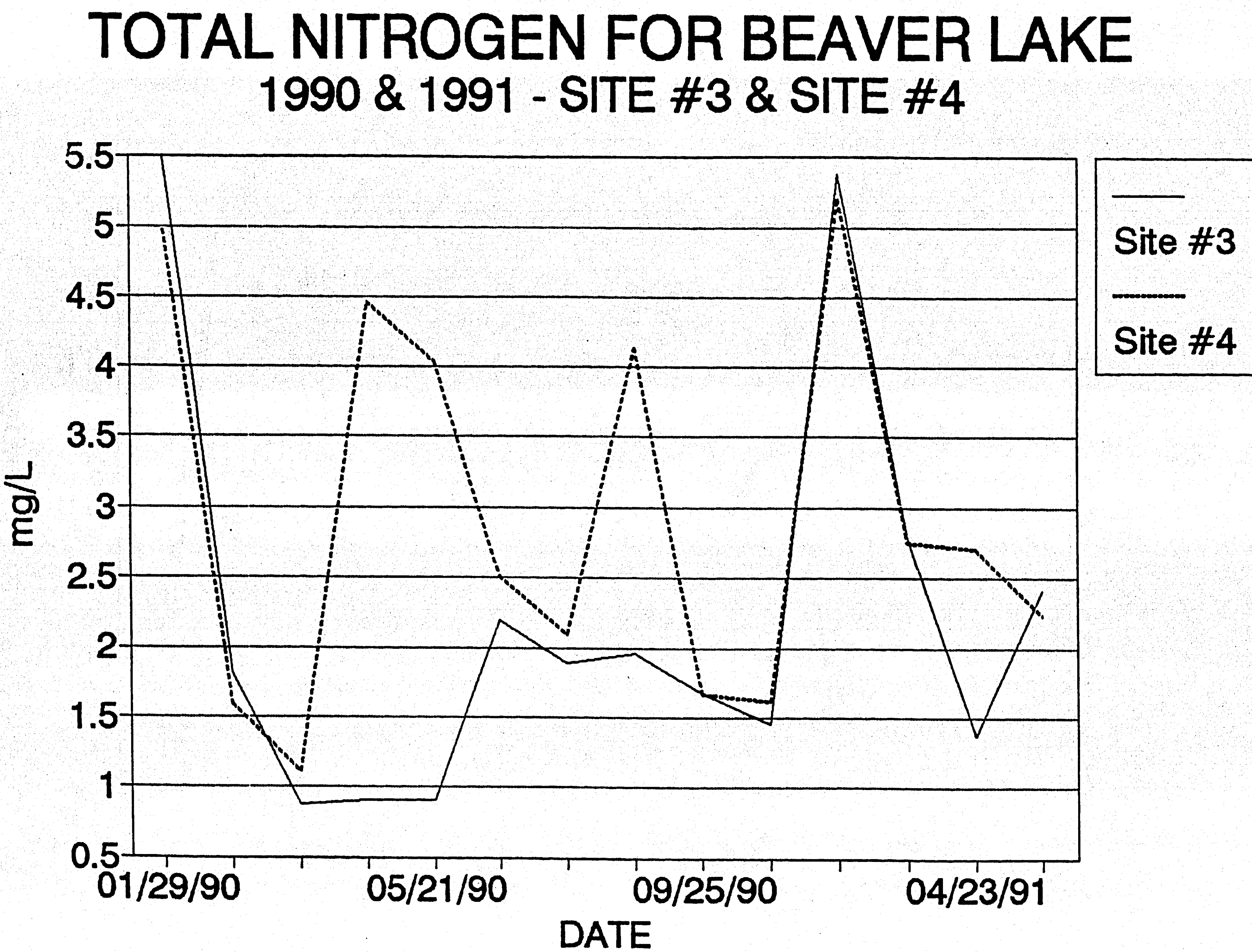

AMMONIA FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4
mg/L
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
01/29/90
05/21/90
09/25/90
04/23/91
DATE
Site #3
Site #4


UNIONIZED AMMONIA FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4
0.25
0.2
0.15
0.1
0.05
0
mg/L
STATE STANDARD FOR A SINGLE GRAB SAMPLE
STATE STANDARD FOR A 24-HOUR PERIOD
Site #3
Site #4
01/29/90
05/21/90
09/25/90
04/23/91
DATE

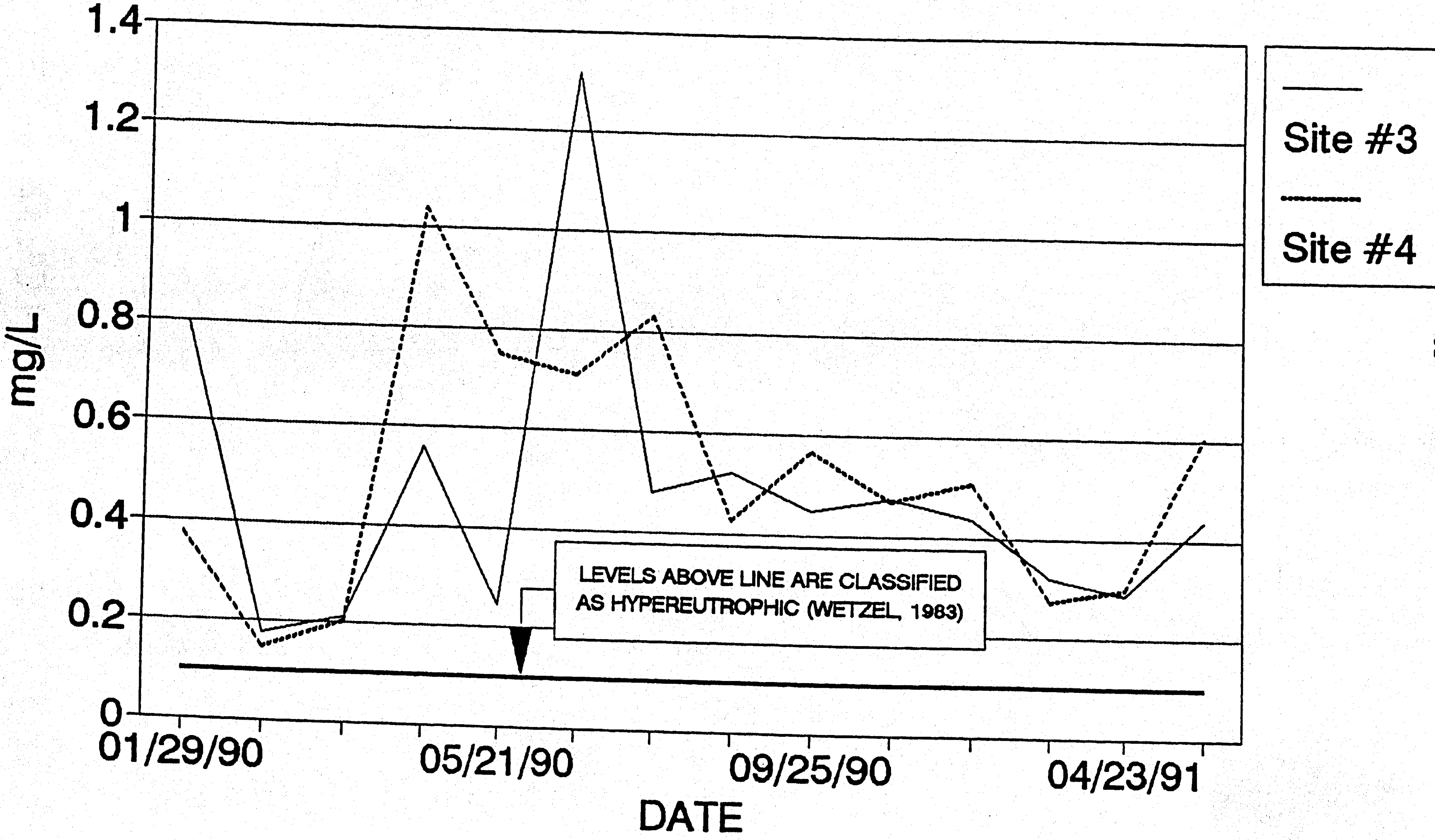
NO3 - NO2 FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4

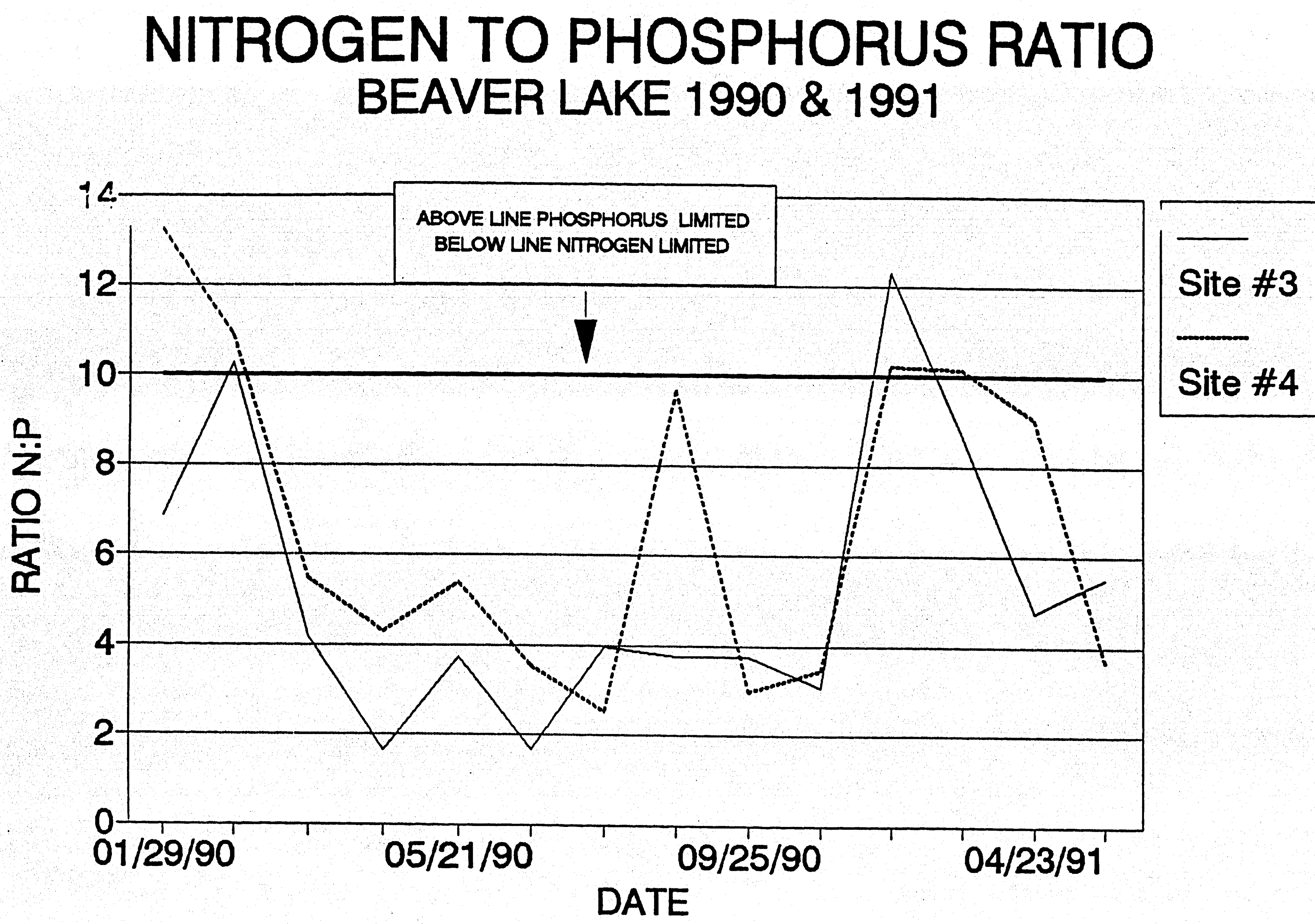



TOTAL KJELDAHL NITROGEN FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4
mg/L
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
01/29/90
05/21/90
09/25/90
04/23/91
DATE
Site #3
Site #4


TOTAL NITROGEN FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4
mg/L
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
01/29/90
05/21/90
09/25/90
04/23/91
DATE
Site #3
Site #4

TOTAL PHOSPHORUS FOR BEAVER LAKE
1990 & 1991 - SITE #3 & SITE #4





NITROGEN TO PHOSPHORUS RATIO
BEAVER LAKE 1990 & 1991
ABOVE LINE PHOSPHORUS LIMITED
BELOW LINE NITROGEN LIMITED
RATIO N:P
0
2
4
6
8
10
12
14
01/29/90
05/21/90
09/25/90
04/23/91
DATE
Site #3
Site #4

APPENDIX E. BEAVER LAKE DAM SUMMARY REPORT - 1989

SUMMARY REPORT ON BEAVER LAKE DAM

County: Yankton
Inventory No.: 690
Hazard Category: 3
Legal Location: NE 1/4 Sec. 34-T95N-R56W
Date of Inspection: June 7, 1989

Beaver Lake Dam is a category 3 dam whose failure may cause limited damage to agricultural lands or county and township roads or minimum economic loss.

Beaver Lake Dam is located on land which is owned by the Department of Game, Fish and Parks. It has a maximum storage capacity of 450 acre-feet with a pool elevation at the top of the dam.

The upstream slope has both an inadequate grass cover and riprap protection. Due to the lack of protection, wave erosion exists along the entire length of the slope. It appears that additional riprap has been placed along the slope but more riprap is still needed. There are also a few small trees growing on the slope. The downstream slope also has inadequate grass cover and some surface erosion due to cattle grazing on the slope. The graveled crest and abutment contacts appeared in good condition.

The concrete primary spillway structure has areas of cracking, scaling, erosion, and exposed reinforcement around the bridge supports. The joints have some offsets and loss of joint material. The spillway slab is slightly undercut and several trees are growing adjacent to the spillway structure. The spillway approach and discharge channels are in good condition.

Recommended Repairs and Maintenance:

1. Trees and brush on the embankment pose a hazard due to the possibility of seepage along decayed root systems. The trees, brush and root systems of the larger trees should be removed and the holes backfilled with impervious material.

2. Erosion on both the upstream and downstream slopes should be repaired and steps taken to prevent further erosion. Adequate riprap protection should be placed on the upstream slope and grass cover established on both the upstream and downstream slopes. Cattle grazing on the downstream slope should be restricted.

3. Repairs to the cracking, scaling, erosion, undercutting, missing joint material and displaced joints should be completed to correct existing deficiencies and prevent further deterioration of the primary spillway structure. Any trees next to the wingwall should be removed.

PHASE I
INSPECTION CHECKLIST

NAME OF DAM: Beaver
STATE:
COUNTY:
INVENTORY NO.:
HAZARD CATEGORY:
TYPE OF DAM:

OWNER: GF&P
DATE INSPECTED: 6/7/89
WEATHER: Sunny
TEMPERATURE: 85° F
POOL ELEVATION: 3' below spillway Crest
TAILWATER ELEVATION:

DIRECTIONS: Mark an "X" in the YES or NO column.
If an item does not apply, write "NA" in the REMARKS column.

ITEM	YES	NO	REMARKS
1. CREST.			
a. Any visual settlements?		X	Gravel Road
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE.			
a. Adequate grass cover?		X	
b. Any erosion?	X		Wave Erosion entire slope
c. Are trees growing on slope?	X		few
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?		X	But Better than Before
g. Any stone deterioration?		X	
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
3. DOWNSTREAM SLOPE.			
a. Adequate grass cover?		X	Grazing
b. Any erosion?	X		"
c. Are trees growing on slope?	X		D/S of Toe - few Near Spillway
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?			NA
i. Are the relief wells flowing?			
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
4. ABUTMENT CONTACTS.			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
5. INTAKE STRUCTURE.			
a. Do concrete surfaces show:			
(1) Spalling?			
(2) Cracking?			
(3) Erosion?			
(4) Scaling?			
(5) Exposed reinforcement?			
(6) Other?			
b. Do the joints show:			
(1) Displacement or offset?			
(2) Loss of joint material?			
(3) Leakage?			

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APPENDIX A

ITEM	YES	NO	REMARKS
c. Do the energy dissipators show:			
(1) Signs of deterioration?			
(2) Are they covered with debris?			
(3) Other?			
d. Is the spillway earth cut?		X	No Secondary
(1) Are slopes eroding?			
(2) Are slopes sloughing?			
(3) Other?			
e. Is the channel:			
(1) Eroding or backcutting?		X	
(2) Obstructed?		X	
f. Has released water:			
(1) Eroded the embankment?		X	
(2) Undercut the outlet?		X	Exposed
(3) Other?		X	
g. Is weir in good condition?	X		
h. Is control at the weir?	X		
9. GATES.			
a. Are the flood gates:			
(1) Broken or bent?			
(2) Corroded or rusted?			
(3) Periodically maintained?			
(4) Operational?			
*(5) Date last operated.			
b. Is there a low level gate?			
c. Is the low-level gate operational?			
10. RESERVOIR CONTROL.			
a. Recent upstream development?		X	
b. Slides in reservoir area?		X	
c. Change in reservoir operation?		X	
d. Large impoundment upstream?		X	
11. INSTRUMENTATION.			
a. List type(s) of instrumentation.			
b. In good condition?			
c. Read periodically?			
d. Is data available?			

Other comments:

This dam was inspected by: Tim Schaal
David Brown

ITEM	YES	NO	REMARKS
c. Metal appurtenances?			
(1) Corrosion present?			
(2) Breakage present?			
(3) Anchor system secure?			
6. CONDUIT.			
a. Is the conduit concrete?			
b. Do concrete surfaces show:			
(1) Spalling?			
(2) Cracking?			
(3) Erosion?			
(4) Scaling?			
(5) Exposed reinforcement?			
(6) Other?			
c. Do the joints show:			
(1) Displacement or offset?			
(2) Loss of joint material?			
(3) Leakage?			
d. Is the conduit metal?			
(1) Corrosion present?			
(2) Protective coatings adequate?			
(3) Is the conduit misaligned?			
7. STILLING BASIN.			
a. Do concrete surfaces show:			
(1) Spalling?			
(2) Cracking?			
(3) Erosion?			
(4) Scaling?			
(5) Other?			
(6) Exposed reinforcement?			
b. Do the joints show:			
(1) Displacement or offset?			
(2) Loss of joint material?			
(3) Leakage?			
c. Do the energy dissipators show:			
(1) Signs of deterioration?			
(2) Are they covered with debris?			
(3) Other?			
d. Is the channel:			
(1) Eroding or backcutting?			
(2) Sloughing?			
(3) Obstructed?			
e. Is released water:			
(1) Undercutting the outlet?			
(2) Eroding the embankment?			
8. SPILLWAY.			
a. Does spillway concrete show:			
(1) Spalling?		X	
(2) Cracking?	X		
(3) Erosion?	X		
(4) Scaling?	X		
(5) Other?		X	
(6) Exposed reinforcement?	X		Bridge Support
b. Do the joints show:			
(1) Displacement or offset?	X		
(2) Loss of joint material?	X		
(3) Leakage?		X	

ERRATA

1) Page 12, third to the last sentence of the paragraph on "<u>Fecal Coliform Bacteria</u>" the date July 17, 1991 should read **July 17, 1990.**

2) Page 17, the last three sentences of the first paragraph, should read, **"Considering a normal year when more water is entering the lake than seeping underneath the dam or evaporating, the AGNPS model estimates 25 acre-feet being captured in the lake basin. The resulting net input of sediment would be 4 inches per storm even. This aspect of the model can be supported when considering the life of Beaver Lake."** End of paragraph.

3) Page 22, second paragraph under "<u>RECOMMENDATIONS</u>" the third sentence should read "1) **permanent grass seeded on all fields with slopes greater than 9%,"**

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