Lake Herman Overview

Introduction

The purpose of the proposed Lake Herman Phase III Post Restoration Study was to determine the long term effectiveness of the restoration efforts on the water quality of Lake Herman and its' watershed. The primary goal of the Phase III was to quantify the reduction in loadings and change in water quality in the lake and watershed as a result of the Lake Herman model Implementation Project (MIP). The second goal of the Phase III is to assess the effectiveness of the Best Management Practices (BMP's) implemented in the Lake Herman watershed. The objectives for the proposed Lake Herman Phase III Post Implementation Study are as follows.

1. To determine the efficiency of the three sediment control structures on the southwest and south tributaries.
2. To quantify loads from the north tributary to emasure the effectiveness of agricultural BMP's constructed during the MIP.
3. Compare water quality data from the proposed study with the historical data to determine trends in tributary water quality.
4. To obtain information about the effectiveness of watershed BMP implementation for future lake restoration projects.

BACKGROUND INFORMATION

Lake Herman is a 546 hectare (1,350 acres) glacial lake that is located in Lake County, South Dakota. It is approximately 40 miles northwest of Sioux Falls (see Figure 1) and has a population of 270,159 persons located within a 65 mile radius (Stewart, 1994). It has a mean depth of 1.7 meters (5.6 feet), a maximum depth of 2.4 meters (8.0 feet), a volume of 9.159 x 10^6 cubic meters (7,425 acre-feet), and a mean hydraulic residence time of 3.3 years. It has a Watershed to Lake Area of 27 and no thermal stratification is exhibited during the year (Stewart, 1994).

The lake is at the head of a chain of four lakes. Silver Creek, the only outlet, is located on the northeast corner of the lake. It flows through the City of Madison, Lake Madison, Round, and Brant, respectively. The lake and its 43,000 acre watershed are in the western lake section of the Central Lowlands Province of South Dakota on the western side of the Prairie Coteau. The Prairie Coteau is a massive, hilly, lake dotted highland lying along the eastern border of the state and is drained by the Big Sioux River and its respective tributaries.

MODEL IMPLEMENTATION PROJECT OVERVIEW

In September, 1977, the U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (EPA) intiated a joint water quality/land management effort, the Model Implementation Program (MIP). This program was devised in order to demonstrate the effectiveness of concentrating and coordinating the various soil conservation and water quality management programs of the USDA and the EPA. Through this program areas were selected for implementation of land treatment measures to control nonpoint sources of pollution and to determine the effect these particular measures would have on the water quality. Lake Herman was selected for this project after an intensive screening process on January 13, 1978. After the selection process was completed a detailed work plan containing specific objectives, goals, and responsibilities for each organization and entity involved with the project was developed.

After intensive analysis of historical and present data was completed it was determined that the following methods would have the greatest impact on the water quaility and overall health of the lake:

Twelve Best Managment Practices were used in the Model Implementation Program. Permanent seedings, terraces, dugouts and other livestock watering facilities, windbreaks and shelterbelts, conservation and reduced tillage, rotation seedings, wildlife cover plantings, wildlife ponds, water impoundment reservoirs, sod waterways, animal waste control facilities, and seeding of critical areas. The most frequently applied BMP's were terraces, grassed waterways, conservation tillage, and windbreaks. Total cost of the BMP's implemented from 1978 through 1983 was $186,000 (see Appendix I for further breakdown of cost). Three sediment control structures were installed of which the first two were completed in June, 1980 and the third structure was finished in July, 1981. When the entire Lake Herman MIP was completed an estimated 87% of the watershed was treated with with some type of erosion control (Figure 2) due to efforts of the ASCS, SCS, LCCD, and MIP coordinator (Payne et al., 1986).

To assess the effects of the MIP on the water quality of Lake Herman and its tributaries, a monitoring program was conducted for the duration of the project (1977-1983). A reassessment of the sediment control structures #1 and #3s' effect on the water quality was conducted during 1984 (Hansen, 1986). These assessments, however, did not determine the long term effect of the BMP's and the sediment control structures on and any existing trends associated with the water quality of Lake Herman and its' watershed.

METHODS and MATERIALS

The Lake Herman Phase III Post Restoration Study was conducted during the 1992 - 1993 sampling seasons (March - October). Field collection was terminated in August, 1993. See Figure 3 for location of sites in the Lake Herman watershed.

Site Descriptions (Sediment Control Structures)

1. Sites fifty-four (54) and fifty-five (55), located upstream and downstream of sediment control structure number one, SE 1/4, Section 6-106-53, were used to determine the effectiveness of structure number one in controlling sediment and nutrient runoff from non-point sources. (Lake Herman Three Year Report 1978-1980). Site 54 -Latitude 43° 59' 16", Longitude 97° 12' 33.5"; Site 55-Latitude 43° 58' 58", Longitude 97° 11' 42".

2. Sites fifty-six (56) and fifty-seven (57), located upstream and downstream of sediment control structure number two, SE 1/4, Section 21-106-53, were used to determine the effectiveness of structure number two in controlling sediment and nutrient runoff from non-point sources. Site 56 - Latitude 43° 57' 49", Longitude 97° 12' 33"; site 57 - Latitude 43° 58' 10", Longitude 97° 11' 31".

3. Sites sixty-one (61) and sixty (60), located upstream and downstream of sediment control structure number three, SW 1/4, Section 23-106-53, were used to determine the effectiveness of structure number three in controlling sediment and nutrient runoff from non-point sources. Site 61 - Latitude 43° 57' 28", Longitude 97° 09' 32"; Site 60 - Latitude 43° 58' 03", Longitude 97° 09' 55".

Sites were located upstream and downstream from each sediment control structure. Current velocity (discharge) measurements and stage monitoring took place throughout the open water season which is considered March through October in 1992 and March through August in 1993 when the equipment was removed.

Stevens Recorders used to monitor the stage were replaced with Omnidata dataloggers during July of 1992 at sites 55, 57, and 60. After placement of the loggers occurred, the loggers at site 55 and 60 malfunctioned and two months of stage data was not recorded. In 1993 these loggers were replaced with the chart stevens recorders but during the flood of 1993 the stage recorder at site 57 was inundated for the entire month of July before the water had receded enough for a new stage recorder to be installed.

Missing data from site 55 (1992) was estimated by conducting a regression analysis (line of best fit) between data taken from site 54 (upstream) and site 55 (downstream) for the entire data set (1992 and 1993). After regression analysis (line of best fit) was conducted the best possible relationship that was developed was that found between Site 54 discharge and Site 55 stage data. Therefore, the missing stage data from site 55 was predicted using the site 54 discharge data. The relationship between these two variables was determined to be the line of best fit.

A strong correlation was also found to exist between the stage taken from site 1 (located downstream from dam #3 near the lake) and the discharge of site 60 (immediately downstream dam #3). Again a regression analysis was completed between these two sites and after the regression analysis was conducted it was determined that the stage from site 1 could be used to estimate the discharge from site 60.

Missing data due to the flood on site 57 during the month of July'93, was predicted by conducting a line of best fit analysis between the discharge from site 56 and the discharge from site 57. So the site 56 discharge was then used to predict what the missing data was during that period of time when site 57 was inundated with water.

In all cases the regression equation values (line of best fit) were compared with empirical or existing data and the estimates were in most cases lower than the original values. In using these prediction equations the water discharge estimates from the sediment control structures are in all probability lower than the actual discharge.

There is also the aspect of the missing data due to the overflow of the emergency spillways during the flood which were and could not be monitored. In certain cases as will be discussed the overall amounts of missing water (acre-feet) can be explained by using the maximum discharge from the emergency spillways taken from the dam specifications. See Appendix II for estimates of emergency spillway discharge from respective sediment control structures.

<u>Site Descriptions (Tributaries)</u>

Site 1 - Located on the south Tributary below sediment control structure # 3 on road culvert. Latitude 43°, 58', 17", longitude 97°, 10', 0", township 106N, range 53W, section 23, SW1/4, SE1/4, SW1/4, NW1/4.

Site 2 - Located on the southwest tributary above Camp Lakota, north side of road culvert. Latitude 43°, 58', 43", Longitude 97°, 11', 5", township 106N, range 53W, section 22, NE1/4, NE1/4, NW1/4, NW1/4.

Site 3A- Located on the tributary flowing into north Lake Herman from the west and through the golf course. Latitude 44°,00', 37", Longitude 97°, 10', 58", township 106N, range53W, section 3, SW1/4, SE1/4, NW1/4, SW1/4.

Site 3B- Located on the tributary flowing into Lake Herman from the north on the south side of the Highway 34 on the culvert. Latitude 44°, 00', 42", Longitude 97°, 10', 47", township 106N, range 53W, section 3, SW1/4, NE1/4, SE1/4, SE1/4.

Site 21- Outlet for Lake Herman located on Northeast section of lake. Latitude 43° 59' 58", Longitude 97° 9' 36", township 106N, range 53W, section 12, NW1/4, NE1/4, SW1/4.

The four tributaries were monitored from March 4 to October 27, 1992 and March 30 to August 24, 1993.

Tributary and outlet water samples were collected primarily on a runoff event basis. All tributary sites were sampled 3 times during the first week of snowmelt and once each following week until runoff ends. Samples were collected at each site daily during storm events. Field and laboratory physical and chemical parameters for tributary and outlet sites are listed in Table 2.

Table 1. Tributary Sampling Parameters

Temperature	Discharge/Flow
Dissolved Oxygen	pH
Total Alkalinity	Ammonia
Nitrate/Nitrite	Total Kjeldahl Nitrogen
Total Phosphorus	Total Dissolved Phosphor s
Total Solids	Fecal Coliform Bacteria
Total Suspended Solids	

EPA approved quality assurance and quality control guidelines wile followed for all samples collected. All laboratory analysis were conducted by EPA approved methods which are shown in Table 2.

Stage (ft) - Stage monitoring data was recorded using Stevens Stage Recorders or Omnidata data loggers.

Current Velocity (CFS) - Current velocity was taken using a portable Marsh/McBirney model 201 current velocity meter whenever watersamples were taken to gain the best possible estimate of discharge associated with the sample concentrations.

After the sampling year was completed the recorders were removed and a regression analysis (line of best fit) was conducted between the discharge data (dependent variable) and the stage data (independent variable). The line of best fit was then used to predict the daily discharge for the entire sampling year. The product of the predicted daily discharge and the daily concentration which was estimated using the average between two successive sampling dates of each parameter could be used to estimate the daily loadings to each sediment control structure and Lake Herman. The loadings were then summed for the entire year and divided by lake area (1350 acres) to produce total areal nutrient and sediment loadings to the lake from each tributary.

The outlet (site 21) samples were collected twice monthly from April through September and one monthly from October through March when flow was present.

Site 3A and 3B were initially one site when stage recorders were installed in March of 1992. During the year Lake Herman increased in volume backing water up in this area causing a ponding effect. On July 24, 1992 this site was then split into two sites and stage recorders were placed further upstream away from the ponding effect. Discharge measurements and watersamples were conducted in the same manner but the number of samples increased by one site.

Table 2. Analytical Methods for Physical and Chemical Parameters.

Parameter	Method	Reference
Temperature	Thermometric	APHA (1985)
Secchi Disk	Shaded Side of Boat	Lind (1985)
pH	pH probe	APHA (1985)
Dissolved Oxygen	YSI DO meter	EPA (1990)
Depth	Tape Measure	EPA (1990)
Fecal Coliform	Membraned Filter	APHA (1985)
Total Alkalinity	Potentiometric titration to pH of 4.5	APHA (1980) EPA (1983)
Total Solids	Evaporation	APHA (1980) EPA (1983)
Total Suspended Solids	Evaporation @ 180^{0}C	APHA (1980) EPA (1983)
Ammonia	Automated phenolate	APHA (1980) EPA (1983)
Nitrate/Nitrite	Automated Cadmium Reduction	APHA (1980)
Total Kjeldahl Nitrogen	Semi-Automated Block Block Digester AAII	EPA (1983)
Total Phosphorus	Persulfate digestion	EPA (1983)
Total Dissolved Phosphate	Filtered persulfate digestion	EPA (1983)

Concentrations Derived By Formula

Parameter	Formula
Total Dissolved Solids	= Total Solids - Suspended Solids

$$Un\text{-}Ionized\ Ammonia = \%(\frac{unionized\ ammonia}{100})\ X\ Ammonia\ Concentration$$

Where: $T = {}^oC + 273.2$

$$pKa = 0.09018 + \frac{2729.92}{T}$$

$$\% un\text{-}ionized = \left(\frac{100}{1 + antilog\ X\ (pKa - pH\ )}\right)$$

$$\% un\text{-}ionized = \left(\frac{100}{1 + antilog\ X\ (pKa - pH\ )}\right)$$

Organic Nitrogen = Total Kjeldahl Nitrogen - Ammonia Nitrogen

Total Nitrogen = Total Kjeldahl Nitrogen + Nitrate + Nitrite

Nitrogen to Phosphorus Ratio = Total Nitrogen - Total Phosphorus

<u>Carlson's Trophic Status Index Fromulas</u>

$$TSI\ Values\ for\ Chlorophyll\ a = 10\ X\ (6 - \frac{2.04(0.68\ X\ \ln Chla)}{\ln 2})$$

$$TSI\ Values\ for\ Secchi\ Disk = 10\ X\ (6 - \frac{\ln SD}{\ln 2})$$

$$TSI\ Values\ for\ Total\ Phosphorus = 10\ X\ (6 - \frac{\ln \frac{48}{TP}}{\ln 2})$$

Where: ln = Natural Log
SD = Secchi Depth in Meters
TP = Total Phosphorus in parts per billion
Chl-a = Chlorophyll a in milligrams per cubic meter

Site 1 did have some ponding in the south side of the lake. However, measurements were taken approximately 20-30 meters upstream away from the lake to gain better estimates of discharge. Measurements had to be taken at the culverts later on in the year due to flooding in this area which made it impossible for field personnel to gain access to this area.

All measurements and methods used during the investigation on this part of the watershed are similar to those procedures conducted on the sediment control structures. All parameters are the same except for that of Chlorophyll-a which was taken only on in-lake samples.

Vollenwieder discussed in following sections was used to aid in the delineation of phosphorus and nitrogen total areal loading rates. The Vollenwieder method was used during this Phase-III investigation as a result of the already completed calculations for Lake Herman preceding and during the Model Implementation Project (1979-1983). In this investigation it is simply used as a mechanism for comparison for the 12 year old data.

Most of the tributaries were monitored for short periods of time during the MIP project and data is somewhat limited. However, yearly means as well as total areal loading rates will be used in the comparison to show any differences that may have occurred since the installation of the Model Implementation Project.

Site Descriptions (In-Lake)

Two in-lake sampling sites were selected for this phase III post implementation study, and the descriptions are as follows:

Site 6A - In-Lake mean depth for 1992 - 1993 was 2.76 meters (range 2.286 to 3.5052 meters).
Latitude: 43° 59' 49" N
Longitude: 97° 10' 20"

Site 6B - In-lake bottom of site 6A - same as 6A sampled approximately 0.3048 meters (1 foot) from bottom
Latitude: 43° 59' 49" N
Longitude: 97° 10' 20"

Site 7 - In-lake site in south bay - Mean depth for this site during project (March 92 through September 93) was 0.4875 meters (1.6 feet), ranging from a minimum depth of 0.5 to a maximum depth of 3.5.
Latitude: 43° 58' 49"
Longitude: 97° 10' 0"

In the comparison of water quality data between pre, during, and post-MIP schedules there were actually three overall sites involved in the investigation in-lake during 1977-1983. However, due to financial constraints it was necessary to downgrade the number of sites to two inlake sites during this particular investigation (Figure 3).

The in-lake sampling schedule during the months of April through September were twice monthly and from October through March, if possible, one sample per month. The entire duration of the project was from March-1992 to September-1993 when the final in-lake sample was taken.

The following in-lake parameters were taken and analyzed for the phase III project:

Table 3. In-lake Sampling Parameters

Chlorophyll-a	Temperature
Secchi Depth	Total Depth
Dissolved Oxygen	pH
Total Alkalinity	Ammonia
Nitrate + Nitrite	Total Kjeldahl Nitrogen
Total Phosphorus	Total Dissolved Phosphorus
Total Solids	Total Suspended Solids
Fecal Coliform Bacteria	

pH - A portable pH meter was used to measure pH routinely

Dissolved Oxygen - Dissolved oxygen was measured with portable meter (Yellow Springs Model 51B). The meter was recalibrated at every site when samples were taken using the elevation percentage method.

Water Depth - This parameter was measured using a rope marked in foot increments.

Temperature - Water temperature was determined using the temperature probe on the portable dissolved oxygen meter (YSI 51B).

Water samples were secured using a Van-Dorn sampling device by taking surface samples approximately .5 meters below the surface and bottom samples approximately .5 meters above the surface of the sediments. There were no bottom samples taken from in-lake site 7 due to lack of depth. Both surface and bottom in-lake samples were taken at site 6. Those taken from site 7 were all surface samples due to the shallow depth. All water quality samples were iced and transported to the South Dakota State Health laboratory (Pierre, SD) for analysis.

Chlorophyll a - 100 milliliters (ml) of water taken from each surface sample during May through September was filtered using a glass fiber filter (0.45 micron aperture size). It was then wrapped in tinfoil, placed on ice to be analyzed later in the lab.

Surface visual observations which may have had possible consequences relative to the chemical parameters (Tables 1 and 3) were also recorded by field personnel and included the following but were not limited to:

Precipitation	Dead Fish	Cattle
Surface water film	Odor	Turbidity
Septic Conditions	Water Color	Algal Blooms
Waterfowl		

Field collection of all samples and associated dicharge and stage measurements as well as the Agricultural Nonpoint Source (AGNPS) data were conducted by the Lake County Soil Conservation Service (SCS).

Table 4. Number of samples including Quality Assurance/Quality Control samples taken from each site during the period of March - October, 1992 and March - August, 1993.

Site	Number of Samples
1	22
2	22
3*	6
3A	16
3B	17
6A	23
6B	22
7	21
21	21
54	21
55	21
56	21
57	21
60	21
61	22
QA/QC	14
Total	311

* - Sampled dates ranged from March through July 24, 1992

Sediment Control Structures

During the Lake Herman Model Implementation project (MIP), a series of land treatment measures were implemented into the Lake Herman watershed to deter the overall sediment yield and control non-point sources of pollution originating in the watershed and to determine the overall effectiveness of such measures on the water quality of the watershed and the lake.

After reviewing several alternatives, agencies involved with project determined that the most effective method for treating the sediment/nutrient loading problems to Lake Herman was the construction of three drawdown type sediment control sturctures and the application of best management practices (BMPs) in the drainage area. Preliminary designs and surveys and best possible locations were completed for the control structures at the end of 1978 based on monitoring data (Lake Herman Three Year Report). The specifications for all three structures can be found in Appendix II. Referring to Figure 3 the three sediment control structures relative to the Lake Herman watershed can be located.

Operational Procedures

All sediment control structures were opened during the winter of 1991. The basic operational procedures in 1992 (Appendix II) are best summarized as during a rainfall event the dams would be closed. A settling period of 72 hours would take place and then the top valves from structures #1 and 2 and the single valve on #3 would be opened. Another settling period of 72 hours would expire and then the bottom valves on #1 and 2 would be opened. A rainfall event would take place and the scenario where the valves were closed etc. would take place throughout 1992 until September 9, 1992 when the dams were left open for the fall and winter season.

In 1993 operational procedures were changed where the top valve remained open at all times and the bottom one closed until a 24 hour period had elasped following the runoff event on control structures #1 and 2. The single valve on #3 was to be operated as the bottom valve on #1 and 2 where a 24 hour period should have elasped following a runoff event before the valve was opened.
During most of the 1993 year the valves remained open due to the excessive flooding. A summary of when the valves were opened and closed during 1992 is given on Table 6 on the following page.

Sediment Control Structure (SCS) #1

This control structure was completed on June 20, 1980. It is also the second largest control structure with a total drainage area of approximately 626.87 hectares (1549 acres)(Appendix II). The total cost of structures #1 and #2 together was $137,461.42 at the time of completion.

Water quality results for the sediment control structures can be found in Appendix II. Site 54 was the monitoring site upstream of

Table 6. Dates on which sediment control structures were opened and closed during 1992.

Date	Opened or Closed	Dam Number	Valve # Opened or Closed
4/07/92	Closed	1, 2, 3	
4/10/92	Opened	1	All
4/30/92	Closed	1	
5/10/92	Opened	1, 2, 3	All
5/30/92	Closed	1, 2, 3	
7/16/92	Opened	1, 2	Top
7/16/92	Opened	3	
7/19/92	Opened	1, 2	Bot
7/21/92	Closed	1, 2, 3	All
7/28/92	Opened	1, 2, 3	All
7/30/92	Closed	1, 2, 3	All
8/03/92	Opened	1, 2, 3	Top
8/06/92	Opened	1 & 2	Bot
8/07/92*			
8/08/92	Closed	3	All
8/09/92	Closed	2	All
8/18/92	Opened	1, 2, 3	Top
8/19/92	Opened	1 & 2	Bot
8/24/92	Closed	1, 2, 3	All
8/27/92	Opened	1, 2, 3	Top
8/28/92	Opened	1 & 2	Bot
9/01/92	Closed	1, 2, 3	All
9/09/92**	Opened	1, 2, 3	All

* - 4 inch rain in which access to the dams to close valves was not possible.

** - Valves remained opened for the entire winter season.

Table 7. Mean concentrations for selected parameters upstream (site 54) vs. downstream (site 55) from 1980,82,83,92, and 1993.

Parameter	Year	Site⇒ 54	55
Total Phosphorus	1980	0.61	0.46
(mg/L)	1982	0.61	0.23
	1983	0.25	0.15
	1992	0.227	0.385
	1993	0.187	0.156
Total Dissolved Phosphorus	1992	0.219	0.245
(mg/L)	1993	0.213	0.138
Organic Nitrogen	1980	2.65	2.60
(mg/L)	1982	1.15	1.00
	1983	1.02	0.44
	1992	0.955	1.194
	1993	1.283	1.393
Total Nitrogen*	1980*	3.44	3.69
(mg/L)	1982*	1.32	1.16
	1983*	2.08	1.03
	1992	1.253	1.410
	1993	2.071	1.697
Total Solids	1980	1365	1488
(mg/L)	1982	591	453
	1983	685	1088
	1992	1853	1631
	1993	1860	1932
Suspended Solids	1980	20	19
(mg/L)	1982	5	8
	1983	27	9
	1992	6	6
	1993	8	16
Dissolved Solids	1980	1347	1469
(mg/L)	1982	587	446
	1983	642	1082
	1992	1847	1625
	1993	1852	1916

* - the sum of inorganic and organic nitrogen means due to lack of raw data.

the sediment control structure and site 55 was the sampling site located downstream of the control structure (Figure 3).

Suspended Solid (sediment) Concentrations

The data available for analysis shows the inconsistency of the sediment control structure at reducing suspended solids and associated nutrients. Figures 4 through 8 show the overall water quality concentrations upstream and downstream of the structure for phosphorus, nitrogen, and suspended solids which give further evidence with Table 7 indicating that the trapping efficiency of these structures for sediment is not as efficient as previously thought.

Suspended solid (sediment) mean concentrations were unchanged between above and below sampling sites in 1992 compared to slightly **higher** below the structure to above in 1993. There may be some overlying variables which might explain these differences such as wind and wave action within the sediment structures retention basin as well as soil type. During the 72-hour operating procedure in 1992, site 54 and site 55 did not show any dramatic differences (reduction) as water drained through the structure as is shown on Table 7 and Figure 4. The water samples taken on April 27, 1992 show a 57% reduction in suspended solid concentrations. This essentially means the water that was sampled upstream (site 54) exhibited a reduction in sediment concentration when comparing site 54 to site 55 (downstream). Seven samples or 87.5% of the total samples (n=8) taken during the 1992 sampling season either exhibited no change or a reduction in the concentration levels (mg/L). In one sample, the concentration taken from site 55 (downstream) increased which may be explained by the fact that the site 54 sample was taken on August 10 and the sample downstream was taken on August 18, 1992. A valid comparison cannot be made due to this 8 day gap in sampling dates.

A total of 26 suspended solid (sediment) samples were taken from sediment control structure #1 during 1993. 13 were taken above the control structure (site 54) and 13 were taken below (site 55). Samples for both sites were usually taken on the same day with a few hours difference between sampling times. 54% of the 1993 sediment samples exhibited an increase in sediment concentration (milligrams/liter) between monitoring sites upstream and downstream of the control structure. 38% of the total samples either showed a reduction or no change in concentration (n=13) between the two sites. A maximum value of 144 mg/L occurred after an extreme rainfall event occurred and may be a result of the force of the incoming water. This force may have caused the already settled material in the basin to become suspended in the retention basin. The suspended material was then sampled as it was discharged from the control structure pipe downstream.

Mean suspended solid (sediment) concentrations taken from 1980-1982 (Table 7) show that dam #1 exhibited an overall positive reduction for 2 of the three years in which samples were taken. The least effective and/or the largest negative impact that occurred during the monitoring years of 1980-1982 and 1992-1993 was 1993. Incidentally this is also the only year in which the 24 hour operating procedure was used. The historical data indicates this structure has shown no significant trend in reduction in suspended sediment as water passes through the retention basin. The inconsistent nature is primarily due to the flucutuating environmental conditions that occur from year to year (precipitation). Throughout the documented history of structure #1 higher concentrations have been observed both upstream and downstream of the structure when samples were taken at both sites (Hansen, 1986). Clay particles occur in a higher percentage of the soils in the southern part of the watershed and the inconsistency of the dams at reducing suspended solid concentrations may be a direct result (AGNPS, 1994) of the clay soils.

Total Phosphorus Concentrations

Total phosphorus concentrations were highly variable during the 1992 set of data as compared to the 1993 data. The similar trends in concentration between samples taken upstream and downstream of structure #1 in 1993 is probably due to the constant flow into and out of the dam. Figure 5 shows the variation which occurred during 1992 as well as the insignificant difference between upstream (site 54) and downstream (site 55) for total phosphorus during 1993. The difference in means between site 54 and 55 during 1992 may be skewed as a result of a first flush situation in the subwatershed of the dam which was not closed until 4/7/92 (Table 6). This first flush phenomenon may have resulted in the increasing phosphorus concentrations. The other spikes that occurred downstream in the latter part of 1992 might have been due to excessive animal waste inputs (fecal coliform = 600 per 100 ml) on August 18, 1992. The dissolved oxygen value of 3.2 mg/L occurred on this date as well as an increase in suspended solids (Figure 4).

Table 7 shows the differences between annual means upstream and downstream of the structure. In all years the phosphorus means are lower downstream of structure #1. This may be due in part to the settling of some suspended solids. Phosphorus which does sorb to clay particles would have been reduced as well. Vegetation in and around the basin pool may have also removed some of the available phosphorus. However, increased concentrations would be observed during a first flush such as that described above. Decaying vegetation in the fall and early spring would have released the assimilated phosphorus and nitrogen.

Nitrogen

Nitrogen was not consistently removed from the water column as was phosphorus. Means from Table 7 show the inconsistency throughout the years in which monitoring took place. Spikes or increased concentrations (milligrams/liter) that did occur such as the sample taken on June 16, 1993 (Figure 7) were probably a result of fertilizer application preceding a runoff event which then caused the high observation to occur. In most cases throughout the sampling year the NO_3-NO_2 (nitrate+nitrite) complex ranged from 7 to 43% of the total nitrogen. However, on June 16, 1993 the nitrate+nitrite complex made up 70% of the total nitrogen. On this same date there was an observation for fecal coliforms of 36,000 per 100 mL along with a very low dissolved oxygen concentration of 2.8 mg/L. A feedlot was not recorded in this area of the watershed so this may be a result of cattle grazing upstream at or around the same date the sample was taken. A similar spike did not occur downstream of structure #1 (site 55) during the same sampling day. Incidentally the suspended solid or sediment maximum value also occurred on this date which may have also been due to the grazing cattle.

SCS#1 Loadings

A hydrologic budget was completed for this structure with the emphasis being placed on the total suspended solids (sediment), total nitrogen, and total phosphorus. Loadings for all parameters can be found in Appendix II. Table 8 shows the overall trapping efficiencies for sediment control structure #1. Although the trapping efficiencies can be explained by the overall reduction of water this still resulted in the overall removal of total suspended solids, phosphorus, and nitrogen from the total load entering the lake.

Loading data from 1993 shows a decrease with all parameters as well. This again can be explained by the reduction of water. However, during the July 4th flooding event the emergency spillway discharged a significant amount of water which was not measured. The maximum discharge from the emergency spillway during a 4.5 inch rainfall event was estimated to be 193 cubic feet per second (cfs) (see specifications in Appendix II). Overflow from the emergency spillway continued for 4.5 days (Goodale, personal communication). Using the maximum discharge of 193 cfs for the entire 4.5 days, the total discharge from the control structure would be 1,723 acre-feet during this 4.5 day period. The total discharge from site 55 (1,723+1,479=3,202 acre-feet) would then increase by 216.5%. However, there would still be a reduction in the amount of water. Table 8 shows a 69.6% reduction in the amount of water. This number would drop 34.3% as a result of additional 1,723 acre-feet indicating a reduction still occurred for the amount of water entering the retention structure. A reduction in the trapping efficiencies would then take place as a direct result of this increase in the amount of water discharged from structure #1.

These loading numbers from 1992 and 1993 would seem to indicate that as the amount of water increases the overall efficiency decreases. This behavior was also indicated by the Agricultural NonPoint Source computer model (AGNPS) which will be discussed later in the report. However, with the amounts of water and the temporal (time) variation that occurred there is

Table 8. Nutrient and sediment total loads to and from sediment control structure #1, March 4 to October 27, 1992 and March 30 to August 23, 1993.

Total Load (Kg/yr)

Site	Total Water (acre-feet)	Total Phosphorus	Total Nitrogen	Total Suspended Solids
1992				
54 (above)	233	98	422	1366
55 (below)	53	39	132	850
% Trapping Efficiency	180(77%)*	59(60%)	48(69%)	516(38%)
1993#				
54 (above)	4872	1793	15451	131808
55 (below)	1479	441	3094	93155
% Trapping Efficiency	3393 (69.6%)	1352 (75.4%)	12357 (80%)	38653 (29.3%)

- Downstream Loadings would increase due to 93 flood emergency spillway discharge.

* - (180/233)*100 = 77% trapping efficiency

insufficient data to determine which particular method is more efficient at removing the nutrients and sediment from the water column based on the loading data. Obviously, this particular structure does have an effect at reducing sediments and in certain cases nutrients. However, the loading data is marginal in providing information as to which method is more conducive to retaining suspended solids. The water quality data that was previously discussed suggests that the 72-hour operating procedure is slightly more effective at reducing concentrations of suspended solids (sediment) than the 24-hour period for this particular structure based on the data collected in 1992 and 1993.

A sediment survey was also completed for this structure during the 1993 by the Soil Conservation Service. The survey results indicated that there was approximately 3,388 cubic yards (2,823 tons) of sediment retained during the 13 years that the structure has been in place. Taking the average whereby 2823 tons/13 years = 217 there has been approximately 217 tons of sediment per year retained by this particular sediment control structure.

Sediment Control Structure (SCS) #2

Sediment control structure #2 is the smallest structure in terms of drainage area and it was completed on June 20, 1980 as was previously discussed. It drains an area of approximately 445.6 hectares (1,101 acres). See Sppendix II for specifications.

Water quality results for all parameters can be found in Appendix II. Graphs showing the overall trends from total phosphorus, nitrate/nitrite nitrogen, total nitrogen, and total suspended solids are shown on the following pages. Table 9 shows the annual means upstream (site 56) and downstream (site 57) through several years of data collection during and after the construction of the dams.

Total Suspended Solids

Total suspended solids usually consist of the colloidal particles which consist primarily of clay, silt-clay complex (Manahan, 1990). Mean levels (Table 9) exhibited a decrease in a general trend for suspended solids since dam #2 was installed. 1980 means are 2 or 3 times higher than the yearly means following 1980 (1982-83, 1992-93). However, yearly means downstream of the sediment control structure are higher than those upstream of the structure. This is also exhibited throughout the 1992 and 1993 data (Figure 9). In most instances suspended solid concentrations are higher downstream (site 57) than upstream (site 56).

In 1992 50% of the samples exhibited no change or actually increased in concentrations when sampled upstream and downstream of the dam. 77% of the suspended solid samples taken in 1993 exhibited no change or increased. This seems to suggest that at least sediment control structure number **1** is more effective than number **2** at removing suspended solids. The mean concentrations

Table 9. Mean concentrations for selected parameters upstream (site 56) vs. downstream (site 57) from 1980,82,83,92, and 1993.

Parameter	Year Site→	56	57
Total Phosphorus	1980	0.68	0.77
(mg/L)	1982	0.98	0.38
	1983	0.34	0.33
	1992	0.283	0.274
	1993	0.451	0.257
Total Dissolved Phosphorus	1992	0.195	0.204
(mg/L)	1993	0.540	0.248
Organic Nitrogen	1980	3.08	2.00
(mg/L)	1982	2.00	1.85
	1983	1.42	1.28
	1992	1.184	1.149
	1993	1.443	1.253
Total Nitrogen*	1980*	4.03	3.75
(mg/L)	1982*	2.23	3.59
	1983*	3.12	2.61
	1992	1.669	1.519
	1993	1.701	1.659
Total Solids*	1980*	1111	2048
(mg/L)	1982*	151	146
	1983*	566	519
	1992	989	1293
	1993	1054	1174
Suspended Solids	1980	52	169
(mg/L)	1982	12	21
	1983	20	17
	1992	8	8
	1993	5	14
Dissolved Solids	1980	1059	1879
(mg/L)	1982	139	125
	1983	546	502
	1992	981	1285
	1993	1049	1160

* - the sum of inorganic and organic nitrogen yearly means due to lack of raw data.
the sum of suspended and dissolved solid yearly means due to lack of raw data.

from Table 9 also show that this particular structure does not have as great an efficiency of removing the suspended solids as compared to structure number 1 (Table 7).

A significant amount of the suspended material may be of a flocculant (clay, silt-clay complex) nature in which a longer time period would be needed to significantly reduce a larger percentage of the sediment.

There were no samples in which fixed and residual solids (inorganic or organic) were determined and there is no other avenue in which one may determine how much of the suspended solids are organic and inorganic. However, there may be more organic material in the 1992 data due to the land operators ability to gain access to the fields whereas in 1993 a larger portion of the organic material may have been reduced due to the flooding. This may explain why the suspended solid (sediment) concentrations were higher in 1992 as opposed to 1993. Also as the 1993 year progresses there is a gradual increase in concentrations which may be explained by the increasing severity of the flooding events. The flooding in late June of 1993 can explain the maximum value of 100 mg/L taken downstream of the structure (site 57). Even with the flooding, however, the yearly mean of 14 mg/L is still considerably lower than those values taken in the early 80's (Table 9). As total phosphorus and soluble reactive phosphorus levels increase as the 1993 year progresses algae and vegetation may assimilate or take up some of the available phosphorus. Even though there is less phosphorus occurring downstream of the sediment control structure the vegetation and algal growth as a result of some of the available phosphorus may have also influenced the suspended solid concentrations. As previously mentioned, spikes of phosphorus and nitrogen may occur in the spring as a result of the degraded vegetation.

Total Phosphorus

Total phosphorus annual means on Table 9 show a gradual decline in phosphorus from this portion of the watershed which is similar to those results from sediment control structure #1. The maximum annual mean that occurred upstream of the dam was 0.98 mg/L in 1982 and downstream was 0.77 mg/L in 1980. There has been a gradual decline in the phosphorus concentrations (mg/L) although there were a number of high concentration levels that occurred during the Phase-III study (Figure 2-7). In fact the maximum value observed for both the upstream and downstream sites was taken upstream (site 56) with a value of 0.943 mg/L on June 8, 1993. Dam #2 did not exhibit any consistent reduction in phosphorus during 1992. Water was sampled when flows were minute or nonexistent and this may have increased the amount of phosphorus in the water column as a result of dead or decaying vegetation in this area. The suspended solids and total phosphorus concentrations were not directly related through any of the years in which sampling took place.

Dam #2 is similar to dam #1 in that dam #1 phosphorus concentrations increased as the flows increased. It also seemed to become more efficient at removing phosphorus as flows increased in contrast to suspended solid concentrations. This may have been due to the increased amounts of sediment contained within the water column. The phosphorus attached to the sediment was probably settled out before the water was allowed to move out of the basin. The dam was fairly consistent throughout 1993 in removing phosphorus. As explained previously the amount of nonpoint source materials increases with increasing flows so material entering the dam would settle out before the water would pass through the structure due to the retention period. However, phosphorus attached to colloidal material are not readily settleable and are very difficult to remove as was previously discussed. In fact phosphorus is usually removed in a wastewater treatment facility by coagulation-flocculation processes (Manahan, 1990).

<u>Total Nitrogen</u>

Control structure #2 did not produce any significant trends as far as reducing nitrogen. Mean nitrogen concentrations and all sample observations for 1992-1993 can be found on Table 9, Figures 12 and 13. Nitrogen is much more soluble than phosphorus and is much more available for use by plants. A wastewater treatment facility would denitrify wastewater by using bacteria to take up ammonia by converting the ammonia to nitrogen gas (N_2). The only trend apparent from the data is that yearly means have decreased since the early 80's (Table 9) where maximum annual means for total and organic nitrogen occurred in 1980 and minimum means occurred in 1992 and 1993 even though there were increasing amounts of water observed in 1993.

<u>SCS #2 Loadings</u>

Table 10 shows the nitrogen, phosphorus, and total suspended solid loadings for 1992 and 1993 in kilograms per years. Loadings for all the parameters are located in Appendix II.

Loading calculations are a product of the discharge rates and sample concentrations. In 1992 there is a considerable gap (443 acre-feet) in the amount of water entering the structure #2 (site 56) which is less than that leaving the structure (site 57) (Table 10). In Appendix II a map associated with the specifications for dam #2 indicates that there is a considerable amount of drainage area upstream of structure #2 which was not monitored. This area may have produced the resulting downstream increase of water. As a result of the increased amount of water recorded downstream of dam #2 a negative trapping efficiency would result. This number causes an increase in the amount of loadings discharged from the

Table 10. Nutrient and sediment total loads to and from sediment control structure #2, March 4 to October 27, 1992 and March 30 to August 23, 1993.

Total Load (Kg/yr)

1992 Site	Total Water (acre-feet)	Total Phosphorus	Total Nitrogen	Total Suspended Solids
56 (above)	178	70	286	3181
57 (below)	621	239	919	4645
% Trapping Efficiency#	443(249%)	169(241%)	633(221%)	1464(46%)#
1993				
56 (above)	6291	4967	10935	43876
57 (below)	4372	2072	7690	137944
% Trapping Efficiency	1919(31%)	2895(58%)	3245(30%)	94068(214%)*

- increase in total phosphorus, total nitrogen and suspended solid loadings
* - increase in total suspended solid loadings

dam reducing the associated trapping efficiency of the dam.

1993 loading calculations are completely different as a result of the excessive amounts of precipitation that occurred. Again, as happened with control structure #1, there was 18 days in which theemergency spillway discharged. If this dam ran with the maximum discharge during the entire 18 days a total of 732 acre-feet would be discharged from the spillway. Obviously there would still be a positive trapping efficiency for both the nutrient loadings. However, the amount of total suspended solids (sediment) discharged from structure would increase resulting in a lower trapping efficiency for the loadings. The amount of suspended solids gained from the control structure is 94,068 Kilograms (103 tons) of material. A considerable amount of this material may have been inorganic which was explained previously.

A sediment survey was to be completed on this structure but due to the inclement weather was postponed until the 1994 field season. This will be conducted by SCS personnel.

Sediment Control Structure (SCS) #3

This sediment control structure was completed in July of 1981 for total cost of $222,568.87 (bid in July of 1980) (Payne et al., 1986). It is the largest of the three structures in the Lake Herman watershed. The drainage area includes 6,937.6 acres (10.84 sq.mi.) (see Appendix II for dam specifications). It has a total sediment capacity of 31 acre feet and during a 4.5 inch rainfall event the emergency spillway would discharge upto 1,365 CFS.

Total Suspended Solids (Sediment)

In all samples which were taken upstream and downstream on the same day in 1992 (Figure 14) many resulted in a larger concentrations of sediment occurring downstream of structure #3. In 1993 61% of the sample concentrations were higher downstream than upstream (site 61). A larger gap between the two sites occurred in the latter part of 1993. A major spike for suspended solids occurred on June 30, 1993 as a result of the intense rainfall event. Organic matter may also have resulted in the overall increase in concentration levels at the sampling site downstream of the dam. From Table 11 suspended solid concentration annual means have not changed dramatically in all years that have been sampled in comparison to the annual means taken from control structure # 1. There has been a slight decrease in suspended solids (sediment) but the total dissolved solids have increased over time. Dissolved solids usually consist of inorganic salts and other dissolved inorganic or organic material. The sampling for this particular area may have also biased the results where sampling took place downstream of the stilling basin. The water discharged from the pipe into the basin moves downstream approxmately 30-40 yards where sampling took place. The force of the water discharged the pipe may have caused resuspension of organic and inorganic material resulting in higher concentrations of sediment downstream. This phenomenon of higher concentrations of suspended solids downstream of the structure was exhibited by all three sediment control structures at one point or another throughout the course of the investigation. These values may bias the loadings as well where increases in concentrations will increase the loadings to Lake Herman. The suspended solid

Table 11. Mean concentrations for selected parameters upstream (site 61) vs. downstream (site 60) from 1982,83,92, and 1993.

Parameter	Year	Site→ 61	60
Total Phosphorus	1982	0.45	0.34
(mg/L)	1983	0.39	0.21
	1992	0.374	0.337
	1993	0.230	0.210
Total Dissolved Phosphorus	1992	0.370	0.253
(mg/L)	1993	0.267	0.206
Organic Nitrogen			
(mg/L)	1982	1.28	1.36
	1983	1.05	0.82
	1992	0.852	1.012
	1993	1.269	1.448
Total Nitrogen*			
(mg/L)	1982*	1.98	2.78
	1983*	2.47	2.06
	1992	1.406	1.606
	1993	1.753	1.982
Total Solids			
(mg/L)	1982	850	578
	1983	1093	1297
	1992	1654	1407
	1993	1625	1634
Suspended Solids			
(mg/L)	1982	19	18
	1983	13	21
	1992	4	13
	1993	8	18
Dissolved Solids			
(mg/L)	1982	831	572

1983	1080	1276
1992	1650	1394
1993	1617	1616

* - the sum of inorganic and organic nitrogen yearly means due to lack of raw data.
the sum of suspended and dissolved solid yearly means due to lack of raw data.

concentrations are also influenced by soil type which compounded with resuspension may have impacted the results of the sampling concentrations.

Total Phosphorus

Total phosphorus concentrations for site 61 (upstream) and site 60 (downstream) are plotted on Figure 15 (total phosphorus). As can be seen from the figure it is apparent that this particular dam is not as efficient at removing some of the phosphorus as the other dams are. The cycles are similar to the previous two dams and are in concert with past investigations conducted on this particular unit. The overall phosphorus annual means, however, do show an annualized reduction in phosphorus although these values are not extremely different. It is interesting to note that Table 11 shows that higher phosphorus concentrations occurred in 1982 than in 1992 and 1993. Even with the excessive amount of runoff there is still a considerable reduction in overall means. Figure 15 shows very little difference occurring between 1992 (72-hour settling period) and 1993 (24-hour settling period) in terms of reduction between upstream and downstream sites. This would seem to indicate that most of the phosphorus attached to the larger sediment particles settles out very soon after entering the sediment basin and the colloidal particles as previously discussed may not settle out or may take longer than the 72-hour time period for any reduction to take place.

Total Nitrogen

Nitrogen which is more soluble is not removed and in fact increases with the discharge of water through the sediment control structure. This structure may act as a collection point for nitrogen from site 61 and the rest of the subwatershed for this structure which was not monitored. The water collection and movement through the sediment retention basin may increase the nitrogen concentration levels. Table 11 shows where total nitrogen annual means were reduced in only one year out of four in which sampling took place. Nitrate/Nitrite reduction is very inconsistent as well (Figure 18) where there seems to be an insignificant difference between upstream and downstream mean concentrations (mg/L). There is essentially no difference between concentrations taken from 1992 and 1993 except once during the early part of 1992 where a first flush phenomenon may explain the spike occurring in March.

SCS #3 Loadings

Table 12 shows the overall loadings upstream and downstream of sediment control structure #3. Only a small portion of the drainage area (see specifications for dam #3 in Appendix II) was used to determine the trapping efficiency of this particular structure. As can be seen there is an increase in all of the loadings downstream of the structure as compared to that which entered the retention basin. The nature of the subwatershed, monitoring, and the extensive amount of rainfall that took place

Table 12. Nutrient and sediment total loads to and from sediment control structure #3, March 4 to October 27, 1992 and March 30 to August 23, 1993.

Total Load (Kg/yr)

Site	Total Water (acre-feet)	Total Phosphorus	Total Nitrogen	Total Suspended Solids
1992				
61 (above)	731	422	1209	2991
60 (below)	1224	655	2009	20845
% Trapping Efficiency#	493(67%)	817(55%)	800(66%)	17854(597%)#
1993				
61 (above)	2374	1007	4545	34320
60 (below)	7448	2588	15339	322462
% Trapping Efficiency	5074(214%)	1581(157%)	10794(238%)	94068(214%)*

- increase in total phosphorus, total nitrogen and suspended solid loadings
* - increase in total suspended solid loadings
% = ((Total Coming In - Total Going Out)/Total Going Out)*100

during the course of the investigation resulted in this negative trapping efficiency. The water quality data seems to give a better overall picture of the removal of nutrients and sediment of the water column. The data gained from the Agricultural Nonpoint Source (AGNPS) computer model as far as trapping efficiency and erosional rates (tons/acre) will be given in subsequent discussion.

With the intense flooding which occurred during 1993 it is difficult to determine the overall effectiveness of these particular dams. No significant trends for the water quality parameters are apparent as a result of the overall use of the sediment control structures.

A sediment survey was proposed to have been completed for this structure during the course of the investigation. However, due to the inclement weather this survey will be completed during the 1994 field season by the SCS.

Agricultural Nonpoint Source Analysis (AGNPS) of the Structures

AGNPS was used to analyze the effects of the sediment impoundments by estimating the volume of sediment that would be trapped during a single storm event (1,5,100 yr. event) and an annualized (yearly) base loading. To estimate the annualized loading a series of AGNPS runs was conducted involving a number of small rainfall events (.8 inches, energy intensity=3.0). From this analysis it was determined that a rainfall event of less than .8" exhibited an insignificant impact on sediment and nutrient yields as compared with larger rainfall events. Loadings from the .8" event was then used as an estimate for the annualized **base** loading whereby .8" was multiplied by 12 (events). This amount accounts for approximately 10" of rainfall out of an average expected annual rainfall of 23.5". One other assumption that was made was that 100% of the sediment and nutrient delivered to the impoundments during the annual base period was captured. It was concluded that due to the large storage capacity of the impoundments, the retention period was sufficient to effectively remove 100% of the sediments and nutrients. This may be slightly optimistic, but should be compensated by the contributions from small rainfall events (i.e. less than 0.8") which was assumed to have 0% contribution to sediment and nutrient loadings. The Agricultural Nonpoint Source (AGNPS) Analysis of the Lake Herman Watershed is a seperate document and contains more specific data relating to sediment control structures as well as the tributaries. A cursory discussion of the results for the sediment control structures is given here.

The results on Table 13 indicate the effect that the sediment control structures have on sediment retention for a single storm event (1,5,100 yr). Impoundment number 1 is a terraced structure which was located in the northern (site 3B) subwatershed. Impoundment number 2 is the referred to sediment control structure (SCS) #1, number 3 is SCS #2, and number 4 is SCS#3.

The most effective of the structures is number 1 which is the a terrace structure. However, as is indicated on the table the soil type in this area of the watershed is made up of a larger particle size (small aggregate to sand) as opposed to the other impoundments which have a higher percentage of clay particles. This terrace structure, however, has no impact on the reduction of nutrients (phosphorus and nitrogen). The other structures have very little impact on reducing the sediment load from 24 hour event. This is primarily associated with the high percentage of clay sized particles contained within the soil type.

Table 14 indicates the trapping efficiency of the structures in the annualized model. The terrace structure removes approximately 66% of the sediment yield from that section of the watershed. It is also apparent that as the intensity of a storm event increases there is an overall reduction in the trapping efficiency. A 1 year storm event would have an estimated 55% trapping efficiency for sediment control structure #1 whereas a 5 year event would result in an estimated 28% reduction in the sediment yield for this section of the watershed. This correlates with the field data as is indicated from Table 8 where the trapping efficiency for 1992 was estimated to be 38% and in 1993 was estimated to be a 29.3% reduction in sediment. These results from the empirical data and the computer model are essentially in the same "ballpark" and give an indication of the problems associated with trapping efficiencies from each of the individual dams.

The trapping efficiencies for the other two structures show similar characteristics as number one although SCS#2 and #3 were slightly less efficient. This may be caused by a higher percentage of clay located in these individual subwatersheds.

The results gained from both field collections and AGNPS seem to suggest that the soil type within the individual watersheds may have a significant impact in the overall efficiencies or lack of trapping efficiencies. The tributary loading data from AGNPS and field collections both indicate that those areas in which clay and silt are the predominate soil types will exhibit a smaller reduction in sediment loading relative to each sediment control structure. These specific soil types require a longer retention period before settling takes place.

Tributary Water Quality

Lake Herman has a watershed of 36,275 acres (14,680 hectares) with 4 unnamed tributaries and an outlet termed Silver Creek (Stewart, 1994). From analysis conducted in 1977 and 1978 it was determined that much of the sediment and nutrient loadings from these 4 tributaries were due to agricultural activities. As a result, many areas along these tributaries were placed in the Agricultural Conservation Program (ACP) of the Agricultural Stabilization and Conservation Service (ASCS) and Best Management Practices (BMP's) were installed (Payne et al., 1986).

The underlying goal of the Phase III Post-Implementation study conducted during 1992 and 1993 was to determine the overall effectivess of the BMP's and associated sediment control structures. During the MIP approximately 55% (Figure 1-1) of the watershed was treated with BMP's. Land operators had a choice of twelve conservation practices which were used during this program (see Appendix I containing list of bmp's).

Water Quality

The four tributaries of Lake Herman monitored in this investigation have been assigned the benefical uses for intermittent streams (9) wildlife propagation and stock water, and (10) irrigation waters. The associated water quality standards for these beneficial uses are listed in Table 15. Appendix III contains the concentrations, means, minimum's, maximums, and loadings for all parameters gained from the 1992-1993 data.

Table 15. Lake Herman Tributary Water quality Standards.

Parameter	Standard
Total Alkalinity	<750 mg/L
Total Dissolved Solids	<2500 mg/L
Conductivity	<4000 micromhos/cm @ 25^{o}C
Nitrates	<50 mg/L
pH	>6.0 & <9.5 units
Sodium, absorption rate	<10:1

SD DENR, Title 74

Tributary water quality is summarized in Table 16.

Site 1

This site was located downstream (Figure 3) from sediment control structure #3 which was previously discussed. Mean concentrations for several parameters are summarized on Table 16. Only part of the drainage area was monitored during the study period (site 61).

Table 16. Tributary Sampling Data Ranges and Mean Values for Lake Herman, Lake County, 1992-1993. All units in mg/L unless otherwise indicated.

Parameter	Mean values and ranges for sites				
	Site 1	Site 2	Site 3*	Site 3A	Site 3B
D.O.	9.6(5.4-15.0)	8.5(2.6-13.3)	9	8.9(5-14.4)	9.1(5.8-13)
Field pH(s.u.)	7.9(7.0-8.7)	7.7(6.9-8.4)	7.8(7.3-8.5)	7.8(7.1-8.5)	7.9(7-9)
Fecal Coliform (#/100ml)	967(2-8300)	187(2-1000)	997(4-4500)	1322(2-10000)	6189 (24-70000)
Total Alkalinity	191(83-294)	191(67-304)	184(106-245)	184(97-241)	200 (127-307)
Total Solids	1519(413-2529)	1404(331-2344)	1276(508-2199)	1175(560-1769)	1393(722-2559)
Total Diss. Solids	1493(355-2511)	1392(323-2342)	1239(382-2179)	1146(539-1754)	1337(700-2525)
Total Sus. Solids	27(5-94)	11(2-98)	37(4-126)	29(2-83)	56(20-156)
Ammonia	0.06(0.02-0.39)	0.05(0.02-0.29)	0.11(0.02-0.48)	0.06(0.02-0.33)	0.35(0.02-4.36)
Unionized Ammonia	0.0007(mean only)	0.0004	0.0008	0.0006	0.0056
Nitrate+Nitrite	0.58(0.1-1.9)	0.34(0.1-1.4)	0.53(0.1-1.6)	1.04(0.1-4.6)	1.3(0.1-5.8)
TKN	1.3(0.7-2.26)	1.2(0.4-2.23)	1.1(0.6-2.2)	1.4(0.6-2.5)	2.4(1.3-

10.5)

Organic Nitrogen	1.3(0.7-2.03)	1.2(0.4-1.9)	1.02(0.6-1.7)	1.3(0.6-2.5)	2.0(1.3-6.2)
Total Nitrogen	1.9(0.8-3.2)	1.5(0.5-3.2)	1.7(0.9-3.1)	2.4(0.7-7.1)	3.7(1.6-12.6)
Total Phosphorus	0.269(0.07-0.55)	0.239(0.05-0.79)	0.346(0.16-0.66)	0.33(0.12-0.73)	0.55(0.1-1.2)
Diss.Phosphorus	0.213(.05-.408)	0.228(.04-0.74)	0.228(0.09-0.49)	0.301(0.1-0.591)	0.474(0.08-1.1)
# of samples	22	22	6	16	17

* - Site 3 sampled from March through July 24, 1992 when it was split into 3A nd 3B.

The following parameters did not exhibit any violations or excessive concentrations during the course of the investigation: dissolved oxygen, field pH, total alkalinity, ammonia, and unionized ammonia.

50% of the fecal coliform samples taken at site 1 exceeded 200 organisms per 100 ml. Although a standard is not applicable in this case these organisms which are a group of bacteria predominantly inhabiting the intestines of man or other warmblooded animals can be used as an indicator for animal waste. The mean numbers of coliforms at site 1 was 967 per 100 ml as compared to site 61 upstream of the control structure #3 (238 per 100ml) and site 60 downstream of dam #3 (242 per 100ml). In several instances when sampling took place cattle were sighted within the pasture and creek south of the section road. The maximum value of 8300 (site 1) was taken on 8/24/92 which correlates with high values taken from the two sites upstream (site 60 and 61). However, the results from the nearest in-lake site (site 7) exhibited no correlation or increase with site 1 coliform results. There were high mean numbers of organisms which occurred during 1979 (1100 per 100 mL) but throughout all monitoring periods fecal coliforms were not a consistent problem.

The mean nitrogen concentration (Table 16) at this site in comparison to the northern tributary sites was considerably lower. No violations for the imposed water quality standards were observed for this site (see Appendix III for raw data). Nitrate+Nitrite (NO_2+NO_3) and ammonia (NH_4^+) which are more available to algae and plants had spikes or high concentrations that occurred during snowmelt in March'92 and storm runoff events during July'92 and June'93. This also correlates with the sites upstream and downstream of the sediment control structure #3 (refer to control structure section). As can be seen by Figure 19 showing total nitrogen concentrations, trends are exhibited between all three sites upstream and downstream of sediment control structure #3. There seems to be no correlation with this parameter at site 1 and inlake site 7 (south bay). The total nitrogen mean concentration for site 1 was 0.58 mg/L whereas the mean concentration found from samples taken immediately downstream of scs #3 was 0.495 mg/L (site 60).

The highest mean concentration that occurred during 1977-1983 was in 1979 where 4.45 mg/L was recorded. Table 17 shows decreased amounts of total nitrogen occurring at site 1 after the year 1979. This same phenomenon occurred with the total kjeldahl nitrogen where concentrations were reduced through the years that monitoring took place. This is an accomplishment when considering that in 1993 there were increased flows which would tend to increase the concentrations of parameters such as nitrogen (EPA, 1990).

Phosphorus is a nutrient bound to sediments and is available (soluble reactive phosphorus-SRP) for immediate assimilation by algae and plants (Manahan, 1990; Wetzel, 1983). There is no standard affiliated with this particular parameter at this time. Site 1 exhibites lower amounts of phosphorus than that of the northern tributaries (site 3A and 3B). However, there is still a considerable amount entering the lake from this subwatershed. Mean concentrations of 0.269 (1992 and 1993 combined) for total phosphorus are still high when considering that it takes approximately 0.02 - 0.05 mg/L of phosphorus to initiate an algal bloom (Manahan, 1990; Wetzel, 1983).

Refer to Table 17 which indicates the reduction in phosphorus since installation of BMP's during the MIP. Mean total phosphorus levels were slightly higher in 1978 than in the following years for site 1. Lower concentrations of phosphorus occurred in 1980; but this may have been due to the reduced discharge which was considerably less than that produced in 1978 and 1979. Concentrations during 1992 and 1993 were also considerably less during flooding events when amounts of sediment and phosphorus would supposedly increase.

The total dissolved phosphorus mean for 1993 was slightly lower for site 1 than any of the other tributary stations sampled during the project. Mean percent total dissolved phosphorus of total phosphorus for 1992 and 1993 was 69% and 79%, respectively. This parameter is highly variable and when compared to the yearly means (Table 17) from previous years may be somewhat biased due to the fact that orthophosphorus was the analyte during 1978-1980.

Total suspended solids (TSS) are referred to as those sediments transported by the water column. Site 1 combined mean for 1992 and 1993 was considerably higher than site 2 which is located downstream of two sediment control structures. The other two sites (3A and 3B) were slightly to largely higher than site 1. However, this can possibly be explained by flooding events and the fact that 3A and 3B have a larger drainage area than site 1 (see AGNPS Data). The maximum value observed at site 1 for TSS (94 mg/L) occurred on June 30, 1993 when a considerable amount of rainfall had occurred. This caused areas of severe erosion around the stream and basin bank. As can be seen by Figure 21 water leaving the dam seems to be picking up sediment and/or organic material between site 60 and site 61. There may be areas of cutbanks along the downstream route but this may also be explained by the wind and wave action resuspending material as a result of the high water levels. Riparian vegetation and the meandering of the stream may reduce the ability for these concentrations to increase but wind from a northerly direction would result in some resuspensed material being sampled from the lake which may have been blown into the site 1 area.

Total suspended solid concentrations have decreased since installment of the control structures took place (Table 17). A larger decrease might have been observed if sampling took place during an average year. Reducing the rate of discharge from the sediment control structure will reduce some of the excessive force that water has when it exits through the discharge pipe. This may also prevent erosion in the stilling basin immediately below the structure which may also in turn reduce suspended solid concentrations.

Site 2

This site is located below scs #1 and 2 where the landslope as well as the channel side slope is considerably less than site 1. This site was dependent upon what was released from the sediment control structures as well as the drainage area between the structures and the monitoring site. Table 16 shows mean concentrations for all parameters taken during the time in which the study took place.

The following parameters did not exhibit any violations or extreme values if there is no existing standard: Total alkalinity, ammonia, and un-ionized ammonia.

The mean number of organisms per 100 ml for fecal coliforms was 187. 20% of the total coliform samples taken were over 200 per 100ml. The maximum number of 1000 per 100ml occurred on June 30, 1993. Numbers exceeding 200 occurred periodically as a result of cattle that may have been grazing along the creek although from the data this does not seem to be a consistent or an overt problem with the lower numbers of organisms sampled observed from this monitoring station.

In one instance the dissolved oxygen concentration dropped to 2.6 mg/L which is associated with the pH of 6.9 and an increased amount of organic nitrogen (1.42 mg/L) which were all observed on 8/24/92. This indicates a larger amount of organic material in the water whereby a higher rate of oxidation (uptake of oxygen) must take place to decompose the organic matter.

The nitrate+nitrite mean for site 2 was much lower than the other tributary monitoring stations (0.34 mg/L). There were also no violations associated with this parameter and its beneficial uses (Table 15). Ammonia was consistently lower in this portion of the watershed as well. The total nitrogen concentration mean was the lowest observed for the tributary sites during 1992 and 1993. Referring to Table 17 monitoring station #2 in past years has also exhibited lower concentration levels. It has dropped accordingly based on the yearly means taken from 1978-1980 and 1992-1993 even though flows were extremely limited in 1979 and 1980. The excessive flooding that occurred in 1993 did not cause the 1993 annual mean to increase substantially. This may be due to better farming practices or may be a result of most of the farmers inability to gain access to their fields due to the flooding. Total nitrogen concentrations between all three monitoring stations (site 55, 57 and 2) located on this tributary exhibited some similar trends as Figure 22 shows.

Apparently there isn't alot of input between the dams and site 2 from fertilizers or animal waste. Most of the creek upstream from monitoring station #2 flows through grazing or non-cultivated areas. Referring to the sediment control section, the means for site 55, 57, and 2 for total nitrogen were 1.59, 1.61, and 1.5 mg/L, respectively. Nitrate+nitrite nitrogen made up a mean percentage of 12.5%, 18.2%, and 18.4% of the total nitrogen from site 55, 57, and 2, respectively.

The total mean phosphorus concentrations for site 2 was 0.239 mg/L which was significantly less than site 3A & B and slightly less than that of site 1. Phosphorus ambient concentrations can change dramatically from site to site because of the ability of algae and other plants high rate of assimilation for this nutrient. However, when looking at Figure 23 all three sites followed a similar pattern and do not show any significant differences. From the graph it is interesting to note that even though both 1992 and 1993 were dramatically different when considering amounts of rainfall, trends are very similar except that higher concentrations occurred in the latter part of 1992 due to the rainfall. Means from site 55, 57, and 2 were 0.243, 0.264, and 0.239 mg/L, respectively.

Comparing MIP and present data, yearly means have slightly decreased (Table 17). During the 93'flood total phosphorus concentrations were less than those of the previous year (1992). The same phenomenon is exhibited for total dissolved phosphorus which displayed some reduction even during the flood when nonpoint source loadings would tend to increase (EPA, 1990). Recorded flows for 1980 were very reduced, yet concentrations for both total and dissolved phosphorus were higher than those exhibited during 1992 and 1993. Again operators may not have been able to gain access to fields surrounding these areas resulting in reduced amounts of available phosphorus. However, both 1992 and 1993 data exhibited similar patterns which seems to indicate that farming practices have changed since the MIP and there may be some reduction of available phosphorus as a direct result.

Total suspended solids from this area are also significantly less than those recorded from previous years. However, with flooding during 1993 increased concentrations of total suspended solids were observed (Table 17). The lowest amount of mean suspended solids concentrations observed occurred during 1979 but overall amounts of suspended solids have remained consistently low over time as can be seen by Table 17. Even with the extensive flooding that occurred during 1993 suspended solids mean was considerably less than that which occurred during 1978. The sediment control structures were not installed until 1980 but yet this particular parameter exhibited a reduction in mean concentration in 1979 which may be caused by reduction in flows and other environmental fluxes which occur throughout the year. Average total suspended solids concentrations for site 55, 57, and 2 were 12.42, 11.57, and 11 mg/L, respectively.

Site 3

Site 3 was originally placed at the confluence of the two northern tributaries (3A coming from the west and 3B coming from the north)(see Figure 3 of Lake Herman). This site was sampled during snowmelt and through the summer and was then split into site 3A and 3B due to ponding of water which skewed the current velocity measurements.

The Fecal coliform mean from this particular site was 997 per 100mL and is slightly biased due to the maximum value of 4500 occurring on 7/13/92. However, based on subsequent data from **3A** and **3B** which were installed in late July of 1992, this is a realistic average. From the water quality data it can be seen that numbers of organisms per 100ml increased as the year progressed. A nitrate+nitrite and total phosphorus spike also occurred on 7/13/92 although dissolved oxygen was 9.0 mg/L indicating that the system had not reached a point where a reduction in the concentration of oxygen was occurring. Another slight nitrogen and phosphorus spike occurred on 3/2/92 during snowmelt which was probably due to a first flush phenomenon.

Site 3A

This site was moved further upstream approximately 100 meters west into the golf course area. There is a fairly low gradient at this site and the stream meanders erratically through the golf course. There are existing areas along this tributary which have been severely eroded as a result of the flood. However, some minor cutbanks were in existence prior to the flood and the riparian vegetation such as cattails was minimal. Both 3A and 3B drain a very large portion of the Lake Herman Watershed. Initially, the northern part of watershed was designed to have sediment control structures implemented in this area; but due to landowner reluctance and unsuitable topography, seeding and fencing areas along the stream were the only options feasible as well as acceptable by all interested parties (Payne et al., 1986).

The fecal coliform mean was extremely high at 1322 per 100ml and is due to extremely high values that periodically occurred during the sampling year. However, values increased during summer months and then gradually reduced for fall and spring periods. Dissolved oxygen followed a similar cycle of increasing then decreasing even though the mean was high at 8.9 mg/L (see results Appendix III). The maximum value for fecal coliforms was 10,000 per 100 mL for site 3A on 8/24/92.

The maximum value for nitrate+nitrite nitrogen was 4.6 mg/L although the mean was considerably lower at 1.04 mg/L. On 8/24/92 the nitrate+nitrite value was 0.8 mg/L and the maximum total phosphorus concentration occurred at this time as well (0.73 mg/L). This indicates that there were excessive animal and other organic inputs taking place above this particular station. Although phosphorus and nitrogen spikes may be a result of fertilizer application from the golf course area, the observed amounts of fecal coliforms that occurred indicate some input may be due to animal waste material entering the stream at some point above this station.

Site 3B

This particular site located at the Highway 34 culvert has areas of streambank erosion, and 2-3 feedlots located in its' drainage area (see AGNPS analysis of Lake Herman). There is a steep channel sideslope immediately above this site providing an area of runoff which may occur periodically during a storm event. The stream may receive extensive organic inputs from feedlots in this area where no buffers exist to filter some of the material entering the stream.

The maximum sample of fecal coliforms during the project period was taken from site 3B with a concentration of 70,000 per 100 mL. The minimum value of dissolved oxygen (5.8 mg/L) occurred with high amounts of phosphorus (1.162 mg/L) as well as nitrate+nitrite (1.7 mg/L) on 8/24/92. The mean fecal coliform for this particular site was in excess of 6,000, nitrate+nitrite at 1.3 and a total phosphorus mean of 0.554 mg/L. The means for all parameters from this site exceeded all other tributary sites that have already been discussed. There was a mean of 9.1 mg/L for dissolved oxygen which was slightly lower than site 1 which had the highest mean.

Improvements in water quality were not overtly apparent since the inception of the Model Implementation Project occurred for this monitoring station. Referring to Table 17, total phosphorus means have generally increased over time as opposed to the other tributaries which, in general, have decreased slightly. All parameters listed on Table 17 have seen a general increase in the overall concentration levels for site 3B which can probably be attributed to some of the inputs from cattle and other livestock.

Tributary Loadings

Table 18 shows Vollenwieder's proposed permissible and dangerous loading levels for a lake with a mean depth exceeding 5 meters. The units for Vollenwieder are expressed in $g/m^2/yr$. It is based on a lakes total areal loading from each source (tributary) where the total amount of phosphorus and nitrogen is divided by the total area of the lake (1350 acres for Lake Herman) (Vollenwieder, 1968).

Vollenwieder's calculations were used during the MIP project to gauge loading levels and to put them on a scale for comparison purposes. It is used to determine which particular area of the watershed contributes more loadings to the lake. For the purposes of comparing and to determine any possible improvements which may have occurred, Vollenwieders was used for this investigation although numbers are also expressed in tons/year as well.

Referring to Table 19, Vollenwieders index for Lake Herman's four tributaries was calculated for the following years: 1978, 1979, 1980, 1992, and 1993. The numbers indicate that a slight improvement occurred for sites 1 and 2 but site 3A and 3B show an increase in loadings for all parameters.

Table 18. Vollenwieder's Proposed Critical Loading Levels for lakes with mean depths up to 200 meters. All loading levels expressed in $g/m^2/yr$.

Mean Depth up to	Permissable Loading Levels N	Permissable Loading Levels P	Dangerous Loading Levels N	Dangerous Loading Levels P
5 m	1.0	0.07	2.0	0.13
10 m	1.5	0.10	3.0	0.20
50 m	4.0	0.25	8.0	0.50
100 m	6.0	0.40	12.0	0.80
150 m	7.5	0.50	15.0	1.00
200 m	9.0	0.60	18.0	1.20

Lake Herman has a mean depth of 5.5 ft (1.7m) and would therefore fall into the 5 meter category for permissable and dangerous loading levels. For total nitrogen site 3A was the only tributary which exhibited a large amount of nitrogen to the lake even though this was not considered a dangerous load by Vollenwieder standards. However, in 1993 all tributaries exhibited excessive amounts of nitrogen which can be attributed to the larger amounts of water discharged from each tributary. Obviously the impact of the flood can be seen by comparing loading numbers and the discharge rates that occurred between 1978, 1979, 1982, and 1992-1993. Site 1 and site 3B were recorded in 1978 as delivering more nitrogen, phosphorus, and dissolved phosphorus to Lake Herman. Site 1 data indicates a decrease in loadings from 1978 to 1993 although during 1993 there was an increase. This increase can again be attributed to the flood. However, during 1993 flooding events site 1 had decreased its delivery rate for nitrogen by more than 35% when comparing 1978 to 1993.

Total phosphorus permissable loading levels for Lake Herman are 0.07 $g/m^2/yr$. Every site during 1978, 1979, 1992, and 1993 exhibited larger phosphorus loads than that which is allowed by Vollenwieder. During 1980 loadings to the lake were minimal due to very reduced discharge rates. The maximum load recorded for total phosphorus occurred during 1993 at site 3B. Site 1 exhibited the highest delivered load in 1979 before the Phase III assessment was completed. Even though a wide disparity of flows has occurred from year to year it is evident that the sediment control structures are having a discernible effect on the loading levels as was previously discussed in the sediment control section. With the extensive flooding which occurred during 1993 Table 19 shows an overall reduction that has occurred at site 1 and site 2 and an increase in loadings from site 3A and 3B over time. In 1979 a total of 24,468 acre feet was discharged to the lake as compared to 62,758 acre-feet in 1993. As can be seen at site 1 the total nitrogen and phosphorus load has decreased in proportion to the amount of water. The opposite is true for sites 3A and 3B where an increase has actually taken place.

Total suspended solids have increased as well, although no loading

Table 19. Lake Herman MIP and Phase III-Post MIP Total Areal Loading - g/m²/yr, Tributary inflow for 1978, 1979, 1980, 1992, and 1993. (Lake Area = 1350 Acres)

Parameter	Year	Site 1	Site 2	Site 3*	Site 3A	Site 3B	Total
Total Nitrogen	1978	6.94	5.53		2.45	10.09	25.01
	1979	18.04	0.589		2.62	7.51	28.76
	1980	0.3296	0.0832		0.3019	0.0962	0.8109
	1992	0.6366	0.3639	1.1805	1.3613	0.9617	4.504
	1993	4.4888	2.5329		14.986	12.0061	34.0138
Total Phosphorus	1978	0.96	0.59		0.41	1.41	3.37
	1979	1.78	0.065		0.374	0.818	3.04
	1980	0.288	0.125		0.0461	0.0163	0.1037
	1992	0.134	0.093		0.455	0.499	1.181
	1993	0.723	0.5988		1.921	2.463	5.7058
Total Dissolved Phosphorus (ortho)#	1978	0.739	0.299		0.368	1.025	2.43
	1979	1.370	0.035		0.336	0.595	2.34
	1980	0.0221	0.0063		0.0414	0.0118	0.0816
	1992	0.0983	0.0808	0.1917	0.3880	0.4284	1.1872
	1993	0.5493	0.4780		1.4559	2.1311	4.6143
Suspended Solids	1992	11.46	1.19	22.45	62.07	26.98	124.15
	1993	102.86	61.00		247.34	203.40	614.60
Total Water (Acre-feet)	1979						24468.1@
	1980						1637.6@
	1992	1624.7	871.80	2813.77	2329.85	3353.21	10993.3
	1993	10660.7	7559.07		24966.12	19571.59	62757.5

* - Site 3 sampled from March to July 24, 1992 and split into 3A and 3B at that time
# - Ortho phosphorus used during 1978 - 1980, total dissolved phosphorus used during 1992 and 1993
@ - Total flows for all sites during 1979 and 1980 only.

was available for 1978-1980 for suspended solids a similar situation as that described for phosphorus and nitrogen has occurred here. Total phosphorus would have a tendency to increase with increasing suspended solids due to the phosphorus sorbed to the sediment. For all 4 sites there are high amounts of suspended solids still entering the lake according to Vollenweider model. Sites of concern are the northern tributaries of which have been previously discussed. A program to upgrade or reevaluate placement of the BMP's and sediment control structures operational procedures is warranted.

Site 21 (outlet) which is listed below on Table 20 shows the amounts of phosphorus, nitrogen, suspended solids that accumulated during the past two years. 1993 was not a typical year and due to flooding has delivered an unusually large amount of material.

In 1992 most of the loadings occurred during August and September whereas in 1993 they took place during June and July. The disparity between years relative to the discharge data show a large magnitude of difference associated with each site due to large precipitation differences. Sites were sampled during the flood only after discharge rates had crested and were beginning to recede.

Tributary sites 1 and 2 which have the sediment control structures placed within their subwatershed show a slight reduction at removing some of the

Table 20. Lake Herman Water, Nutrient and sediment Mass Balance, for 1992 and 1993 sampling seasons. All parameters in tons unless otherwise specified.

Parameter	Year	Inflow (All Sites)	Outflow (Site 21)	Accumulated
Water	1992	10993.3	11067.07	-73.77
(acre-feet)	1993	62757.5	46324.18	16433.32
Total	1992	26.64	21.22	2.42
Nitrogen	1993	201.23	132.98	68.25
Total	1992	8.39	4.52	3.87
Phosphorus	1993	33.75	21.17	12.58
Total				
Suspended	1992	734.54	414.34	320.20
Solids	1993	3636.07	1137.17	2498.90

nutrients which was previously discussed. Obviously, the flow rates fluctuated dramatically from year to year, however, the dams were installed in 1980 and considering that 1993 was a flooding year significant increases in nutrients and suspended solids didnot occur on site 1 and 2 as was exhibited by the northern tributaries site 3A and 3B. From the Table 19 higher loadings occurred during 1978 than during the flood in 1993 for site 1 and 2.

"Nutrient losses by erosion tend to be selective in the sense that organic matter and clay particles, which in soil are relatively high in nutrients, are more subject to erosion than coarser particles" (Biggar et al., 1969) This particular phenomenon was exhibited by the terraced structure north of site 3B. The soil type in this area exhibits coarser or larger particles (AGNPS analysis of the Lake Herman Watershed) and so would settle out or not be as susceptible to erosion as areas west and south of Lake Herman.

Agricultural Nonpoint Source Modeling for Lake Herman

The entire data set which contains feedlot information, critical cells in relation to erosion for each subwatershed (tributary), and more information on the efficiency of the sediment control structures for a 1, 5, and 100 yr storm event as well as an annualized estimate of the above scenarios is contained in a seperated document and is available upon request from the Department of Environment and Natural Resources.

The AGNPS analysis of the tributaries and their individual loading rates was determined from data that was recorded from 1992 cropping season. The data gained from this analysis was put in tabular form and is located on Table 20 and 21. These tables indicate that the tributary at site 1 has the largest **per acre** impact on nonpoint source loadings to Lake Herman, while sites 3A and 3B have the largest **total** loadings to Lake Herman. This correlates with the data collected during the field investigation.

Problems with the suspended solid concentrations that were discussed previously with the sediment control structures may be attributed to the soil types. The associated problems with sediment control structure #3 where there were significant differences between upstream and downstream sampling sites suggest that this may attributed to the high rate of erosion occurring in this section of the watershed. This phenomenon is indicated on the following tables.

Most of the nitrogen and phosphorus inputs from the subwatershed of 3A and 3B can probably be attributed to feedlots located in this area. The monitoring stations for Site 3A and 3B also recorded the largest loadings for suspended solids (sediment) from this area as well.

Critical cells and subwatershed analysis by sediment and associated nutrient erosion is located in the AGNPS document. This document can essentially be used as a map in locating critical areas in the subwatersheds for possible installations or reinstallations of bmp's and adjustments to the operational procedures for the sediment control structures.

Feedlot Analysis

Feedlots were analyzed for nutrient production and ranked by AGNPS on a scale of 1-100 with 100 being the worst scenario possible. An AGNPS computer analysis was conducted for each feedlot. A 1, 5, and 100yr storm event was setup to reveal the potential amounts of phosphorus and nitrogen inputs into the surrounding tributaries. Results indicated that there were two existing feeding areas which exhibit extremely high phosphorus and nitrogen inputs. Some of the nitrogen and phosphorus could be prevented from entering the lake if two animal waste collection systems were installed.

Table 20. Tributary Loading - Per **Acre**

Site	Drainage Area (Acres)	Sediment Ton/Ac/Yr (Ann.1Yr)	Sediment Ton/Ac/Yr (An100Yr)	Tot.Nitro Ton/Ac/Yr (Ann.1Yr)	Tot.Nitro Ton/Ac/Yr (An100Yr)	Tot.Phos Ton/Ac/Yr (Ann1Yr.)	Tot.Phos. Ton/Ac/Yr (An100Yr)
1	7320	.18	1.66	.00313	.00617	.00079	.00210
2	8760	.10	.77	.00253	.00421	.00064	.00130
3A	13240	.13	1.11	.00185	.00384	.00051	.00134
3B	11120	.15	1.21	.00241	.00464	.00060	.00152

Table 21. Tributary Loading - Per **Subwatershed**

Site	Drainage Area (Acres)	Sediment Ton/Yr (Ann.1Yr)	Sediment Ton/Yr (An100Yr)	Tot.Nitro Ton/Yr (Ann.1Yr)	Tot.Nitro Ton/Yr (An100Yr)	Tot.Phos Ton/Yr (Ann1Yr.)	Tot.Phos. Ton/Yr (An100Yr)
1	7320	1317	12151	22.9	45.2	5.8	15.4
2	8760	876	6745	22.2	36.9	5.6	11.4
3A	13240	1721	14696	24.5	50.8	6.8	17.7
3B	11120	1668	13455	26.8	51.6	6.7	16.9

Lake Herman In-Lake Data

Lake Herman has a surface area of 546.3 hectares (1,350 acres), a mean depth of 1.7 meters (5.6 feet), a maximum depth of 2.4 meters (8.0 feet), a volume of 9.16 x 10^6 cubic meters (7,525 acre-feet) and a mean hydraulic residence time of 3.3 years (Stewart, 1994).

The in-lake data has been extensively documented and has depicted Lake Herman as being eutrophic to hypereutrophic. The principal problem in the past is the degree of siltation in the lake and excessive nutrient inputs associated with siltation (i.e. phosphorus)(East Dakota Conservancy Report). Most of the inflow from the tributaries causing the pollution problem usually occurs within 1 or 2 storms during the year.

Several Pre-MIP investigations have been completed on Lake Herman concerning the water quality of the lake. The earliest documented report concerning chemical analysis was conducted by the geological survey in 1957 (State Geological Survey, 1959). The earliest documented evidence associated with Lake Herman concerning nitrate+nitrite was on December of 1961. Sampling observations revealed nitrate-nitrate levels of 1.2 parts per million (ppm). Phosphorus on the other hand had been analyzed the earliest in October of 1964 and results indicated that this particular sample contained 1.3 ppm. Cyanophytes (blue-green algae) require an estimated 0.02 mg/L (ppm) of total phosphorus before they become a nuisance but other parameters such as temperature and light transmissivity must also be taken into consideration (Wetzel, 1983). Phosphorus remained high at that time and continued to be excessive as was documented in many of the subsequent investigations. On November 4, 1966 the phosphate levels exhibited an increase where 2.76 ppm was documented as the level for Lake Herman (Schmidt, 1968).

Many restoration alternatives have been discussed and implemented on Lake Herman. Dredging has been conducted twice in the past twenty-five years. In 1970 dredging began and continued through 1972, ending in August of that year. For a total of three dredging seasons 47,864 $meters^3$ (62,600 $yards^3$) of sediment was removed from Lake Herman (Lake Herman Development Association,Inc., 1973). In 1985, a 5 year, Section 314 Phase II dredging project was begun to remove accumulated sediment from selected portions of the lake. A total of 512,300 $meters^3$ (670,000 $yards^3$) of sediment was removed from Lake Herman.

Due to the exorbitant amount of data existing for Lake Herman, the data comparing the overall in-lake water quality will be taken from 1974, 1977-1983. This is the period immediately before, during, and after the Model Implementation Project.

Water Quality

The parameters already discussed in Table 3 have an existing water quality standard and if the standard is violated it is due to the fact that the parameter may negatively impact the beneficial uses (Table 23) associated with Lake Herman.

Table 23. BENEFICIAL USES AND WATER QUALITY STANDARDS OF SELECTED PARAMETERS FOR LAKE HERMAN GRAB SAMPLES

Parameter	Beneficial Use: Warmwater Marginal Fishlife Propagation	Immersion Recreation	Limited Contact Recreation	Wildlife Propagation and Stock Watering
Ammonia-N (unionized) mg/L	0.05*	N/A	N/A	N/A
Dissolved Oxygen mg/L	4.0	5.0	5.0	N/A
pH standard units	6.0-9.0 6.5-8.3	6.0-9.0	6.0-9.5	
Suspended Solids mg/L	150*	N/A	N/A	N/A
Total Dissolved Solids mg/L	N/A	N/A	N/A	2500
Temperature (°F)	90	N/A	N/A	N/A
Fecal Coliforms #/100 ml	N/A+	400**	2000**	N/A
Total Alkalinity mg $CaCO_3$/L	N/A	N/A	N/A	750*
Nitrates-N mg/L	N/A	N/A	N/A	50*

* - may not exceed 0.05 mg/L with a variation allowed under subdivision 74:03:02:32(2 which states that the numerical value of a parameter found in any one grab sample collected during the period may not exceed 1.75 times the applicable criterion.

** - Fecal Coliform organism samples taken from May 1 to September 30

+ - Not applicable.

Temperature - During the course of the investigation temperatures in Lake Herman ranged from a minimum of 0.2°C in March (site 6A) to a maximum temperature of 25°C during August of 1993. There was no appreciable temperature differences between the bottom and surface layers of the lake primarily due to the lack of depth. This is consistent with other investigations conducted on Lake Herman (Payne et. al., 1986). The highest beneficial use (Table 23) states that 32.2°C (90°F) is the maximum temperature before a negative impact will result. See Appendix IV for seasonal temperature fluctuations.

Water Depth - has been a problem with Lake Herman in the past and was one reason why Herman was dredged. The MIP dams were installed to reduce the sediment load and to maintain the existing depth of Lake Herman. The minimum and maximum depth achieved during the 1992-1993 sampling were 1.68 meters (5.5 feet) and 3.51 meters (11.5 feet), respectively. The mean depth (Table 24) was slightly higher in 1993 than in 1992 mainly due to the flood. The shallowness of Lake Herman causes many typical problems associated with very shallow lakes, chemically as well as physically. The extreme productivity (hypereutrophy) of the lake can be attributed in part to the lack of depth which allows for redistribution of sediments (i.e. wind and wave action) through the water column and therefore maintaining and/or increasing the severity of turbidity and algal blooms.

Secchi Transparency (Z_{sd}) - ranged from a minimum of 0.15 meters (0.5 feet) in April'93 to a maximum of 1.98 meters (6.5 feet) in September of the same year. The overall clarity of the water was seasonally dependent with the majority of the deeper secchi depths occuring in the winter and shallower depths occurring in the summer months. There is no standard for this parameter although typically the deeper Z_{sd} the better the water quality. After reviewing the summary statitics for Lake Herman from 1977 through 1983 secchi depths and comparing them to 1992-93 data, the mean secchi depth at site 6 in 1993 was 0.79 meters as opposed to the mean of 1.47 meters observed in 1983. This particular parameter is highly dependent upon wind and wave action especially in shallow lakes.

Dissolved Oxygen - Violations for this parameter were not observed during the course of the investigation. The highest beneficial use states that the standard of 4.0 mg/l for warmwater marginal fishlife propagation should be maintained at all times. The minimum observed value occurred on March 17, 1993 with a value of 5.5 mg/L found at the bottom of site 6B. The concentrations ranged from this low value of 5.5 to maximum of 14.5 mg/l. The trend for Lake Herman seems to indicate a fairly well-oxygenated system with periods of anoxia occurring during midwinter which is consistent with what Payne discussed in 1986 as well as authors previous to the MIP. The dissolved oxygen levels have not decreased far enough to cause any major fish kills since dredging has taken place.

pH - The warmwater marginal fishlife propagation and immersion recreation beneficial use standards for pH range from a minimum pH of 6.0 to a maximum of 8.3. Measurements of this parameter exhibited a range of 6.7

Table 24. Mean in-lake values for 1992-93 Lake Herman Data.

Parameter	Year	Site6A	Site6B	Site7
Water Temperature	1992	17.1	17.0	16.9
(°C)	1993	16.3	15.8	15.9
Water Depth (meters)	1992	2.7	2.7	2.1
	1993	2.8	2.8	2.2
Secchi (Z_{sd}) (meters)	1992	0.46	N/A	0.37
	1993	0.79	N/A	0.61
Dissolved Oxygen	1992	9.20	8.89	8.24
(mg/L)	1993	9.42	8.17	8.70
Field pH	1992	7.69	7.60	7.71
(su)	1993	8.42	8.41	8.44
Fecal Colonies	1992	26.90	37.10	19.00
(#/100 ml)	1993	81.00	75.00	39.00
Total Alkalinity	1992	158.50	158.90	154.80
(mg/L)	1993	185.00	182.70	186.70
Total Solids	1992	1223.10	1228.30	1260.30
(mg/L)	1993	980.40	984.40	1199.90
Total Dissolved Solids	1992	1194.10	1191.40	1221.30
(mg/L)	1993	964.80	967.90	1182.10
Total Suspended Solids	1992	29.00	36.90	36.90
(mg/L)	1993	15.60	16.50	17.80
Ammonia (mg/L)	1992	0.063	0.0646	0.030
	1993	0.189	0.2230	0.182

Unionized Ammonia	1992	0.0020	0.0013	0.0008
(mg/L)	1993	0.0127	0.0133	0.0137
Nitrate-Nitrite	1992	0.115	0.115	0.117
(mg/L)	1993	0.260	0.250	0.230
Total Kjeldahl Nitrogen	1992	1.19	1.25	1.19
(mg/L)	1993	1.44	1.49	1.51
Organic Nitrogen	1992	1.12	1.18	1.16
(mg/L)	1993	1.25	1.27	1.33
Total Nitrogen	1992	1.30	1.36	1.31
(mg/L)	1993	1.70	1.74	1.74
Total Phosphorus	1992	0.260	0.280	0.287
(mg/L)	1993	0.328	0.349	0.306
Total Diss. Phosphorus	1992	0.132	0.133	0.128
(mg/L)	1993	0.249	0.257	0.218
TDP/TP x 100	1992	48.5%	43.8%	42.4%
	1993	74.4%	71.7%	68.7%

(8/4/92) to 8.95 (4/14/92) from all three sites. Percent of violations (number violations/total # of samples) X 100 = 40.3% all which exceeded the 8.3 pH standard associated with immersion recreation beneficial use. pH is associated with the buffering capacity and is effected by aquatic plants and algae which can increase or decrease the hydrogen proton (H^+) activity. There were no violations below the minimum pH of 6.0. The State Lakes Preservation Committee in 1977 stated that values near 9.0 are commonplace for lakes of the Prairie de Coteau region and are a result of the photosynthetic processes (Payne et al., 1986). pH levels were consistently higher in 1993 when compared to data from 1992 which is probably due to the increased input of organic material during the flood. There were dramatic differences between the means from 1977-1983 and 1992-93 which can be explained by the anoxia (lack of oxygen) that may or may not occur during each winter season and the amount of water and its contents which enter the lake on a yearly basis.

Fecal Coliform - (FC) This particular family of bacteria is associated with warm-blooded animals. During the course of the investigation (3/92 to 8/93) there were no violations based on the standards associated with the beneficial uses found on Table 23. Fecal coliform may also be used as an indicator for possible excessive nutrient inputs due to animal waste. Colonies ranged from minimum number of 2 at site 6B and 7 (4/14/92) to maximum of 330 colonies at site 6B (7/27/93). 1992-93 data results show an overall trend of increased counts during more productive summer months especially during 1993. 1993 data means also show larger counts when compared to 1992 data. This can probably be attributed to the excessive amounts of inputs from the tributaries due to 93 flooding events. Higher means at site 6A and 6B could be due to the high counts which occurred at the northern tributary sites 3A and B during similar sampling periods.

Total Alkalinity - The capacity to accept protons (H^+) is called alkalinity and primary basic species responsible for this buffering capacity are bicarbonate ion, carbonate ion, and hydroxide ion (Manahan, 1990). In the range of pH previously discussed (6.7 to 8.95) the predominate chemical species would be the bicarbonate ion (HCO_{3^-}). The highest standard for this parameter is 750 mg/L and is expressed in units of $CaCO_3$ (Calcium Carbonate). This particular parameter is typically not a problem in most South Dakota lakes. Range for this parameter was 76 mg/L (site 7) and 269 mg/L (site 6B). Typically this range would seem to indicate a well-buffered aquatic system (Wetzel, 1983). As mentioned previously higher amounts were observed in 1993. These means (1993) do not seem to be significantly different than those in 1977-1979 which ranged from 184-230 mg/L.

Total Dissolved Solids - This parameter consists of salts and organic residue (Cole, 1983) and has standard of 2500 mg/L based on the wildlife propagation and stock watering beneficial use. Values ranged from 590 mg/L (site 6B) to 2546 mg/L (site 7). The only violation occurred on 8/25/93 at site 7 with a value of 2546 mg/L. During 1992 and 1993 total solids in contrast to most of the other parameters (Table 23) decreased. This phenomenon can probably be attributed to the fact that most nonpoint source pollution increase with increasing volumes of water whereas with solids such as **dissolved** solids decrease from dilution. Values ranged from a low of 816 at site 5 (1977) to 1348 mg/L at site 6 (1992).

Total Suspended Solids (TSS) - Under the warmwater marginal fishlife propagation beneficial use the standard for this parameter is 150 mg/L. Suspended solids can cause severe turbidity problems which in turn may reduce the overall productivity of the lake and can smother fish eggs and fry (EPA, 1993). A TSS concentration level of 90 mg/L or greater may negatively impact the fishery (SDDENR, 1994). An inverse relationship can be drawn between secchi depth and total suspended solids where the maximum Z_{sd} = 1.98 meters and the minimum TSS of 4 mg/L were observed on the same date. The minimum Z_{sd} = 0.15 meters with a TSS value of 22 mg/L at site 6A on the same date as well. The maximum value for suspended solids (TSS) was 66 mg/L and was recorded from site 6B. Mean values again were found to be lower in 1993 in contrast to the 1992 results although values were consistent throughout the course of the investigation ranging from 3 to 66 mg/L. Mean values were also consistently higher at site 7 when compared to site 6 which is probably due to shallower depth located in the south bay. Shallow lakes such as Lake Herman have problems with the resuspension of bottom material due wind and wave action which will increase turbidity. If there is a significant amount of clays in the overall soil composition in the watershed there may be a large amount of material which remains suspended. This may also increase the soluble reactive phosphorus which may be attached to the resuspended material.

Comparing in-lake data from 1977-1983 to 1992-1993 (Table 25) the 1993 average exhibited the lowest total suspended solids value for site 6 and the second smallest value for site 7. The tremendous amount of water carrying sediment and other solids may have decreased the concentration of such materials as a result of the flood (dilution). The increased depth (dilution) and the water leaving at an exorbitant rate may have influenced the amount of suspended solids. These two phenomenon may have also caused a reduced amount of organic material contained within the suspended solids. With lower mean temperatures and the turbid lake bioproduction (smaller algae bloom) was slightly decreased resulting in lower solids concentrations. Although the highest concentration occurred in 1977 for site 6 and site 7 there is no trend towards decreased or increased suspended solid concentrations (mg/L). The lower water levels and wind may have been responsible for increased concentration levels during each year data was taken.

Ammonia (NH_3) - This particular species of ammonia is not toxic as is unionized ammonia species. However, ammonia which is a by-product of the decay of nitrogenous organic wastes (animal waste) may indicate the presence or excessive inputs of organic waste material (Manahan, 1990). The maximum concentration of 0.66 mg/L occurred at site 6B on 3/17/93 and the means for the individual sites were highest during the 1993 sampling year which correlates with the increased amounts of nitrogen and phosphorus inputs for that same year due to the flood. Ammonia-N (NH_4-N) concentrations have been documented ranging upto and above 10 mg/L in the bottom water layer of eutrophic lakes (Wetzel, 1983). The highest mean recorded during the 1977-1983 was 1.04 mg/L for site 5 (1983).

Unionized Ammonia (NH_{4-OH}) - Concentration levels may not exceed 0.05 mg/L with a variation allowed under subdivision 74:03:02:32(2) (see Table 23) allowed under warmwater marginal fishlife propagation beneficial use. Mean levels were higher in 1993 than 1992 due to the increased amount of available ammonia that was discussed above. No violations occurred with this parameter during the course of the investigation. The maximum value for unionized ammonia was 0.04146 mg/L taken from site 6B on 8/25/93. Neither site 6 nor site 7 showed any consistency in terms of being more concentrated than the other.

Nutrients

Phosphorus and Nitrogen are essential for growth but when excessive quantities exist, productivity (biomass) increases and can eventually become a severe problem within a lakes' ecosystem (i.e. aquatic plants, algal blooms) during the growing season. During winter months periods of anoxia (lack of oxygen) may develop in the bottom water layer if a temperature stratification takes place. This is primarily due to the excessive amount of plant and animal material produced during the growing season that is now undergoing decomposing. Nitrogen and phosphorus when considered as a component of nonpoint source pollution will increase in concentration as the amount of water increases as opposed to a point source which will decrease (EPA, 1990).

Nitrogen - The wildlife propagation and stock watering beneficial use requires that in any one grab sample collected during a 24-hour period, the nitrate concentration may not exceed 1.75 times the applicable criterion which is 50 mg/L (Table 23) (Surface Water Regulations). Nitrates/Nitrites yearly means were higher in 1993. However, site 6 and site 7 were not significantly different (Table 4-3). Maximum and minimum in-lake values were 1.3 mg/L (site 6A - 6/21/93) and 0.1 mg/L (Site 6A and 7), respectively. Interestingly values for nitrate/nitrite were fairly consistent with only an exceedingly high observation (maximum value) occurring on 6/21/93 as opposed to several other parameters (fecal coliform) which fluctuated dramatically throughout the study period.

Total Nitrogen - No standard has been implemented for this particular parameter. Concentrations ranged from a maximum value of 2.79 mg/L (site 6B) and minimum value of 0.79 mg/L (site 6A). There did not seem to be any overall trends associated with nitrogen. However, peak rates for 1992 and 1993 occurred during the summer months as opposed to the spring or fall seasons. This is probably partially due to the overall amounts of algae which may be fixing atomospheric nitrogen to a more usable form such as ammonia or nitrate+nitrite (Manahan, 1990). From Table 24 and 25 the total nitrogen concentrations have generally decreased over time. With increased amounts of water entering the lake, the nitrogen concentrations didnot increase with increasing amounts of water and in fact during the 1993 flooding resulted in lower amounts of nitrogen as compared to a low water year in 1980 which had slightly higher total nitrogen means (Table 25) (Payne et al., 1986).

Phosphorus - The species of phosphorus which is typically more available or more rapidly solubilized than nitrogen is usually considered to be orthophosphate. It is typically found to be the limiting nutrient for algae under most conditions. Wetzel (1983) has stated that an estimated 0.02 mg/L is usually required before nuisance blue-green algal bloom develops. However, since orthophosphate is more difficult and expensive to analyze total dissolved phosphorus was chosen as the analyte. If phosphorus inputs from the watershed are dramatically reduced, there is a considerable amount of phosphorus which is exchanged with the lake sediments. This phenomenon still increases the availability of phosphorus for the synthesis of more biomass or in this case algal blooms.

Total phosphorus means were higher in 1993 as opposed to 1992 data (Table 24). Minimum values were 0.11 taken from site 6A on 6/10/92 whereas the maximum value was 0.568 mg/L taken from site 6B on 3/17/93. Site 7 (south bay) mean concentrations for 1992 were higher in comparison to site 6A and 6B. As discussed previously the mean depth at site 7 is considerably less than at site 6A (for locations see Figure 3) and when combined with wave action may redistribute sediments (suspended solids levels were higher at site 7 than site 6) throughout the watercolumn causing considerably higher concentration levels to occur. However, higher concentrations did occur at site 6 in 1993. This may be a result of the higher input of phosphorus from the two northern tributaries. The shallower depth may have caused the higher concentrations at site 7 during 1992 but the inputs contributed from the northern tributaries site 3A and 3B during the 93'flood probably caused the higher concentrations to occur at site 6a and b.

Mean concentrations levels for the lake have not changed dramatically since the Model Implementation Project was intiated. Phosphorus concentrations (Table 25) have not shown any significant changes over time. However, with high water years occurring in 1992 and 1993 which caused overall amounts of the relative chemical species to increase there may not be any validity in comparing a flooding year to a normal or average year. The highest mean concentrations that occurred during the periods of 1977-1983 and 1992-1993 was 1982 (0.721 mg/L at site 6). This is in comparison to the lowest mean concentration which occurred in 1978 (0.215 mg/L at site 5).

<u>Total Dissolved Phosphorus (TDP)</u> - This particular component of total phosphorus is an estimate of the concentration of chemical species available for immediate uptake by biological organisms (i.e. plants and algae). Again referring to Table 24 mean levels of TDP were higher in 1993. Maximum values were 0.468 mg/L at site 6B (bottom) on 3/17/93. Minimum values were 0.033 mg/L at site6A on 6/23/92 (Appendix IV). The samples taken from the bottom would typically show higher amounts of phosphorus due to

the nature of sediments and there storage capacity for phosphorus. The minimum value taken from the surface suggests that there is still enough to cause an blue-green algal bloom (cyanophyceae). The mean percent levels of total dissolved (available) phosphorus to total phosphorus were higher for both years at site 6. In 1993 the percentage for TDP of total phosphorus were almost double of those found in 1992. This is mainly due to the influx of excessive amounts of sediment entering Lake Herman from site 3A and B as was discussed previously in the tributary water quality summary.

<u>Limiting Nutrient</u> - Liebig's Law of the Minimum states that certain ecological events (i.e. growth, photosynthesis, and primary production) are limited by the availabilty of certain chemicals or factors that may exist in smaller amounts as compared to other resources which may go unused. This phenomenon described above can be applied to the overall production of algal biomass and the availability of nitrogen and phosphorus. A ratio of 10:1 is typically used to determine which is the limiting nutrient in the production of algae (Wetzel, 1983) where a ratio exceeding 10 would result in phosphorus being the limiting nutrient.

Phosphorus was only a limiting nutrient two times throughout the course of the investigation. Once during June of 1992 at site 6A and once during June of 1993 at site 6a and 7 on the same day. Mean values for both years (Table 24) ranged from 4.84 to 6.13 indicating a nitrogen limited lake. These findings are also consistent with the results given in previous reports where nitrogen was the limiting factor (Payne et.al., 1986). The maximum value for TN:TP was 11.78 taken from site 6B on 6/10/92 whereas the minimum value of 1.98 was also taken from site 6B on 9/16/92.

The mean nitrogen to phosphorus ratios from table 4-4 show that Lake Herman has consistently exhibited nitrogen limitation. This indicates an overall abundance of phosphorus to the point that an organisms growth is limited theoretically by nitrogen. However, with shallow lakes and the ability of certain blue-green algae to fix atmospheric nitrogen it is doubtful that nitrogen limitation is taking place. A more plausible explanation is the turbidity of the lake and light transmissivity which can severly limit algal and submerged aquatic plant growth.

<u>Chlorophyll-a</u> - Samples were only taken during the growing season which is typically May through September. The chlorophyll-a parameter is a biomass measurement for the amount of algae found at the surface of the lake and is expressed in milligrams per cubic meter (EPA, 1990). 6 samples were taken at each site between July and September of 1992 and 6 were taken at each site during May through September of 1993 (Appendix III). Due to

differing methods of extraction (see methods section), uncorrected chlorophyll values were used in 1992 (ethanol extraction) whereas in 1993 (acetone extraction) corrected values were used. In either case, mean levels of Chlorophyll were lower in 1992 at site 7. In 1993 the reverse was true where there were increased amounts at site 7 as opposed to site 6. This phenomenon can also be attributed to the amounts of water entering from site 3A and 3B and leaving the lake at a higher rate than that of site 7 (south bay). As discussed in the tributary loadings section and the above section on phosphorus the total dissolved phosphorus to total phosphorus ratios (tdp/tp) indicated that the larger amounts of available phosphorus may have resulted in the large differences occurring between years as well being influenced by the excessive inputs of water (dilution effect). The light transimissivity may have also been reduced due to the large inputs of nonpoint source material. This would reduce the overall algae production which would explain some of the decreased chlorophyll concentrations.

Trophic Status - To determine the trophic state of a lake several factors are used in the classification of a particular lake. It is based on the overall productivity, total phosphorus concentration, and water clarity at time the analysis is conducted. Carlson's Trophic Index uses algal biomass (chlorophyll-a), total phosphate concentration, and secchi depth.

Table 26. TROPHIC STATE CRITERIA FOR CARLSONS INDEX

Parameter	Eutrophic	Hypereutrophic
Carlson's*TSI Total Phosphorus	>50	≥65
Carlson's TSI Secchi Depth	>50	≥65
Carlson's TSI Chlorophyll-a	>50	≥65

* - Carlson's TSI scale is 0-100.

Based on the criteria described above and seen in the table at right, Lake Herman is an extremely productive lake and would therefore be placed in the category of hypereutrophic. Mean trophic states (Appendix IV) for total phosphorus were higher in 1993. However, both secchi TSI and Chlorophyll-a TSI were lower during 1993. The lowest TSI value of 47.04 occurred with chlorophyll-a at site 6A on 9/16/92. Maximum values occurred occurred on March 17, 1993 with 92.4 TSI value for total phosphorus. The means previously discussed which are found on Table 25 indicate the lake was extremely productive (hypereutrophic) during the investigation. Means TSI for the years 1977 through 1983 and 1992-1993 are in the table below. Figure 25 shows a gradual decline of water quality during the MIP but the post-MIP data seems to indicate a gradual decline or improvement in the Lake trophic status. If inputs from the watershed stop completely it may take a number of years before any effect is exhibited by the lake due to the overall amounts of phosphorus that may be contained within the sediments.

Aquatic Plant Survey

Figure 26 on the following page shows the aquatic plant distribution on Lake Herman. This particular survey was completed on 8/25/93 approximately 1.5 months after the severe flood had taken place in July.

The survey began at the boat ramp on the eastern shore and began by moving south. The survey was completed by moving slowly along the shoreline and approximately every 30 yards or so a garden rake was thrown over the side and dragged along the bottom for approximately 5 yards. It was then brought to the surface and the material attached to the rake was placed into the boat to be identified at a later date.

At no time were any submergent aquatic weed beds located. The figure on the following page shows the locations of the large beds of emergent vegetation. These large dense beds (100 meters X 50 meters) consisted of a community dominated by cattails (typha spp.) and Giant Reed Grass (Phragmites australis) which is typically found in marsh-like areas, along lake margins, and in water up to 6 feet deep (Eggers and Reed, 1987). River bulrush (Scirpus fluvialtilis) as well as several other species of the sedge family were present but were not the dominant plants within the macrophyte community.

Submergent plants were not located within any area of the lake proper. This may be due to the flooding situation which with increased water levels, turbidity, and algal blooms didnot allow large submergent plant beds to develop this particular year. However, this may be a situation which develops consistently from year to year. The limiting agent for growth is not lack of a specific nutrient but rather light. Emergent plants are more successful in this particular situation where they can expose themselves to light whereas the submergent vegetation cannot gain enough surface area exposed to the sunlight thereby limiting there rate of growth. Lack of any aquatic weed beds may limit the types of fish species which may use these areas for spawning and nursing as well (EPA, 1993). It may be necessary to document the growth of the aquatic plants in an average year. The impact of excessive amounts of water and turbidity may have severely impacted the submergent plant growth.

During the MIP approximately 1,280 meters (4200 feet) of shoreline was riprapped with fieldstone from local landowner rockpiles. During the plant survey areas of severe erosion such as cut banks were not sighted. However, periodic surveys of the shoreline and riprapped areas should be conducted to maintain and reduce potential problem areas.

CONCLUSION

In 1992 a Phase III sampling program was initiated on the Lake Herman watershed to assess the effect of land treatment measures (BMPs) which were installed during the late 1970's and early 1980's during the Model Implementation Project (MIP). Data was collected from 11 sites within the watershed and 2 sites on the lake proper. Six sites located above and below the three sediment control structures were used to determine the effectiveness these structures at reducing sediment and nutrient input into the lake.

The results of the monitoring of the sediment control structures suggest that sediment control structure #1 is more effective than 2 and 3 at reducing total suspended solids (sediment). The 72-hour retention period seems to be slightly more effective with respect to this individual dam. Nitrogen sampling produced varying results throughout the investigation with no particular trend associated with this parameter. Phosphorus did exhibit trends throughout the investigation resulting in a slight reduction during 1993. Dam #1 resulted in the highest trapping efficiency for sediment. The sediment survey resulted in an average annual retention of 217 tons for 13 years (217 X 13 = 2,821 total tons trapped).

Dam #2 did not exhibit any overt trends associated with the reduction of suspended solids. Significant differences were not apparent from the water quality data. Suspended solids varied throughout the monitoring period without any consistent reduction taking place. 77% of the 1993 samples either exhibited no change or actually increased in concentrations. This same situation occurred for phosphorus and nitrogen. Phosphorus was reduced for the 1993 flooding year in which a constant flow through the top valve occurred. There didnot seem to be any differences between the 72-hour and 24-hour operating procedures.

Dam #3 was the least effective at reducing concentrations for suspended solids and associated nutrients. Data gained by the Agricultural Computer Model and field measurements show the inefficiency of this dam at reducing concentrations of suspended solids. The soil type is dominated by clays which may take a period of 7-14 days to settle out due to their colloidal nature. Again there did not seem to be any overall differences between the 24-hour and 72-hour operating procedure which may have been a result of the increased amount of clays in the soil type.

After analyzing the data from water quality collected downstream of the dams and comparing it to the results collected from those samples leaving the dam there does not seem to be any large inputs of phosphorus, nitrogen, or suspended solids. Each particular site (upstream and downstream) follow the same particular seasonal patterns.

AGNPS data revealed that the highest erosion rate in tons/acre occur in the site 1 subwatershed with high rates of erosion for phosphorus, nitrogen, and sediment. However, sites 3A and 3B to the north are almost as high in rates of erosion as well as having the highest overall amounts of predicted loadings due to the larger drainage areas. This confirms the empirical data which also indicates that loadings from the northern part of the watershed are high in sediment and nutrients when compared to that from the other tributaries. However, the highest rates of erosion occur upstream of sediment control structure #3 (subwatershed #1) which in all probability impacts the efficiency of the control structure. This is in contrast to the northern tributaries where most of the organic inputs can be associated with animal waste. High fecal coliforms occurred throughout the investigation from these two areas along with high phosphorus and nitrogen means.

The water quality from the tributary's has varied from year to year. Means from 1978 to 1993 have not indicated dramatic decreases in phosphorus, nitrogen, and suspended solids. Peak rates for phosphorus and nitrogen occurred in 1978 for sites 1 and 2 as opposed to site 3A and 3B where the highest means occurred during 1992. In general though means have shown a slight decrease in the southern part of the watershed where the control structures were installed. Variability was quite dramatic from year to year where the flows from the tributaries ranged from a low of 0 acre-feet in 1980 to a high of 62,759 acre-feet in 1993.

The water quality of Lake Herman since the inception of the MIP and the 5-year, Phase II 314 dredging project has not shown an a dramatic improvement. A slight decrease in phosphorus and nitrogen means from the sampling sites, however, has occurred. The inputs from the northern tributaries seem to be directly correlated with some of the results from inlake site 6A and B such as fecal coliforms. Chlorophyll-a results have decreased as well but this is primarily a result of the turbidity and dilution of the lake from the flood of 1993 as well as the lower temperatures which also occurred. Even with the resulting flood in 1993 sampling results were slightly less than those sampled from 1978 to 1983. The lake continues to be nitrogen limited and still exhibits periodic intense algae blooms. Carlsen's mean trophic index for chlorophyll, total phosphorus, and secchi depth has exhibited a steady hypereutrophic status for Lake Herman. It has dropped slightly since 1982 where the maximum number occurred but still maintains a high Carlsons Trophic Index.

With a shallow lake such as Lake Herman the amount of resuspension of sediment releases more phosphorus into the ecosystem. If all phosphorus inputs are reduced to zero the amount of time necessary to remove the phosphorus existing in the sediment will take an extended period of time before any actual improvement has taken place.

Recommendations

Specific areas of concern are addressed in the document produced from the Agricultural Nonpoint Computer Model (AGNPS). This document should be used as a map in determining critical cells associated with sediment and nutrient inputs to the lake. Based on data collected during the Model Implementation Project, AGNPS, and the Phase III Post-Implementation investigation the following activities are suggested to improve existing conditions and upgrade treatment measures implemented during the MIP in the Lake Herman watershed.

1. Animal Waste Management Systems

   It is recommended that at least two animal waste management systems be constructed, with nutrient management systems and follow-up monitoring to ensure proper application of wastes. There were 13 feedlots identified within the watershed which are all contributing to sediment and nutrient runoff. However, there are two which were ranked much higher than the other eleven and if funds are lacking these two should receive top priority.

2. Reevaluate BMP's and/or increase the number of BMPs and determine the farming practices within the identified critical cells introducing nitrogen and phosphorus (AGNPS) into the lake. There are a number of 40 acre cells which indicate excessive amounts of fertilizer application. Minimum tillage practices should continue to be stressed as a preferred method of crop residue management in the watershed.

3. Continued promotion of Best Management Practices by providing both technical and financial assistance in areas of extensive erosion (subwatershed 1, 3A, and 3B).

4. Intermittent streambank stabilization of areas damaged by the flood of 1993 by riprapping, increasing the areas of grassed waterways, or amount of riparian vegetation which may have been reduced or eliminated by the flood or changing farm practices in the last 10-12 years. The northern tributaries

and the area above and below sediment control structure #3 should be prioritized for this particular activity.

5. Sediment control structures should be operated in way as to provide a longer retention period of 7-14 days to allow the clay particles to settle out. The structures should be operated in a similar manner as the present procedure dictates but the retention period should be increased to 7-14 days after a rainfall event has occurred. After the retention period has elapsed the valves should then be operated in a similar manner as present procedure dictates. However, with flooding conditions such as those which occurred during 1993 this procedure would have to be modified to reduce the damaging effects of the excessive amount of water. This procedure would be more convenient for the local sponsors responsible for opening and closing the valves as well.

6. The efficiency of the terrace structure located in subwatershed of site 3B was fairly efficient at preventing erosion from occurring. This was attributed to the soil type which contained larger particles. If possible to prevent further erosion more terracing could be implemented in this section of the watershed. Planned grazing systems should be applied to the immediate area drained by the four tributaries to prevent overgrazing and/or other damage which may occur to streambanks by reducing the riparian vegetation.

8. Grassed waterways should either be reestablished or upgraded within areas that undergo intensive tillage practices. There were several areas above sediment control structure #2 and #3 in which sheet erosion was sighted.

9. Establish a series of check dams to reduce the velocity of water decreasing the rate of erosion. This should be located in the subwatersheds of site 3A and 3B. If stormwater runoff is detained for minutes or hours some solids will be deposited (McComas, 1993).

10. Although shoreline stabilization was completed during the MIP whereby 4200 feet of shoreline was stabilized it is necessary continually monitor and maintain areas that have been riprapped and locate spots which may begin to degrade.

11. In addition to the maintenance of the shoreline an educational program should be implemented to reduce any lawn fertilizers containing phosphorus.

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