PHASE I
WATERSHED ASSESSMENT
FINAL REPORT

CLEAR LAKE
DEUEL COUNTY, SOUTH DAKOTA

South Dakota Water Resources Assistance Program
Division of Financial and Technical Assistance
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Nettie H. Myers, Secretary

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State of South Dakota
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June 1999

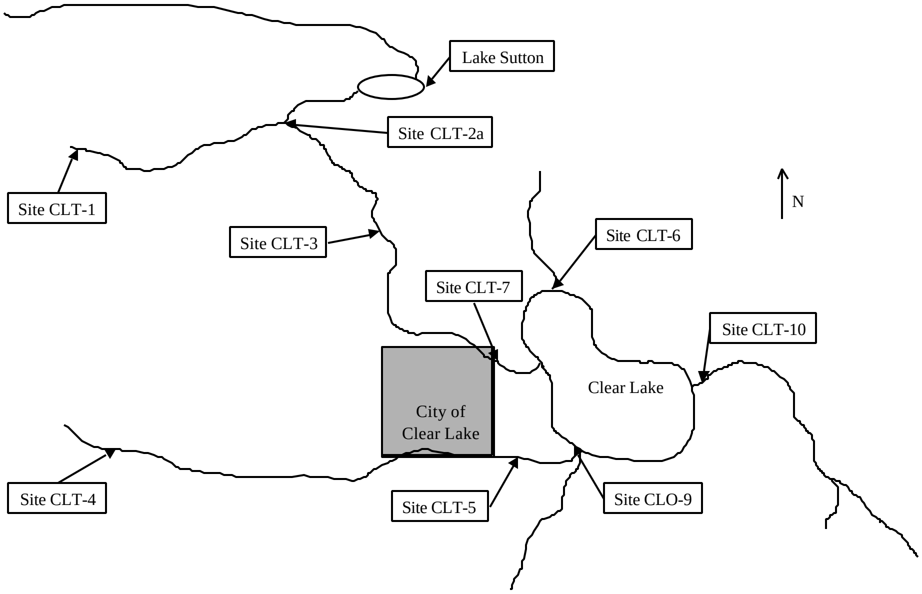
EXECUTIVE SUMMARY

In 1996, a lake and watershed water quality assessment study was initiated for the watershed of Clear Lake. Clear Lake is located in northeastern South Dakota in Deuel County. The watershed size for this lake totals 27,360 acres (11,072.6 ha). The watershed is defined by the drainage area from the headwaters of the main northwestern tributary to the outlet of Clear Lake located directly east of the city of Clear Lake (see diagram).

Main components of the assessment consisted of inlake water quality monitoring and algae sampling, tributary monitoring, storm sewer monitoring, groundwater monitoring, and a landuse assessment. The project included nine tributary monitoring sites, two inlake monitoring sites, and three storm sewer monitoring sites. In order to further evaluate the water quality of the Clear Lake watershed, landuse and geo-technical information was compiled. This information was incorporated into the Agricultural Nonpoint Source computer model (AGNPS) to produce:

1. Nonpoint source yields from each subwatershed and the net loading at the outlet of Clear Lake;
2. Critical nonpoint source cells within each subwatershed (identified by elevated sediment, nitrogen, phosphorus); and
3. A priority ranking of each animal feeding area and a quantification of nutrient loading.

Tributary water quality data collected during the project exhibited no exceedances of the



water quality standards. Inlake samples collected from Clear Lake exhibited a total of five pH exceedances, and eight observations were below the dissolved oxygen standard of 5.00 mg/L. The standard for fecal coliform was not exceeded.

The main tributary from the northwest ran continuously during 1997 and comprised more than 83% of the hydrologic budget, 99% of the total sediment load, and 93% of the entire phosphorus budget for Clear Lake (see previous diagram). The other tributaries at Sites CLT-5, 6 and 10, were minor contributors to the overall hydrologic load to Clear Lake.

The AGNPS computer model indicated that three of the 10 primary subwatersheds had high sediment deliverability rates. The suspected sources of this sediment were relatively steep agricultural lands with slopes of 4% and greater that are currently cropped or have poor vegetative cover. Four of the 10 primary subwatersheds analyzed had high nutrient deliverability rates contributing very high amounts of nutrients especially in the form of water soluble (dissolved) nutrients. The model indicated that major nutrient sources may have been streamside animal feeding operations and runoff from fertilized cropland.

Twenty-five animal feeding areas were evaluated as part of the study. Of these, 16 were found to have an AGNPS rank of 50 or more and 10 had an AGNPS rank of 60 or more on a scale of zero (no impact) to 100 (severe). Compared to other watersheds in eastern South Dakota, the density of potentially critical feeding areas found in the Clear Lake drainage was high (10 with an AGNPS rank exceeding 60).

Inlake monitoring of Clear Lake indicated that the lake is too shallow to undergo permanent stratification. The predominant algal species in Clear Lake during the summer were the blue greens *Aphanocapsa* spp., *Anabaena* spp., *Aphanizomenon flos-aquae,* and *Oscillatoria agardhii.* These algae favor high concentrations of phosphorus. Mean concentrations of phosphorus in surface samples from the two inlake monitoring sites (CL-1 and CL-2) were 0.167 mg/L and 0.174 mg/L, respectively. This is considerably higher than the 0.02 mg/L required to initiate intense blue-green algal blooms.

The average total nitrogen to total phosphorus ratio for both Clear Lake indicated phosphorus limitation. The mean total phosphorus trophic status (TSI) was 77 for Clear Lake indicating that it classified as hyper-eutrophic. The summer chlorophyll *a* concentrations for Clear Lake also ranged well within the hyper-eutrophic range.

Reduction response models were developed for Clear Lake sites using the significant relationship between total phosphorus and chlorophyll *a*. A 20% reduction of tributary phosphorus loading to Clear Lake would result in a chlorophyll *a* concentration reduction of 30%. If the reduction could be reached, the TSI ranking for chlorophyll *a* would fall to well below the hyper-eutrophic level.

With BMP installation on the 40-acre critical cells identified by AGNPS as having a rate of erosion greater than 9.0 tons per acre, nitrogen yields of 10.0 lbs/acre, and phosphorus yields of 5.0 lbs/acre, a 10% reduction in nutrient loadings to Clear Lake can be achieved. An additional 10% reduction can be achieved through the installation animal waste management systems on 10 livestock feeding areas rated greater than 60 by the AGNPS computer model. Additional reductions in phosphorus loadings can be obtained if phosphorus from lawn fertilization and storm sewers is contained or reduced.

The contribution of internal phosphorus loading to the nutrient budget of Clear Lake was not calculated. However, Clear Lake continually receives phosphorus from the main northwestern tributary. The shallow nature of Clear Lake allows the phosphorus trapped within the lake basin to be recycled year after year. A sediment removal project to increase the depth may help to reduce inlake phosphorus concentrations.

ACKNOWLEDGEMENTS

The cooperation of the following organizations and individuals is gratefully appreciated. This assessment project of Clear Lake could not have been completed without their assistance.

Dave Kringen
Deuel County Conservation District
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SD Department of Game Fish and Parks
SD Department of Environment and Natural Resources – Water Rights
SD Department of Environment and Natural Resources – Environmental Services
SD Department of Environment and Natural Resources – Watershed Protection
US Environmental Protection Agency – Section 319 Nonpoint Source Program

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INTRODUCTION

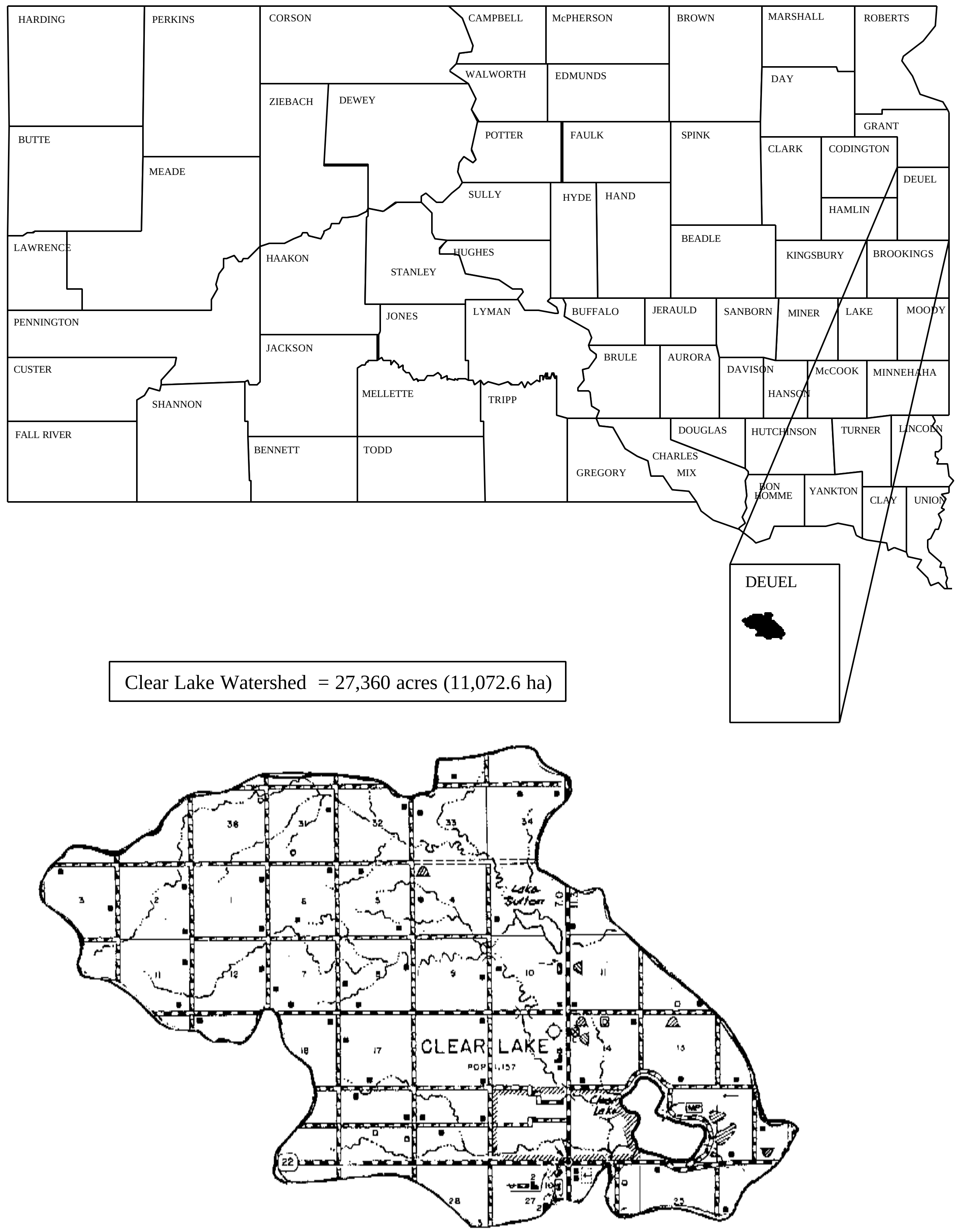
Clear Lake is a 532 acre (215.3 hectare) natural lake located in central Deuel County in the Prairie Coteau region of northeastern South Dakota (Fig. 1). The lake was derived from glacial activity and has a contributing watershed of approximately 27,360 acres (11,072.6 ha). The maximum depth of Clear Lake is 6 feet (1.8 meters) with a mean depth of 4.5-ft (1.4 m) and has an estimated volume of 2,400 acre-feet (2.761×10^6 cubic meters).

The major surface water connection with the lake is an unnamed tributary draining into the lake from the northwest. The importance of this tributary increased substantially during the early 1900s when a diversion channel was created that allowed a direct surface connection to the lake. Without this diversion, the tributary would have entered the lake only during times of heavy flooding by passing through a natural wetland complex. Since that time, Clear Lake has experienced loss of depth and declining water quality and other related problems due to activities that are usually associated with agricultural watersheds.

The natural outlet of Clear Lake is located in the southwest corner of the lake and delivers water into Hidewood Creek which eventually enters the Big Sioux River. In 1996, a new concrete spillway was constructed to replace the old one, which had been broken out and replaced with rocks. The new spillway was built at an elevation of 6 inches (1773.5 msl) below the ordinary high water mark of 1774.0 msl.

In the past, Clear Lake has been used for general recreation and immersion recreation purposes such as swimming, boating, and fishing.

In 1996, a Phase I diagnostic/feasibility study was initiated for Clear Lake and its surrounding watershed. The purpose of this study was to locate and document sources of nonpoint source pollution in the watershed and to produce feasible restoration alternatives. The study was done to provide adequate background information needed to drive a watershed implementation project to improve water quality in the tributaries and the lake. This task was accomplished through in-lake and tributary water quality monitoring as well as by computer simulation of the Clear Lake watershed using the Agricultural NonPoint Source computer model (AGNPS).



Clear Lake Watershed = 27,360 acres (11,072.6 ha)

Figure 1

Methods and Materials

Hydrologic Data

Nine tributary locations were chosen for collecting hydrologic and nutrient information from the Clear Lake watershed (Figure 2). These monitoring locations were placed at specific areas within the watershed that would best show DENR which sub-watersheds were contributing the largest nutrient and sediment loads. Gauging stations were installed where water quality samples were collected to record the daily stage (water level) of the tributary. The recorders were checked weekly and data was downloaded monthly. A Marsh-McBirney flow meter was used to take periodic flow measurements at different stage heights. The stage and flow measurements were used to develop a stage/discharge table that was used to calculate average daily loading for each site. The daily loadings were totaled to determine the annual loading rate.

Monitoring was conducted from March through November of 1997. Monitoring took place primarily during 1997 although samples were collected March-June of 1998. At that time it was decided to continue to monitor the hydrologic loadings until August of 1998 when all the monitoring and gauging equipment was finally removed. Continuous base flow data was collected from each tributary monitoring site. Data that was collected included average daily stage, instantaneous discharge, and water quality samples. When possible, peak flow event data was also collected in order to determine the loadings delivered during these events. All tributary water quality samples collected during the project were collected with a model DH-47 suspended sediment sampler. When using the DH-47, a similar length of time is used to travel from the surface of the stream to the bottom of the stream and back to the surface (called a vertical). A series of verticals is spaced evenly across the stream. The sampler is designed in such a way as to collect water based on the discharge at each specific vertical, i.e. the faster the flow the more water will be collected at that vertical during the same time interval. This allows for a more representative sample to be collected at a specific cross-section of stream. See the South Dakota Department of Environment and Natural Resources *Watershed Protection Standard Operating Procedures* manual for further details.

Tributary Water Quality

All sites, (tributary and lake outlet) were sampled twice weekly during the first week of snowmelt runoff and once a week thereafter until the runoff stopped in April. Base flow monitoring also took place after the snowmelt runoff ceased. All nutrient and solids parameters were sampled using approved methods documented in South Dakota's EPA-approved *Standard Operating Procedures for Field Samplers*. The South Dakota State Health Laboratory in Pierre, SD, analyzed all samples. The purpose of these samples was to develop nutrient and sediment loadings to determine critical pollution areas in the watershed.

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

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

Water quality parameters which were calculated from the measured parameters analyzed above were:

Un-ionized Ammonia
Total Dissolved Solids
Organic Nitrogen
Total Nitrogen

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

Water Temperature
Field pH
Air Temperature
Dissolved Oxygen

Inlake Water Quality

Inlake water quality samples were collected once monthly at two inlake monitoring sites except during periods of unsafe ice conditions (Figure 3). The objective of this sampling was to assess the current chemical, physical and biological conditions in the lake and calculate the trophic condition of Clear Lake in Deuel County. Due to the shallow nature of Clear Lake (mean depth = 4.5 feet) samples were collected one foot beneath the surface of the lake only.

In addition to the water quality parameters described above, chlorophyll *a* and algal samples were collected at each inlake site. Chlorophyll *a* is an index used to determine quantity of algae present in the water. Algae were identified to determine the population dynamics and how these relate to the water quality of Clear Lake.

Inlake water quality parameters were the same as those previously listed with the addition one parameter –secchi disk visibility. Dissolved oxygen and temperature profiles were also collected monthly for Clear Lake.

Elutriate samples were also collected from each inlake site (a total of two samples) to analyze the sediment for pesticides and nutrient content.

Water Quality Parameters Defined:

A total phosphorus sample consists of two general forms of phosphorus. The first is dissolved phosphorus, which is a measure of the phosphorus dissolved in one liter of water, not bound to any particle and available for immediate uptake by plants. The second form of phosphorus is the particulate phosphorus which is attached to a sediment particle. The particulate form is calculated by subtracting the dissolved phosphorus from the total phosphorus.

Dissolved phosphorus is not attached to sediment particles and is the form of phosphorus most available for uptake by plants and algae. Sources can be fertilizer, animal waste runoff, and phosphorus detergents. The quantities of phosphorus entering streams through land runoff vary greatly and are dependent upon soils, vegetation, quantity of runoff and pollution (Wetzel, 1983).

Suspended solids are those solids transported in the water column to the receiving body of water (lake or reservoir). Suspended solids concentrations are an estimate of the sediment transported in the stream.

Fecal coliform is a bacteria that is an indicator of waste material from warm-blooded animals and usually indicates presence of livestock wastes.

Nitrogen is found in many forms in the environment, both inorganic and organic. Nitrates + nitrites (NO_{3+2}) and ammonia (NH_4^+) can be indicators of excessive inputs of fertilizer and animal wastes as well as the products of natural breakdown of vegetation. Ammonia is a breakdown product of the biodegradation of vegetation and other organic matter, such as animal wastes. Un-ionized ammonia is highly toxic to many organisms and is subject to South Dakota water quality standards. The concentration of un-ionized ammonia is dependent upon the temperature and pH of the water.

Total Nitrogen is calculated by summing total kjeldahl nitrogen and the nitrate+nitrite nitrogen.

Organic nitrogen is an estimate of the amount of nitrogen tied up in vegetation or animal biomass. To estimate organic nitrogen, ammonia is subtracted from total kjeldahl concentrations.

The buffering capacity of water is estimated by measuring the concentration of total alkalinity.

Quality Assurance/Quality Control samples were collected according to South Dakota's EPA approved *Clean Lakes Quality Assurance/Quality Control Plan*. This document can be obtained by contacting the South Dakota Department of Environment and Natural Resources at (605) 773-4254.

The subsequent discussion reviews the water quality and flow data from each site within the northwestern drainage upstream of Clear Lake (Sites CLT-1, 2a, 3, and 7). The discussion begins with Site CLT-1, the site located furthest upstream of Clear Lake, and moves progressively downstream discussing how each downstream monitoring site is effected by the upstream sites and Clear Lake.

The next discussion will compare Site CLT-6 and Site CLT-10, located on two small tributaries draining from the north and east draining through small wetlands and then into Clear Lake. Another drainage from the west is then discussed. This subwatershed includes Sites CLT-4 and CLT-5. The final discussion will include the water quality trends and loadings associated with Sites CLO-9 (outlet of Clear Lake), and CLT-7 which has been found to provide the majority of water, nutrients and sediment to Clear Lake.

Sites for the Clear Lake drainage were numbered in consecutive order progressing downstream to the final monitoring site on the outlet (Site CLT-9) (Figure 2).

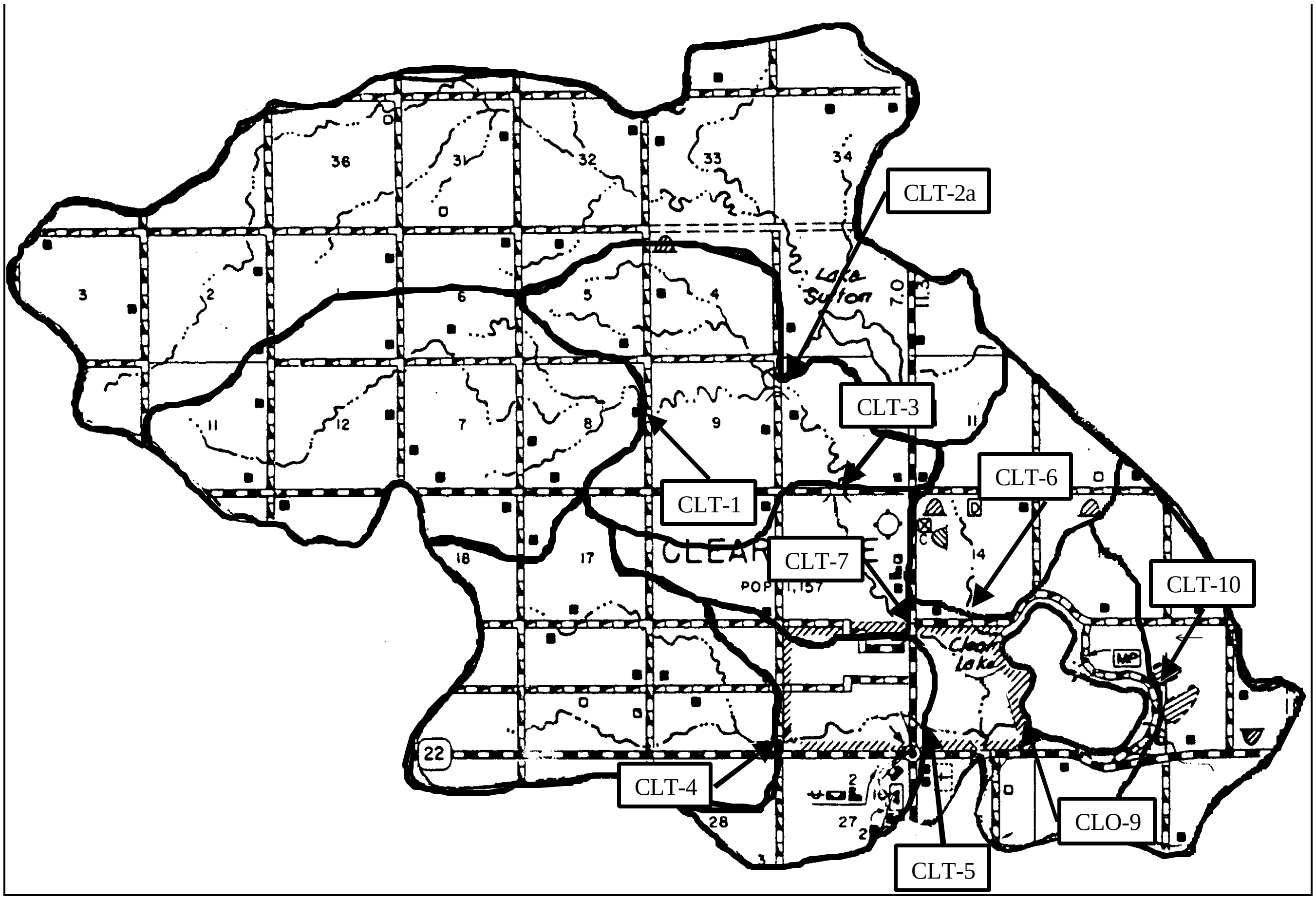


Figure 2. Location of Tributary Monitoring Sites for the Clear Lake Assessment Project, Deuel County, South Dakota.

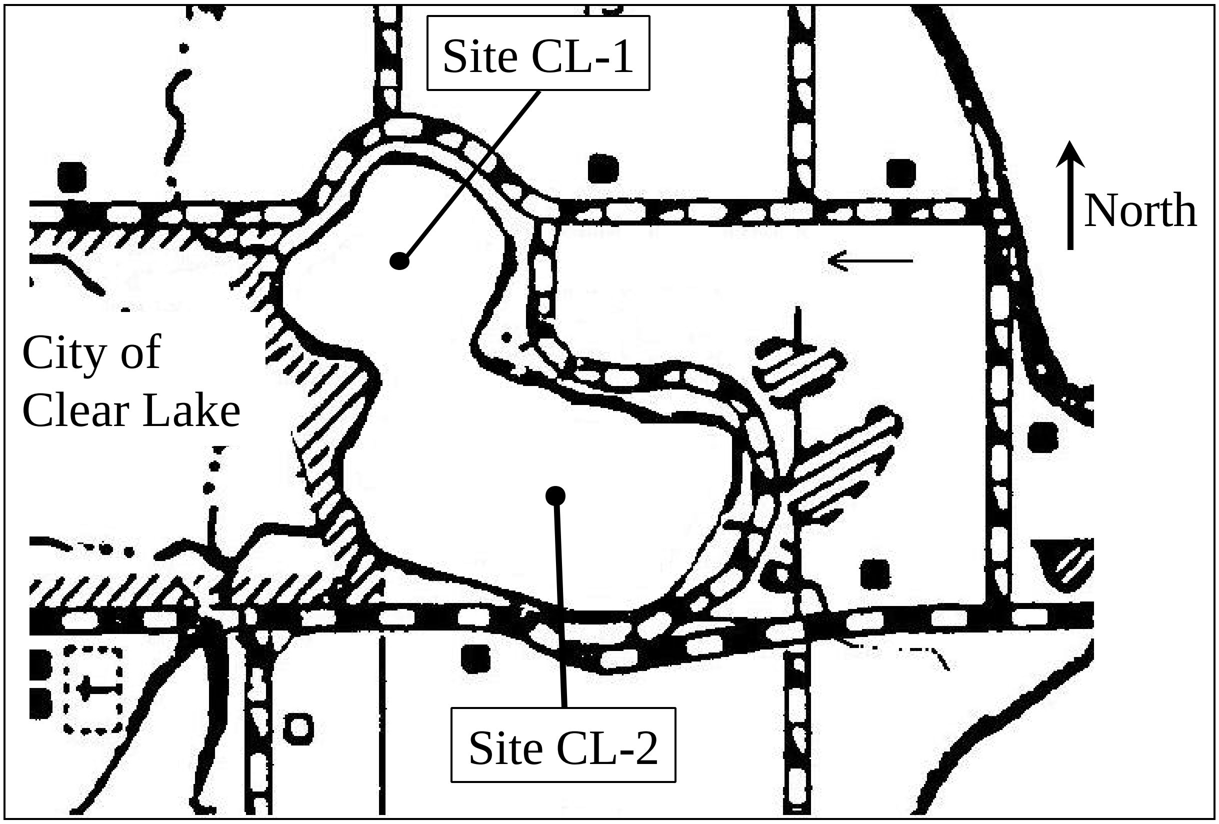


Figure 3. Clear Lake Inlake Monitoring Sites.

WATER QUALITY DISCUSSION

South Dakota Water Quality Standards

Inlake Standards

The beneficial use classifications established for Clear Lake are not to be construed as limiting the actual use of the lake. The classifications designate the minimum quality at which the surface waters of Clear Lake are to be maintained and protected. Clear Lake has been assigned the following water quality beneficial uses:

(6) Warmwater Marginal Fish Life Propagation
(7) Immersion Recreation
(8) Limited Contact Recreation
(9) Wildlife Propagation and Stock Watering

A set of water quality parameters is associated with each of these beneficial uses. Each of those water quality parameters has a set numerical standard which cannot be exceeded. In a case where two or more beneficial uses have different standard limits for the same parameter, the most stringent standard is applicable. The most stringent standard limits for the water quality parameters collected for this study are shown in Table 1.

Table 1. Applicable Criteria for the Assigned Beneficial Uses to Clear Lake.

Parameter	Limits
Un-ionized Ammonia*	≤ 0.05 mg/L
Dissolved Oxygen	≥ 5.0 mg/L
pH	≥ 6.0 and ≤ 9.0 su
Suspended Solids	≤ 263 mg/L
Total Dissolved Solids	≤ 4,375 mg/L
Temperature	≤ 32.22°C
Fecal Coliform**	≤ 400/100 mL (grab sample)
Alkalinity	≤ 1313 mg/L
Nitrates	≤ 88 mg/L
Conductivity at 25°C	≤ 7,000 mg/L

* The daily maximum of un-ionized ammonia must be ≤ 1.75 times the applicable criterion found in Appendix A to ARSD Chapter 74:51:01.

** Fecal Coliforms from May 1 to September 30 may not exceed 200 per 100 mL, which is a geometric mean based on a minimum of 5 samples obtained during separate 24-hr periods for any 30-day period. They may not exceed this value in more than 20 percent of the samples examined in the 30-day period. Also, fecal coliforms may not exceed 400 per 100 mL in any one sample from May1 to September 30.

There was a total of 36 samples collected from Clear Lake during the course of this investigation. Eight of these samples (22.2%) had dissolved oxygen concentrations less than the standard of 5.00 mg/L. The dissolved oxygen standard is set at 5.00 mg/L because fish and other aquatic life begin to show signs of stress due to lack of oxygen at this point. These exceedances of the dissolved oxygen standard occurred during the winter and summer months. During the January and February sampling dates both inlake sites exhibited an extreme drop in the dissolved oxygen concentration to levels significantly less than the standard 5.00 mg/L. In addition, the dissolved oxygen concentrations were not significantly different during these two sampling dates, ranging from a minimum of 1.20 mg/L to a maximum of 1.60 mg/L. Clear Lake is an extremely shallow lake (mean depth = 4.8 ft) with excessive amounts of nutrient enriched sediment. Moreover, the amount of organic material accumulated over the growing season needs to undergo biodegradation. This process of biodegradation, which requires oxygen, continues during periods of low light when photosynthetic rates are reduced. During the two sampling dates in January and February of 1997 the depth of the snow reached two feet on certain areas of the lake which reduced the rate of oxygen production from photosynthesis. Coupled with the shallow depth and the snow the dissolved oxygen levels continued to decline through November and December (1996) until reaching their lowest point in January and February of 1997.

A similar phenomenon occurred during the summer of 1997 when the remaining four exceedances of the dissolved oxygen standard were documented. Four samples collected from the two inlake sites during June and July'97 exhibited concentrations of oxygen less than the standard of 5.00 mg/L. Again both sites were not significantly different, ranging from a minimum concentration of 3.75 mg/L to a maximum of 4.50 mg/L. Biodegradation uses oxygen in the chemical breakdown of organic matter. This is the same phenomenon that occurs during the summer. Summerkill occurs when there is not enough oxygen produced to replace the oxygen used in the oxidation of the tremendous amount of organic matter (algae blooms) that needs to undergo biodegradation.

pH is another parameter subject to the water quality standards assigned to Clear Lake (Table 1). pH is strictly an index of how acidic or basic a solution is through the measurement of the hydrogen ion concentration. The pH of typical calcareous water is the result of the ratio of hydrogen ions (arising from the two dissociations of carbonic acid) to hydroxyl ions (provided by the hydrolysis of bicarbonate and carbonate). The importance of photosynthesis is obvious here, for plants and algae can successively absorb CO_2, and eliminate bicarbonates, precipitate carbonates, and form hydroxyl ions. All these events account for rises in pH. Most of the pH exceedances can be attributed to algal blooms and the heavy aquatic plant growth that occurred during the summer of 1997. There were five documented exceedances in Clear Lake. Appendix B lists all the water quality results for the parameters that are subject to water quality standards.

There were no exceedances of the remaining water quality standards identified in Table 1.

Tributary Standards

The beneficial use classifications established for the streams within the Clear Lake watershed designate the minimum quality at which they are to be maintained and protected. Those un-named streams have been assigned the beneficial uses:

(9) Wildlife Propagation and Stock Watering
(10) Irrigation Waters

A set of water quality parameters is associated with each of these beneficial uses. The most stringent standard limits for the water quality parameters collected for this study are shown in Table 2.

Table 2. Applicable Criteria for the Assigned Beneficial Uses to all the Streams within the Clear Lake Watershed.

Parameter	Criteria	Special Conditions
Total Alkalinity as Calcium Carbonate	≤ 750 mg/L	30-day average
	≤ 1,313 mg/L	Daily maximum
pH	≥ 6.0 and ≤ 9.5 su	
Total Dissolved Solids	≤ 2,500 mg/L	30-day average
	≤ 4,375 mg/L	Daily maximum
Nitrates	≤ 50 mg/L	30-day average
	≤ 88 mg/L	Daily maximum
Conductivity at 25°C	≤ 2,500 micromhos/cm	30-day average
	≤ 4,375 micromhos/cm	Daily maximum

There was a total of 134 water quality samples collected from nine tributary monitoring sites within the Clear Lake watershed. No exceedances of the water quality standards were observed for any of the nine monitoring sites.

TRIBUTARY WATER QUALITY AND LOADINGS

A listing of all the sites monitored during this study is located in Figure 2. Ten tributary sites were monitored during the course of the investigation to locate potentially high phosphorus, nitrates, and sediment loadings. A total of 11 parameters were analyzed and used to determine the state of the water quality at each of these monitoring stations during 1996-1998.

Monitoring was conducted from March through November of 1997. Monitoring commenced in late 1996 after the monitoring stations were installed in October with one sample collected from sites that were currently running water. Water quality and discharge monitoring continued through the spring of 1998. At that time it was decided to continue to monitor the hydrologic loadings until June of 1998 when all the monitoring and gauging equipment were finally removed. Continuous base flow data were collected from each tributary monitoring site. Data that were collected included average daily stage, instantaneous discharge, and water quality samples. When possible peak flow event data were also collected in order to determine the loadings delivered during these events. All tributary water quality samples collected during the project were collected with a model DH-47 suspended sediment sampler. When using the DH-47 a similar rate of time is used to travel from the surface of the stream to the bottom of the stream and back to the surface (called a vertical). A series of verticals is spaced evenly across the stream and the sampler is designed in such a way as to collect water based on the discharge at each specific vertical, i.e. the faster the flow the more water will be collected at that vertical. This allows for a more representative sample to be collected at a specific cross-section of stream. See the *Watershed Protection Standard Operating Procedures* manual for further details.

Seasonal Water Quality

Different seasons of the year can yield different water quality in a tributary due to changes in precipitation and agricultural practices. Tributary samples were separated into spring (March 15 to May 31, 1997), summer (June 1 to August 31, 1997), and fall (September 1 to October 30, 1997). According to the water quality samples collected in 1997, the largest nutrient and sediment concentrations and loadings typically occurred during the spring (Table 3).

The heavy snows that occurred during the 1996-97 winter explain this. The excessive amount of snow that melted during spring transported the bulk of the nutrients and sediment during the 1997 sampling year. This was also evident from the data collected from the outlet of Clear Lake. Although Clear Lake retained some nutrients and sediment, the period in which the greatest amount of nutrients/sediment was transported out of the lake also occurred during the spring runoff period.

Table 3. Average Chemical Concentrations for All Tributary Sites by Season*

Parameter	Spring		Summer		Fall	
	Count	Average	Count	Average	Count	Average
Flow	42	97.50	77	15.30	17	5.8
Dissolved Oxygen	15	9.17	47	5.75	21	7.53
Field pH	20	8.28	47	8.53	21	8.42
Fecal Coliform	20	69	40	13,416	21	1409
Alkalinity	20	172	47	181	21	262
Total Solids	20	373	47	490	21	545
Suspended Solids	20	40	47	28	21	16
Ammonia-N	20	0.170	47	0.038	21	0.074
Nitrate-Nitrite - N	20	0.89	47	0.80	21	0.43
Total Kjeldahl - N	20	1.08	47	1.39	21	1.35
Total Phosphorus	20	0.364	47	0.280	21	0.182
Dissolved Phosphorus	20	0.153	47	0.199	21	0.118

* The shaded area is the highest seasonal concentration for that parameter.

The concentrations of phosphorus, nitrogen, and suspended solids are higher in the spring than at any other time of year with the exception of dissolved phosphorus. Applied fertilizer, and the presence of animal waste, which are indicated by the increased fecal coliform concentrations during the summer, are probably the cause of the higher concentrations of bioavailable phosphorus during the summer season. The other increases in nutrients and sediment during the spring are the result of the heavy spring flows and the decaying vegetation from the previous year's growing season. Nitrate is water-soluble; meaning it can easily dissolve in water. In the spring the soil may be either frozen or water-saturated so most of the flow is overland into surface waters. During summer, with the presence of livestock in summer pastures, increases in bioavailable phosphorus during this season are not unreasonable.

Water Quality and Loadings Discussion

Site CLT-1

Site CLT-1 is located in the far upper reaches of the Clear Lake watershed (Figure 4). This monitoring site is near the beginning of the northwestern tributary which is the primary contributor to Clear Lake. The discharge for Site CLT-1 is derived from the 3,840-acre watershed identified by the AGNPS computer program. A stage monitor was placed on the culverts to monitor the total discharge from this small subwatershed and derive pollutant loadings at or near the point of origin of the main tributary for Clear Lake.

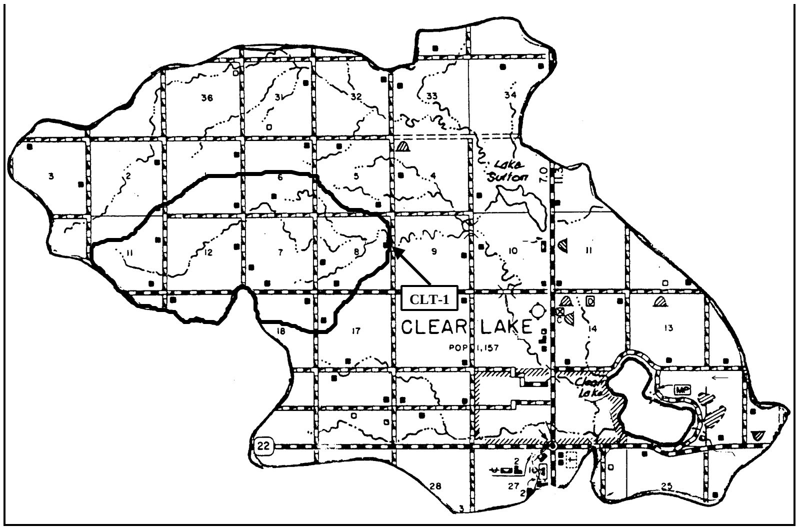


Figure 4. Location of Subwatershed for Monitoring Site CLT-1.

A total phosphorus sample consists of two general forms of phosphorus. The first is dissolved phosphorus, which is a measure of the phosphorus dissolved in one liter of water not bound to any particle and available for immediate uptake by plants. The second form of phosphorus is the particulate phosphorus attached to a sediment particle. The particulate form is calculated by subtracting the dissolved phosphorus from the total phosphorus.

The mean total phosphorus concentration sampled from CLT-1 during 1997 was 0.254 mg/L. Figure 21 indicates the range of phosphorus concentrations for all of the tributary sites involved in the Clear Lake project. As can be seen, TP concentration at Site CLT-1 is slightly higher than at Sites CLT-2A, CLT-3, and CLT-7. Those 4 monitoring sites are all in the same drainage, as will be discussed later. Sites CLT-4 and 5 are in a separate subdrainage, Site CLT-6 drains a small wetland from the north and Site CLT-10 drains a small wetland from the east. Site CLT-1 was not significantly different from the two sites immediately downstream (Sites CLT-2A and 3). Site CLT-1 exhibited two peaks in phosphorus concentration during the course of the sampling year. These peaks occurred during the spring and again during late summer. The maximum total phosphorus concentration for Site CLT-1 was 0.438 mg/L and the minimum concentration was 0.033 mg/L. The minimum and maximum concentrations were observed from samples collected on May 12 and July 25, 1997, respectively. TP concentrations in all of the 10 samples collected during 1997 were greater than 0.020 mg/L. A concentration of 0.020 mg/L is the level of phosphorus where nuisance blue-green algae blooms begin (Wetzel, 1983). The two peaks in concentration noted above may have been due to fertilizer application or improper manure management in addition to the spring runoff. This correlates with the high fecal coliform mean of 13,228/100ml (Table 5). Fecal coliform bacteria are indicators of animal or human waste. The AGNPS computer program identified two feedlots with pollution ratings greater than 50 in this subwatershed, which may be the cause of these high phosphorus and fecal coliform concentrations.

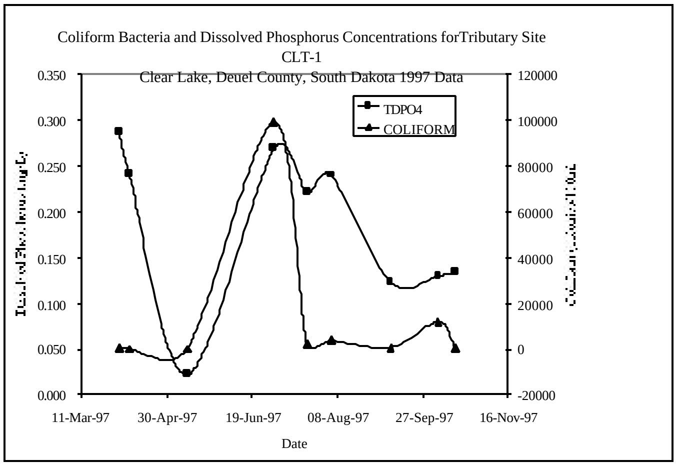


Figure 5.

Dissolved phosphorus is the phosphorus not attached to sediment particles and most available for uptake by plants and algae. Sources can be fertilizer, animal waste runoff, and phosphorus detergents. The quantities of phosphorus entering streams through land runoff vary greatly and are dependent upon soils, vegetation, quantity of runoff and levels of pollution (Wetzel, 1983). The mean concentration for Site CLT-1 was 0.202 mg/L. The minimum and maximum concentrations of dissolved phosphorus were 0.022 and 0.350 mg/L, respectively. These concentrations occurred on the same dates as the total phosphorus minimum and maximum (May 12 and July 25). Total dissolved phosphorus was the primary component for total phosphorus. On average, 79% of the total phosphorus was dissolved-P (Table 5). This indicates that phosphorus-laden sediment from croplands is not a problem in this subwatershed. There are other sources of phosphorus that have a high dissolved –P component. For example, the two feeding areas identified within this subwatershed and the 12 critical nutrient cells that were also identified by AGNPS.

Fecal coliforms are an indicator of waste material of warm-blooded organisms and usually indicate the presence of livestock wastes. Coliform bacteria usually occur together with high concentrations of nutrients. Fecal coliforms were a significant problem in the water quality samples collected from Site CLT-1. The mean concentration was 13,228 colonies per 100ml. This is a significantly high concentration of coliform bacteria, strongly indicating the presence of some type of livestock operation. As indicated in Figure 5, the concentrations of dissolved phosphorus and fecal coliform have a slight relationship. The sharp increase in dissolved phosphorus concentrations on July 2 was accompanied by a correspondingly steep increase in the concentration of coliform bacteria (99,000 colonies per 100ml).

Suspended solids are those solids transported in the water column to the receiving body of water. Suspended solids concentrations are an estimate of the sediment transported in the stream. Concentrations of suspended solids ranged from 5 mg/L to 68 mg/L for Site CLT-1. The mean concentration for Site CLT-1 was 18 mg/L (Table 5). Seasonally, the concentrations for suspended solids were significantly higher in the springtime with the large snowmelt runoff. The maximum concentration of 68 mg/L was observed on April

2, 1997. After this maximum concentration only one of the remaining nine samples exceeded 20 mg/L (27 mg/L). This slight increase in suspended solids concentration occurred on July 25 and was probably due to a rain event. In comparison to the other sites in this subdrainage (Site 2a, 3, and Site CLT-7) Site CLT-1 was significantly lower in TSS than Site 3 and CLT-7 which are located downstream. A mean of 18 mg/L indicates that erosion is not a significant problem in this subwatershed. However, AGNPS did identify twenty-one 40-acre cells within this subwatershed that had higher than average erosional characteristics and should receive some type of land treatment to reduce this problem.

Total phosphorus and suspended solids concentrations can be related to periods when there is heavy erosion occurring. During these kinds of events, particulate phosphorus should be higher than dissolved phosphorus. A regression analysis was conducted to determine the significance of the relationship between total suspended solids and total phosphorus concentrations. The R^2 values in a regression analysis range from 0 to 1. An R^2 value of 1 would indicate that all of the variability within the total phosphorus concentration is due to the suspended solids concentration. The analysis indicated no relationship between these two water quality variables collected from Site CLT-1. The R^2 value was 0.37 (d.f. = 9, n=10). A strong relationship between these two variables would have given evidence that total phosphorus is closely linked with erosion problems via higher suspended solids concentrations.

Nitrogen is found in many forms in the environment, both inorganic and organic. Nitrates + nitrites (NO_{3+2}) and ammonia (NH_4^+) can be indicators of excessive inputs associated with fertilizer and animal wastes as well as the natural breakdown of vegetation. The mean concentration of nitrates for Site CLT-1 was 1.46 mg/L which was the maximum mean for all of the tributary sites. Site CLT-1 was consistently high throughout the course of the year. The minimum and maximum concentrations were 0.20 and 3.30 mg/L, respectively (Table 5). The date when the fecal coliform maximum concentration was observed (99,000) was also the date at which the maximum concentration for nitrates was observed (July 2, 1997). This is also an indication of a livestock presence in this subwatershed.

Ammonia is a breakdown product of the biodegradation of vegetation and other organic matter such as animal wastes. Although ammonia is often used to indicate the presence of livestock, this particular site did not exhibit high concentrations. The mean concentration of ammonia (0.07 mg/L) was not significantly different than any of the other tributary monitoring sites. Ammonia was significantly higher in the spring. The maximum concentration of 0.38 mg/L was observed on April 2, 1997. After this date the concentrations dropped significantly for the rest of the sampling year.

Total nitrogen which is calculated by summing total Kjeldahl nitrogen and nitrate+nitrite nitrogen, was significantly higher at Site CLT-1 when compared to the other sites in this subdrainage (Site CLT-2a, 3, and 7). The mean concentration was 2.71 mg/L and the maximum concentration was 5.29 mg/L. The maximum concentration was observed on the same date as the maximum concentrations of fecal coliform and nitrate+nitrite concentration. The larger nitrogen concentrations at Site CLT-1 from the parameters described above were the primary reason for the higher mean concentration. For an estimate of organic nitrogen, ammonia is subtracted from total kjeldahl concentrations. The mean concentration of organic nitrogen (1.18 mg/L) was not significantly different than at any of the other sites (Table 5). Nitrates+nitrites were consistently higher than any of the organic nitrogen species resulting in the higher concentrations of total nitrogen observed from Site CLT-1. The higher nitrate+nitrite concentration can be attributed to the feeding areas and the 11 critical nutrient (P and N) cells discussed previously.

The buffering capacity of water is estimated by measuring the concentration of total alkalinity. The minimum and maximum concentrations for Site CLT-1 were 92 mg/L and 376 mg/L, respectively. The mean concentration was 232 mg/L (Table 5). The buffering capacity of natural waters should range between 20 to 200 mg/L (Lind, 1985).

The remaining parameters did not exhibit any extreme values or significant differences between Site CLT-1 and the sites downstream. Table 5 shows the minimum, maximum, mean, median, and standard deviation for each parameter collected from all of the tributary sites.

From April 1 to November 10, 1997, Site CLT-1 discharged 2,725 acre-feet of water. This amount of water transported 1.05 tons of total phosphorus and 1,298 tons of suspended solids. Because of the excessive amount of snowfall during the winter of 1997-1998 the spring run-off exhibited the highest rate of runoff, which occurred during the months March - May 31, 1998.

Export coefficients are calculated through the use of total loadings discharged from a site divided by the surface area (subwatershed) that this particular site drains. For example, Site CLT-1 drains 3,840 acres. To determine the phosphorus export coefficient for Site CLT-1 the total phosphorus loadings (2,096 lbs) was divided by the surface area of the Site CLT-1 subwatershed (3,840 acres). The phosphorus export coefficient for Site CLT-1 would be 0.55 lbs of total phosphorus/acre. The nutrient export coefficient for Site CLT-1 is not significantly higher than for the other three sites in the northwestern tributary subdrainage for Clear Lake. Of the four sites in this drainage Site CLT-1 was lower than Sites CLT-7 and CLT-3 for the phosphorus, dissolved phosphorus, and total nitrogen export coefficients (Table 4). The nitrate export coefficient for Site CLT-1 was significantly higher than the other tributary sites. The suspended sediment export coefficient was significantly lower than Sites CLT-2A, 3 and 7 (Table 4). The higher nitrate+nitrite export coefficients can be attributed to the significantly higher NO_{3+2} concentrations collected from Site CLT-1.

Site CLT-2a

Site CLT-2a monitored a large subwatershed that drains most of upper watershed for Clear Lake. The AGNPS program estimated the size of the subwatershed at 9,000 acres. The subwatershed drains into Lake Sutton which then drains into the main northwestern tributary of Clear Lake (Figure 6).

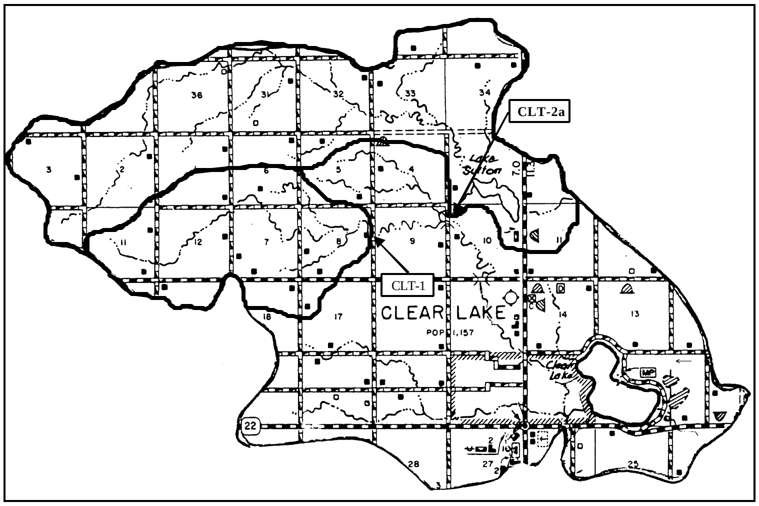


Figure 6. Location of Subwatershed and Monitoring Site CLT-2a.

Site CLT-2a total phosphorus concentrations were not significantly different from the other three sites in the northwestern tributary subdrainage. The minimum and maximum concentrations of total phosphorus for Site CLT-2a were 0.096 mg/L and 0.458 mg/L, respectively. The maximum concentration was collected on July 21, 1997. Seasonally, phosphorus exhibited higher concentrations during the summer months. During the spring and fall the concentrations were significantly lower than at other times during the sampling year. The maximum concentration is still more than twenty times (>0.02 mg/L) the necessary level for nuisance blue-green algae blooms to begin. This particular subwatershed is different in that the outlet of a lake was monitored instead of a tributary. The water quality is reflective of Lake Sutton and the wetland located on the outlet, in addition to the contribution of the subwatershed above Lake Sutton, which is why phosphorus concentrations were not significantly higher. The lake and wetland serve as a filtering apparatus, reducing the effect of the 9,000-acre subwatershed on the remaining downstream watershed. AGNPS identified 4 feeding areas with ratings that exceeded 50 (scale 0-100) which can be classified as moderately severe. The computer program also identified 24 critical nutrient cells (40 acres each) in this 9,000 acre subwatershed. Concentration levels for phosphorus, nitrogen, and coliform bacteria could be reduced if these nutrient cells and feeding areas are treated.

Total dissolved phosphorus concentrations were very similar to the total phosphorus concentrations. The minimum and maximum concentrations of dissolved phosphorus were 0.031 mg/L and 0.421 mg/L, respectively. The maximum concentration was the highest dissolved phosphorus concentration observed for the project. This concentration of 0.421 mg/L was observed on the same date as the maximum total phosphorus concentration (July 21, 1997). For this sample the dissolved phosphorus constituted 92% of the total phosphorus. Dissolved phosphorus was consistently the predominant form of phosphorus. During the summer, there may have been times when algal blooms in Lake Sutton die off, releasing the phosphorus as the dissolved fraction. This may explain the increases in concentrations at this time, in addition to the four animal feeding operations which can contribute high fractions of dissolved phosphorus.

The fecal coliform mean concentration was 3,830 colonies/100ml (Table 5). Although this concentration is the lowest when compared to means of other subwatersheds it is still a relatively high concentration. The maximum concentration was 24,000 colonies/100ml which was sampled on July 21. This is the same date when the phosphorus and organic nitrogen maximums were observed as well. According to the AGNPS modeling results there were 4 feedlots with ratings exceeding 50 (scale = 0 to 100). A feedlot with a rating a 50 or greater is moderately severe in contributing nutrients to a waterbody. The higher phosphorus and coliform concentrations seem to confirm that there is some contribution from the feeding operations located in this subwatershed. Lake Sutton and the wetland located on its outlet are not able to consume all of the nutrients from the subwatershed. This results in the movement of dissolved phosphorus out of this subwatershed and into the northwestern tributary where it is then transported into Clear Lake.

The suspended solids (TSS) mean was significantly lower than at the other sites at 9 mg/L. A regression analysis conducted on TP and TSS concentrations indicated there was no significant relationship between these two variables. TSS ranged from a minimum of 4 mg/L to a maximum of 20 mg/L (Table 5). The low suspended solids concentrations can be attributed to Lake Sutton and the wetland located on the outlet. The lake and the wetland act as sediment traps reducing the amount of sediment transported downstream. However, there were 28 critical erosion cells (40 acres each) identified in this subwatershed. These cells exhibited erosional levels exceeding 9.0 tons per acre. These cells should be treated to decrease the rate of sediment deposition into Lake Sutton.

The mean concentrations for the nitrogen forms were all consistently lower than any of the other sites and did not indicate a problem. Mean nitrate+nitrite concentrations for CLT-2a were 0.19 mg/L which is significantly lower than the other sites in this subdrainage (Site CLT-1, 3, and 7). Minimum and maximum nitrates ranged from 0.10 to 0.80 mg/L, respectively (Table 5). Although nitrates were significantly higher at Site CLT-1 there seems to be no problem in this subwatershed which is probably due to the filtration process completed by Lake Sutton and the wetland located on the outlet. With the exception of Site CLT-1, there was no significant difference between Site CLT-2a and the remaining two sites in the northwestern drainage with regard to the remaining nitrogen species (ammonia, organic, and total nitrogen).

The mean dissolved oxygen concentration for Site CLT-2a was 4.3 mg/L. This was significantly lower than any of the other sites in this tributary drainage (Table 5). This can be explained by the presence of the wetland which has a tremendous amount of organic material that needs to undergo biodegradation. During the summer, the dissolved oxygen concentrations decreased significantly due to warmer temperatures and stagnant water.

Other parameters such as alkalinity, pH, and dissolved solids did not indicate any other water quality problems in this 9,000-acre subwatershed (Table 5).

As with the other sites, most of the hydrologic loading occurred during the spring. For Site CLT-2a 60% of the total water discharged during 1997 occurred during the spring. The majority of the sediment and nutrient loadings were also discharged during the spring.

The 1997 phosphorus loading data exhibited an export coefficient of 0.29 TP-lbs/acre/yr (Table 4). This is minor in comparison to other sections of the watershed where 1.0 TP-lbs/acre/yr was exceeded. A total of 2,654 lbs. in 1997 of phosphorus was discharged from Lake Sutton. This quantity would have been higher if Lake Sutton would not have acted as a nutrient and sediment trap. Total dissolved phosphorus annual loadings totaled 1,949 lbs for a dissolved phosphorus coefficient of 0.22 lbs/acre. This was also very low in comparison to the other monitoring sites (Table 4). Suspended solids and total nitrogen export coefficients were 15 lbs/acre/yr and 2.33 lbs/acre/yr, respectively. These values were significantly lower than Sites CLT-1, 3, and 7. This is can be attributed to Lake Sutton acting as a nutrient and sediment trap.

Site CLT-3

Site CLT-3 drains an additional 3,000 acres from the north. Both the subwatersheds for Sites CLT-1 and CLT-2a drain through Site CLT-3 for a total drainage area of 15,840 acres (Figure 7). Landuse is primarily agricultural in this subwatershed. There were no exceedances of the water quality standards.

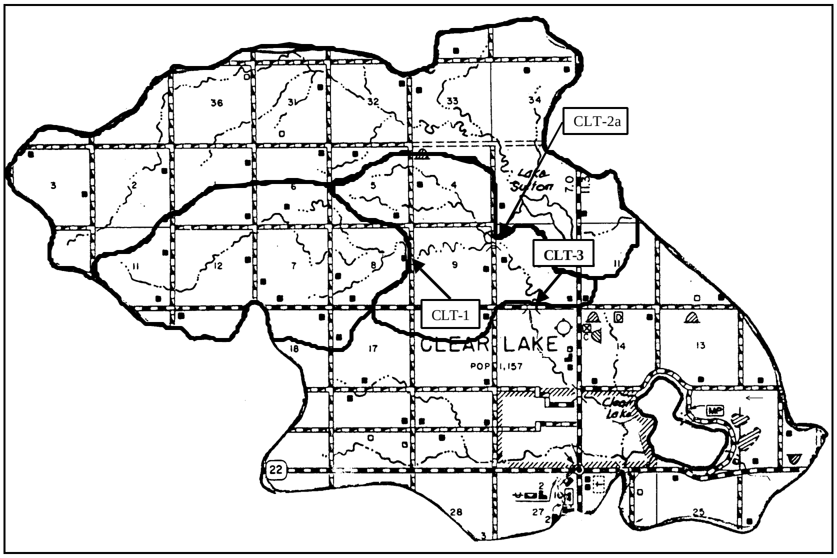


Figure 7. Location of Subwatershed and Monitoring Site CLT-3.

Water quality results from the data collected in 1997 indicated no violations but some chronic impairments were revealed. The median fecal coliform count for Site CLT-3 was 1,400 colonies per 100 ml but the mean was 17,174 colonies per 100 ml primarily because of the maximum concentration of 95,000 coliform colonies/100ml. Of the four sites included in this subdrainage (Site 1, 2a, 3, and 7) Site CLT-3 exhibited the highest mean of 17,174 colonies per 100ml and highest maximum concentration of 95,000 fecal colonies per 100 ml. The maximum concentration occurred on July 21. On this date the maximum concentrations for ammonia, total nitrogen, and dissolved phosphorus were also observed. During 1997, there were other periodic spikes of fecal coliform accompanied by higher concentrations of suspended solids, nitrates, and, total and dissolved phosphorus. In addition to the two animal feeding operations identified in the subwatershed of CLT-1 and another four identified in subwatershed CLT-2a there was one feeding area identified in the additional 3,000 acres downstream of the two upstream sites. According to the AGNPS program this feedlot was also rated > 50 (scale=0-100). In addition, there was a heavily grazed pasture through which the northwestern tributary traveled prior to reaching the Site CLT-3 monitoring site which may have caused some increases in fecal coliform. The higher concentrations of fecal coliform occurred during the summer and fall months which may be due to cattle grazing during these times whereas during the winter and spring they were moved to other areas.

Although there were high concentrations of fecal coliform bacteria, the mean concentration of total phosphorus (0.221 mg/L) was not significantly different from Sites CLT-1 and 2a. However, it was significantly less than Site CLT-7. Seasonally, the total phosphorus concentrations were slightly higher in the spring runoff period. The two maximum concentrations for Site CLT-3 occurred during the month of July. On July 2 and July 25, concentrations of 0.418 mg/L and 0.445 mg/L were observed. This was also the period in which high fecal coliform levels were observed. The maximum concentration of total phosphorus recorded from Site CLT-1 was collected on July 25 as well.

The dissolved phosphorus mean concentration was 0.144 mg/L (Table 5). The mean percentage of dissolved phosphorus was 65%. This was slightly lower than the two previous sites and correlated with the higher suspended solids that were observed from this site. The nitrate+nitrite concentrations from Site CLT-3 were significantly lower than those recorded from Site CLT-1. However, the maximum nitrate+nitrite concentration for Site CLT-3 was 2.8 mg/L and was collected on July 2. This was the same date for which the maximum concentration occurred at Site CLT-1 (3.30 mg/L). The maximum coliform concentration at Site CLT-1 (99,000 colonies/100ml) and a high coliform concentration at Site CLT-3 (81,000 colonies/100ml) were both recorded on this date as well. This indicates a significant problem located in Subwatershed CLT-1 and its effect on downstream water quality.

The buffering capacity of this site was consistently high (alkalinity mean = 184 mg/L). The pH levels ranged from 7.92 to 8.67 su and dissolved oxygen ranged from 4.2 mg/L to

10.0 mg/L (Table 5). In addition to the problem located in the Site CLT-1 subwatershed there are two animal feeding operations rated > 60 located within the immediate subwatershed of Site CLT-3.

The high concentrations of nutrients (TP mean = 0.221 mg/L) at Site CLT-3 are largely bioavailable and susceptible to immediate plant and algal uptake. Total phosphorus was weakly correlated with the suspended solids concentrations (R^2 = 0.49,n=12,df=11). Mean and median suspended solids concentrations (mean = 32 mg/L, median = 16 mg/L) were slightly higher here compared to the previous two sites. The data collected at Site CLT-3 indicated that erosion was a more significant problem between Sites CLT-1, CLT-2a, and Site CLT-3. This can be attributed to the two livestock feeding areas as well as 21 critical nutrient cells located in this subwatershed.

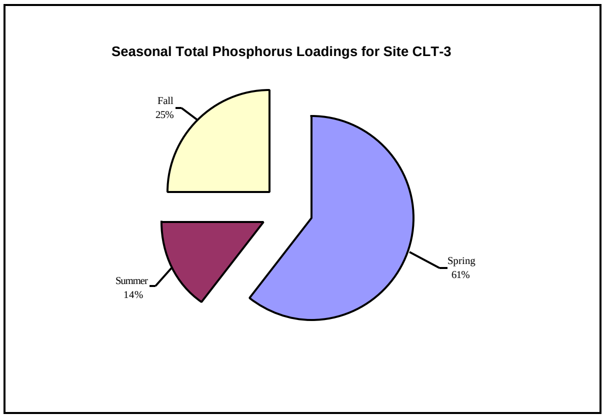


Figure 8. Seasonal Phosphorus loadings at Site CLT-3

The subwatershed size above monitoring Site CLT-3 contributes 15,840 acres to the total Clear Lake watershed (27,360 acres). This constitutes approximately 58% of the total watershed. Over 50% of the nutrient and sediment loadings occurred during the spring snowmelt and rains (Figure 8). During 1997, 27,304 acre-feet of water were discharged through this site into Clear Lake. This water transported 5.9 tons of total phosphorus, 13,652 tons of suspended solids, 4.0 tons of dissolved phosphorus, and 56.7 tons of total nitrogen. The phosphorus export coefficient for Site CLT-3 was 0.74 and was slightly higher than that for Sites CLT-1 and 2a (Table 4). The dissolved phosphorus export coefficient of 0.50 lbs/acre was relatively high in comparison to the other sites (Table 4). This difference constitutes 26% increase in the phosphorus export coefficient between Sites CLT-1 and CLT-3.

Site CLT-7

Site CLT-7 is the final site in the main tributary for Clear Lake (Figure 9). This subdrainage is 16,720 acres including the surface areas of the sites previously discussed. This monitoring site was located on the north side of the city of Clear Lake and approximately ½ mile west from where the tributary enters Clear Lake.

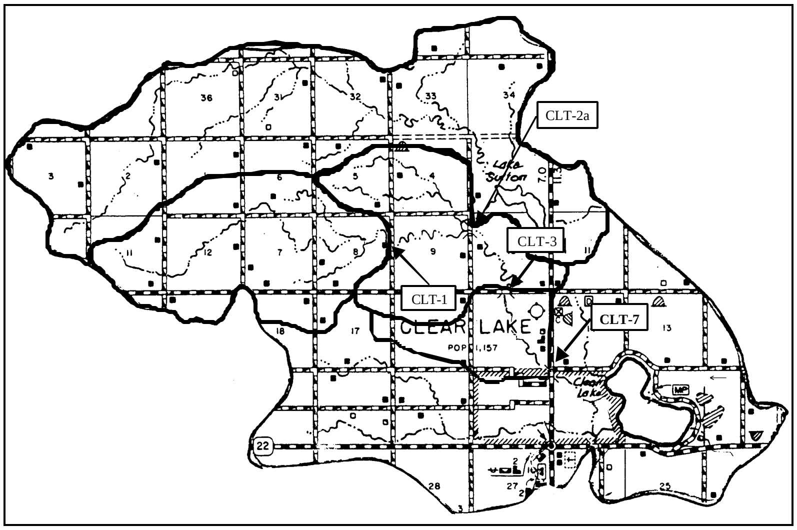


Figure 9. Location of Subwatershed and Monitoring Site CLT-7.

The mean total phosphorus concentration for Site CLT-7 was 0.305 mg/L. This was significantly higher than the other 3 sites in this subdrainage (Table 5). This higher mean can be attributed to the maximum concentration of 1.250 mg/L which was collected on April 1, 1997. This high concentration was associated with a high concentration of suspended solids (66 mg/L). The dissolved phosphorus fraction constituted only 16% of this sample. The high spring flows due to the excessive amount of snow, transported a large amount of sediment during the runoff. Particulate phosphorus or that fraction of phosphorus attached to sediment was very high during this time period. In addition, fecal coliform concentrations were not a problem at this time. The median concentration was not significantly higher than for the other three sites. In fact, it was significantly lower than the median concentration recorded from Site CLT-1 (Table 5). The median is the middle value when all the observations are ranked highest to lowest.

The mean concentration for dissolved phosphorus was 0.143 mg/L (Table 5). The mean dissolved phosphorus fraction of total phosphorus was 57% which was slightly lower than any of the upstream sites in this drainage. This can be attributed primarily to the higher suspended solids concentrations or the addition of more particulate-bound phosphorus between Site CLT-3 and CLT-7. The suspended solids mean concentration was 43 mg/L. The maximum suspended solids concentration was 146 mg/L and was collected on July 25, 1997. Usually, the higher the suspended solids (sediment) concentrations the lower the dissolved phosphorus. As mentioned previously, this was also the date when the maximum suspended solids concentration for Site CLT-3 (178 mg/L) was observed. Although there were high concentrations of total phosphorus that could be attributed to an increase in suspended solids, a significant relationship was not evident. A regression analysis was conducted between these two parameters which indicated no relationship between these two parameters (R^2=0.17,n=13,df=12). The dissolved phosphorus fraction was still relatively high during the course of the year. The upstream sites in this drainage seem to be having a significant impact on Site CLT-7 and Clear Lake water quality.

Fecal coliform concentrations were not significantly different from Site CLT-3. The mean concentration for Site CLT-7 was still excessively high at 15,082 colonies/100ml (Table 5). The maximum concentration was 64,000 colonies/100ml and was collected on July 21. Again the maximum concentration collected at Site CLT-3 was also on this date indicating a significant influence of the upstream site on Site CLT-7.

Excluding Site CLT-1 from the comparison because of its extremely high nitrate concentrations, Site CLT-7 did not differ from the remaining two sites for all of the chemical forms of nitrogen (Table 5). The mean concentration for the nitrate+nitrites was 0.54 mg/L and the maximum concentration was 2.80 mg/L. The maximum nitrate concentration was collected on the same date as Site CLT-3 which was also 2.80 mg/L (Table 5). Seasonally, the concentrations for the forms of nitrogen peaked during the summer months. The maximum concentration for total nitrogen and nitrate+nitrite nitrogen occurred on July 2.

Site CLT-7 discharged 26,010 acre-feet of water, 11,921 tons of sediment, and 149 tons of phosphorus during 1997. The overwhelming majority (>90%) of the loadings for all of the parameters including water occurred during the spring runoff (Figure 10).

The export coefficient for total phosphorus was significantly than higher than the previous sites which can be attributed to the significantly higher mean concentration of phosphorus. This increase in the phosphorus export coefficient between Site CLT-3 (0.74 lbs/acre) and Site CLT-7 (1.78 lbs/acre) constitutes an over 50% increase. The concentration of phosphorus was biased by one extremely high observation recorded on April 1, 1997 (1.250 mg/L). As mentioned in the water quality discussion for Site CLT-7, the median concentration for total phosphorus was not significantly different than the median concentration for Site CLT-3. This anomaly must be taken into consideration when using the export coefficients to identify problem

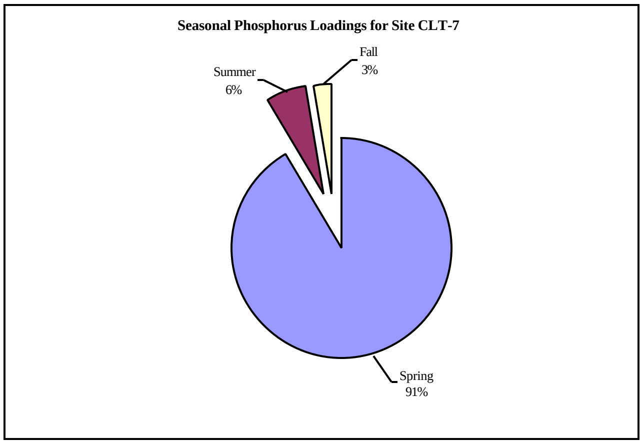


Figure 10. Seasonal Phosphorus loadings Site CLT-7.

subwatersheds in the Clear Lake watershed. The export coefficients for the different forms of nitrogen were slightly less than those for Site CLT-3.

The water quality data and loading coefficients indicated that there was not a significant problem in water quality between Site CLT-3 and CLT-7. The data indicated that the sources of water quality problems for Site CLT-7 were located above Site CLT-3. This conclusion was also supported by the AGNPS computer model. No significant livestock feeding areas or nutrient and erosion cells were identified by this computer model. Any effort towards implementation should focus on the 15,840-acre subwatershed above Site CLT-3.

<u>Site CLT-6</u>

Site CLT-6 is located immediately north of Clear Lake (Figure 11). According to the AGNPS program this subwatershed is 1,000 acres in size and drains into a wetland which drains into Clear Lake. This subwatershed is a minor contributor to Clear Lake, constituting 4% of the total watershed. There is one feeding operation located in this subwatershed with a rating of 57.

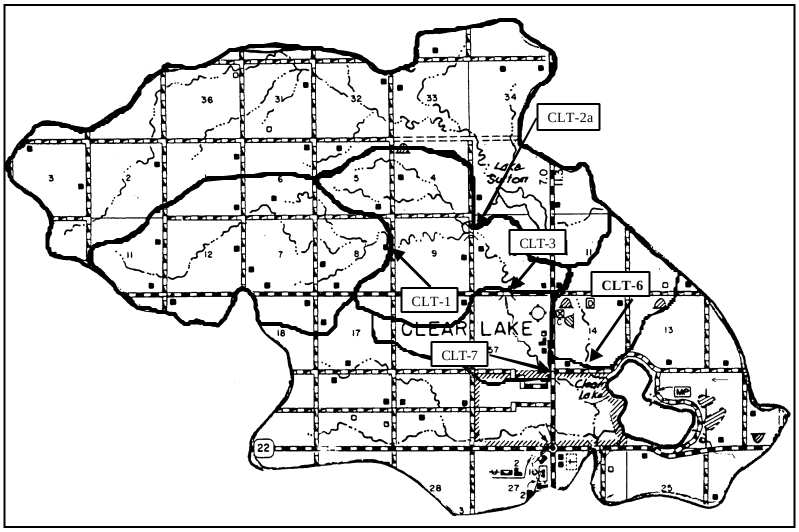


Figure 11. Location of Subwatershed and Monitoring Site CLT-6.

The values of the concentration data for total phosphorus were significantly lower than any of the other sites. The mean concentration was 0.082 mg/L. The minimum and maximum concentrations for Site CLT-6 were 0.096 mg/L and 0.159 mg/L, respectively. The maximum concentration was sampled in April during the spring runoff. The fecal coliform concentrations did not exceed 10 colonies/100ml. However, only three samples were collected from this drainage due to the lower flows during most of the year (<5cfs). The suspended solids mean concentration was 6 mg/L with a maximum concentration of 10 mg/L which was collected on October 20, 1997. Total nitrogen was significantly lower at this site as well. The mean concentration was 1.32 mg/L with a maximum concentration of 1.37 mg/L.

The remaining water quality parameters were also significantly lower at this site which is reflective of the smaller watershed and the wetland filtering process. Although there is a livestock feeding area with a high rating in this subwatershed, it should be field-verified prior to any implementation. There were only two 40-acre cells identified as having high erosion potential within this subwatershed.

Site CLT-6 discharged 1,508 acre-feet of water directly into Clear Lake. This water transported 9.10 tons of suspended solids, 2.76 tons of nitrogen, and 0.21 tons of phosphorus (Table 4). The export coefficients were also significantly lower than the rest of the sites with the exception of Site CLT-10 which is a small wetland located east of Clear Lake.

<u>Site CLT-10</u>

Site CLT-10 monitored another small watershed which drains into a wetland prior to draining into Clear Lake (Figure 12). This subwatershed is 2,880 acres in size comprising 11% of the Clear Lake watershed. It drains the southeastern section of the Clear Lake watershed.

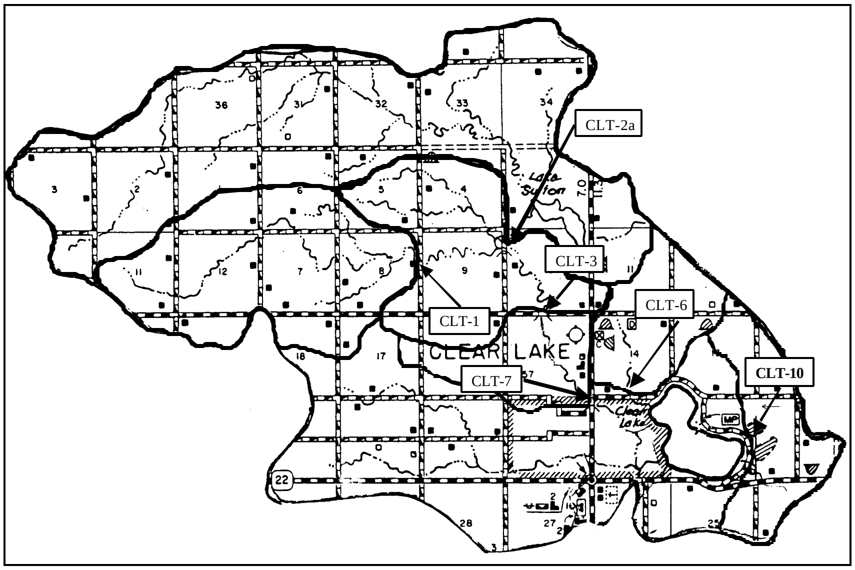


Figure 12. Location of Subwatershed and Monitoring Site CLT-10.

The concentrations were slightly higher in this particular subwatershed for most of the parameters. However, there were only two samples collected during 1997. For both of these samples a concentration of 0.381 mg/L was observed for total phosphorus. The dissolved phosphorus concentrations were 0.272 mg/L and 0.345 mg/L for both samples. The dissolved phosphorus concentrations constituted over 70% of the total phosphorus values. In 1998, two samples were also collected from this wetland. These samples were also very high in nutrient concentration. The higher concentration during 1998 was 0.658 mg/L. This site exhibited moderately high concentrations of fecal coliform bacteria as well. The mean concentration was 505 colonies/100ml with a maximum concentration of 980 colonies/100ml. AGNPS identified 4 animal feeding areas within this subwatershed which rated >50 (scale=0-100). AGNPS also identified 6 critical nutrient cells and 7 critical erosion cells for this subwatershed and designated it as a priority watershed regarding its contribution of sediment and nutrients to Clear Lake.

The nitrogen concentrations were actually higher in comparison to the other sites (Table 5). This is reflective of the wetland which contained higher organic nitrogen concentrations mean = 1.66 mg/L). The ammonia concentrations were also higher which was a by-product of the biodegradation process taking place within the wetland. This was also reflected in the dissolved oxygen concentrations which exhibited extremely low concentrations during the summer sample collected on July 28. The dissolved oxygen concentration at this time was 0.2 mg/L. This was also a product of biodegradation. Dissolved oxygen is required to break down any organic material and in a stagnant wetland during baseflow conditions oxygen can be used up quickly. The suspended solids concentrations were relatively low and as indicated with the other sites in this discussion the suspended solids were not a problem. Alkalinity and pH did not indicate any apparent water quality problems either.

Site CLT-10 discharged only 452 acre-feet of water which transported 4.91 tons of sediment, 1.31 tons of nitrogen, and 0.23 tons of phosphorus. Over 80% of the loadings (water, sediment, and nutrients) were transported during the spring (Figure 13).

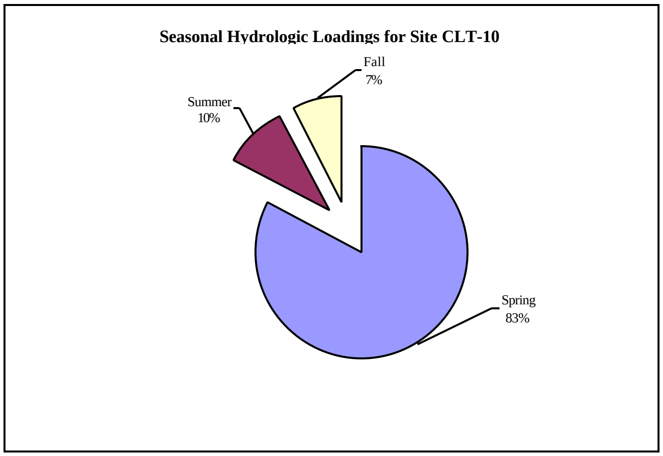


Figure 13. Seasonal Phosphorus loadings Site CLT-10.

The export coefficients were extremely low due to the relatively small amount of water that was discharged into the lake. The nutrient and sediment export coefficients for this subwatershed were significantly lower than the export coefficients for the other sites (Table 4).

Site CLT-4

Site CLT-4 is the beginning of a subwatershed that is located directly west of Clear Lake (Figure 14). Site CLT-4 and CLT-5 (Figure 17) subwatershed tributaries drain approximately 3,800 acres from west of Clear Lake. This is a drainage which does not drain primarily into Clear Lake but empties into the outlet area of Clear Lake. Only during times of flooding does this drainage make it into Clear Lake. During the course of this project this drainage did not flow back into Clear Lake. The potential is there and the data suggest that this drainage does have some water quality problems.

According to the AGNPS program, the subwatershed area for Site CLT-4 is 3,000 acres. Site CLT-4 has 2 animal feeding areas rated at 17 and 18 (scale 0-100). However, AGNPS did identify eight 40-acre critical nutrient cells and 15 critical erosion cells. The computer model indicated that this subwatershed is critical for high concentrations of sediment, phosphorus and nitrogen. This was also indicated by the water quality data.

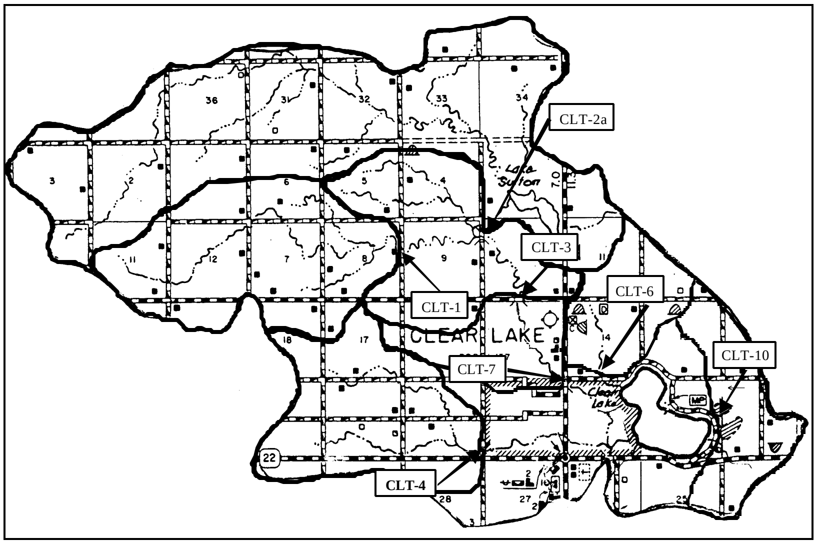


Figure 14. Location of Subwatershed and Monitoring Site CLT-4.

The mean phosphorus concentration for Site CLT-4 was one of the three highest mean concentrations recorded for the project (Table 5) (Figure 21). The mean concentration for Site CLT-4 was 0.319 mg/L. The minimum and maximum concentrations were 0.064 mg/l and 0.504 mg/L, respectively. The higher concentrations occurred during both the spring and the summer. The dissolved phosphorus mean concentration of 0.254 mg/L was the second highest mean (Table 5). Site CLT-10 was the only site in which a higher mean concentration was observed. The higher concentrations for total phosphorus and dissolved phosphorus did occur during higher flow periods (Figure 15). A slight relationship did exist between total phosphorus and discharge (R^2=0.29,n=9,df=8). Suspended solids (TSS) concentrations for Site CLT-4 were not excessively high for the project. The mean TSS concentration was 31 mg/L (Table 5). TSS concentrations peaked during the spring runoff with a maximum concentration

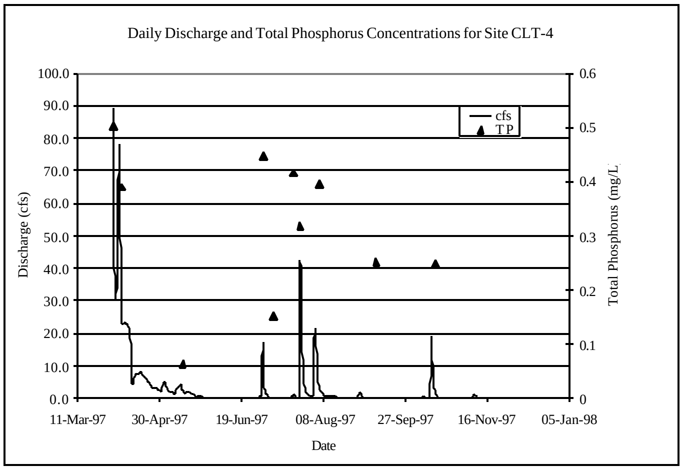


Figure 15.

of 192 mg/l recorded on April 1, 1997. This was the same date when the total phosphorus maximum concentration was observed. The dissolved fraction was slightly less at 59% of the total phosphorus. After the spring runoff the dissolved fraction increased significantly in the remaining samples, resulting in a mean dissolved fraction of 79%. The samples collected from this drainage were consistently higher in phosphorus and suspended solids than the other drainages previously discussed (Table 5).

The mean total nitrogen concentration was 2.90 mg/L which was the highest mean recorded for the project (Table 5). The higher total nitrogen concentrations occurred on the same dates as the higher total phosphorus concentrations (Figure 16). Fecal coliform concentrations did not consistently follow N/P trends although grazing cattle may have been impacting the stream. The concentrations for fecal coliform do not suggest that livestock are a significant problem for this subwatershed. The maximum concentration for the fecal coliforms was 7,600 colonies per 100ml. This concentration is far lower than those for other sites that have been discussed. Although livestock are present, they do not seem to be a significant problem. Most of the local phosphorus and nitrogen seems to be derived from other sources.

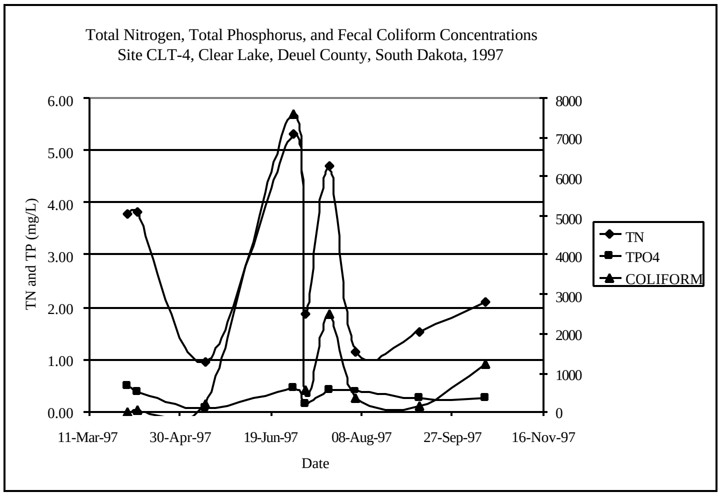


Figure 16

Although AGNPS indicated that the Site CLT-4 subwatershed was a critical subwatershed for Clear Lake, the water quality loadings data did not show a significant problem for this watershed. The 3,000-acre subwatershed discharged 1,572 acre-feet of water which transported 125.4 tons of sediment, 6.71 tons of nitrogen, and 0.75 tons of phosphorus. These loadings convert into relatively moderate individual export coefficients (Table 4).

Site CLT-5

Site CLT-5 is located approximately 1 mile downstream of Site CLT-4 (Figure 17). That drainage area comprises an additional 800 acres which is included in the watershed downstream of the Site CLT-4 subwatershed for a total area of 3,800 acres.

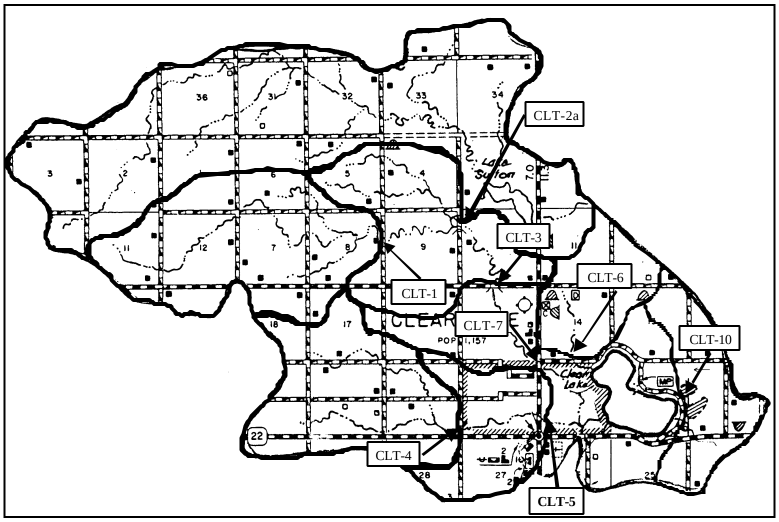


Figure 17

The water quality conditions for Site CLT-5 are reflective of those located above Site CLT-4 and the 800 acres that are located between these two monitoring sites. The mean total phosphorus concentration for Site CLT-5 was significantly higher than those of the other monitoring stations (Table 5). This higher mean concentration can be attributed to a single high concentration which was the maximum TP value recorded for the project. This maximum total phosphorus concentration of 2.400 mg/L was collected on April 1,1997. The maximum suspended solids concentration (316 mg/L) for the project was also observed on this date as well. These extremely high concentrations for phosphorus and suspended solids were collected on the same date as the maximum concentrations for these same parameters were collected from Site CLT-4. On this sample date (April 1) the fraction of dissolved phosphorus was extremely low at 10% whereas the mean for the entire sampling year was 71%. This high concentration of total phosphorus and suspended solids with low dissolved phosphorus is a reflection of the extremely high flows that were occurring at this site during snowmelt runoff.

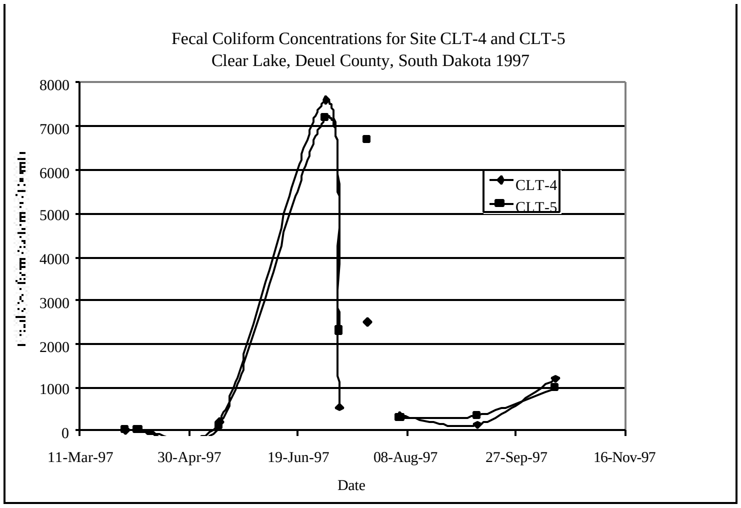


Figure 18

The mean concentration of dissolved phosphorus was slightly lower than at Site CLT-4 (Table 5). This may be attributed to the slightly higher suspended solids mean for Site CLT-5.

The water quality at Site CLT-5 is highly dependent on the water quality at Site CLT-4 upstream. Although there were higher concentrations observed at Site CLT-5 for nutrient and solids parameters, the concentrations followed the same general trends as indicated on Figures 18 and 19. There is a small drainage that contains an additional 800 acres downstream of Site CLT-4 which may be having an impact on the water quality of Site CLT-5. In addition to this smaller drainage there are storm sewer outlets which enter Site CLT-5 under the highway bridge just upstream of where the monitoring station was located. Two water quality samples were collected during 1998 which exhibited high concentrations of nutrients (TP=0.505 mg/L), suspended solids (172 mg/L), and fecal coliform (15,000 colonies/100ml). Although there is a very small portion of the city of Clear Lake included in this subwatershed there are always much higher phosphorus, solids, and coliform concentrations associated with urban runoff.

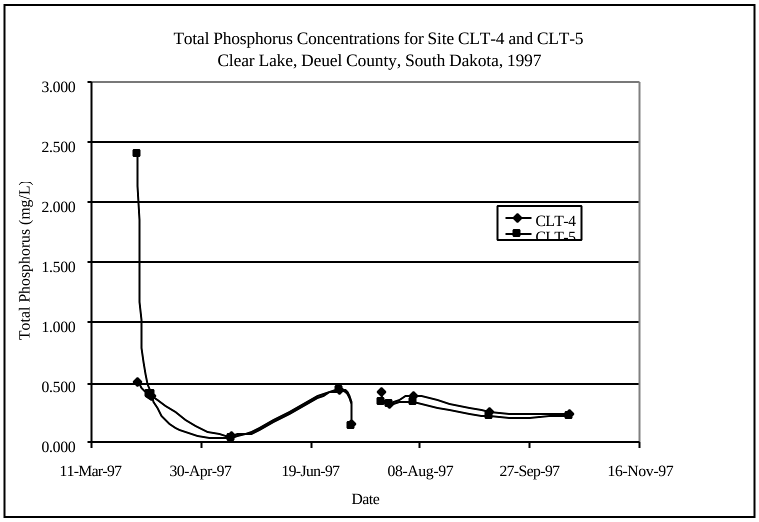


Figure 19

There was 3,384 acre-feet of water discharge through Site CLT-5. This represents a 54% increase between Site CLT-4 and CLT-5. This water transported 597 tons of sediment, 10.4 tons of nitrogen, and 5.1 tons of phosphorus (Table 4). These amounts convert into substantial increases in the suspended solids and phosphorus export coefficients between these two sites. This can be attributed to the much higher concentrations of those parameters that were observed at Site CLT-5 coming from the identified urban and agricultural sources. There is also a golf course located between Sites CLT-4 and CLT-5. Golf courses can provide substantial amounts of nutrients to a stream or other waterbody as a result of high rates of fertilization.

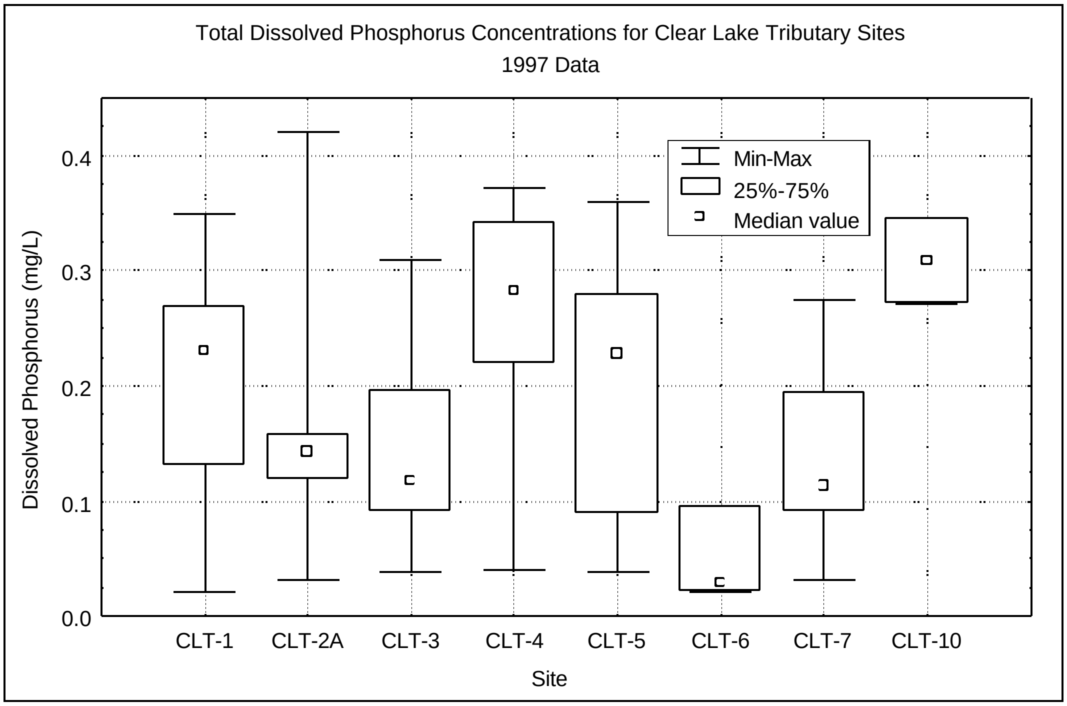


Figure 20

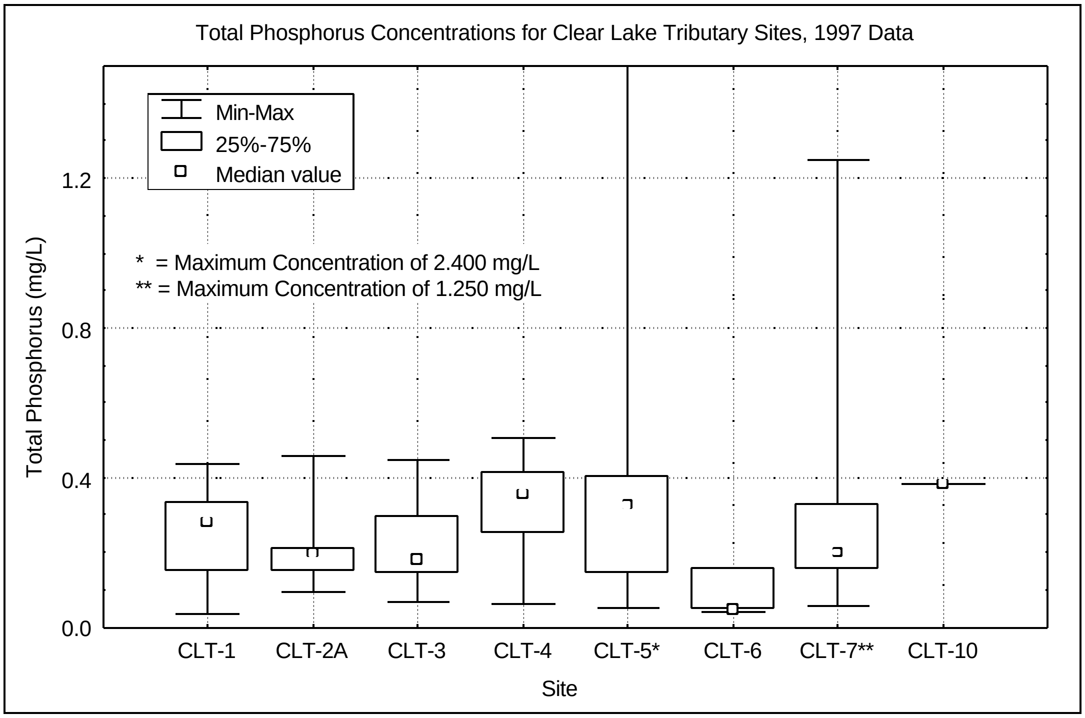


Figure 21

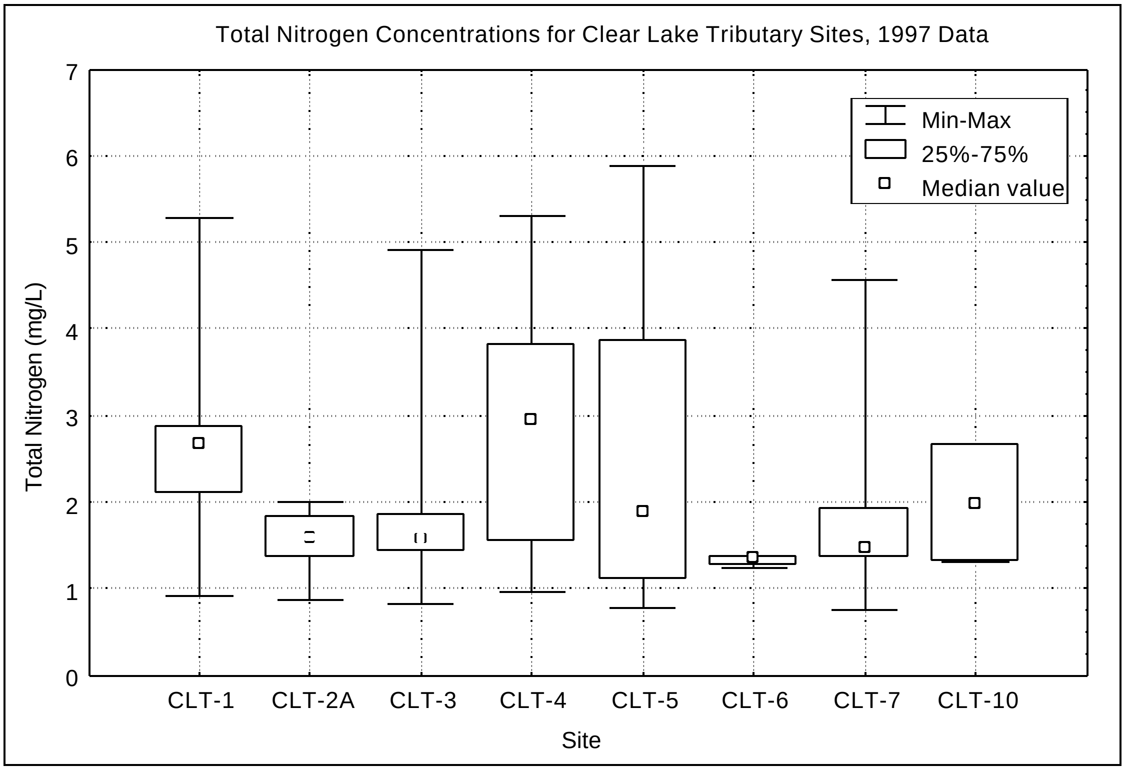

Total Nitrogen Concentrations for Clear Lake Tributary Sites, 1997 Data
Total Nitrogen (mg/L)
0
1
2
3
4
5
6
7
Min-Max
25%-75%
Median value
CLT-1
CLT-2A
CLT-3
CLT-4
CLT-5
CLT-6
CLT-7
CLT-10
Site

Figure 22

Table 4. Total Loadings and Nutrient Export Coefficients for All Tributary Monitoring Sites. Clear Lake, Deuel County, South Dakota, 1997

SITE	Watershed acres	WATER acre-feet	TALKAL lbs/year	TSOL lbs/year	TSSOL lbs/year	TDSOL Lbs/year	AMMO lbs/year	UN-AMM lbs/year	NO3+2 lbs/year	TKN-N lbs/year	Org Nitro lbs/year	Tot Nitro lbs/year	TPO4P lbs/year	TDPO4P lbs/year
CLT-1	3,840	2,725	1,410,626	2,828,604	218,737	2,595,618	1,371	18	11,767	9,971	8,578	21,689	2,096	1,638
CLT-2a	9,000	5,611	2,711,969	6,445,570	134,313	6,313,817	829	49	4,813	16,106	15,268	20,996	2,654	1,949
CLT-3	15,840	27,304	12,617,758	28,447,145	1,147,133	27,304,488	5,263	1,277	41,816	71,213	65,950	113,477	11,726	7,956
CLT-7	16,720	26,010	10,801,260	25,832,941	1,973,650	23,842,203	7,839	150	47,590	61,883	54,044	109,484	29,822	8,819
CLT-4	3,000	1,572	769,143	1,741,106	250,897	1,490,047	997	4	6,684	6,733	5,735	13,415	1,507	1,175
CLT-5	3,800	3,384	1,631,173	4,409,078	1,193,061	3,173,816	2,119	24	11,265	10,092	7,973	20,885	10,138	2,159
CLT-6	1,000	1,508	857,488	1,643,567	18,193	1,625,374	136	7	951	4,550	4,414	5,526	417	261
CLT-10	2,880	452	215,850	390,825	9,821	381,284	243	4	194	2,419	2,177	2,613	468	372

Export Coefficients

Site	Watershed acres	WATER feet	TALKAL lbs/ac/yr	TSOL lbs/ac/yr	TSSOL lbs/ac/yr	TDSOL Lbs/ac/yr	AMMO lbs/ac/yr	UN-AMM lbs/ac/yr	NO3+2 lbs/ac/yr	TKN-N lbs/ac/yr	Org Nitro lbs/ac/yr	Tot Nitro lbs/ac/yr	TPO4P lbs/ac/yr	TDPO4P lbs/ac/yr
CLT-1	3,840	0.71	367	737	57	676	0.36	0.0047	3.06	2.60	2.23	5.65	0.55	0.43
CLT-2a	9,000	0.62	301	716	15	702	0.09	0.0055	0.53	1.79	1.70	2.33	0.29	0.22
CLT-3	15,840	1.72	797	1,796	72	1,724	0.33	0.0806	2.64	4.50	4.16	7.16	0.74	0.50
CLT-7	16,720	1.56	646	1,545	118	1,426	0.47	0.0090	2.85	3.70	3.23	6.55	1.78	0.53
CLT-4	3,000	0.52	256	580	84	497	0.33	0.0012	2.23	2.24	1.91	4.47	0.50	0.39
CLT-5	3,800	0.89	429	1160	314	835	0.56	0.0064	2.96	2.66	2.10	5.50	2.67	0.57
CLT-6	1,000	1.51	857	1,644	18	1,625	0.14	0.0068	0.95	4.55	4.41	5.53	0.42	0.26
CLT-10	2,880	0.16	75	136	3	132	0.08	0.0015	0.07	0.84	0.76	0.91	0.16	0.13

Table 5. Descriptive Statistics for several physical and chemical parameters collected from eight tributary monitoring sites on Clear Lake, Deuel County, South Dakota, 1997.

		WTEMP	FPH	DO	FECAL	TALK	AMM	UN-AMM	NO3+2	TKN	Or-Nit	T-Nit	TPO4P	TDPO4P	%TDP	TS	TSS	TDS
CLT-1	**Mean**	13.4	8.35	7.3	13228	232	0.07	0.0017	1.46	1.25	1.18	2.71	0.254	0.202	79%	465	18	447
	Median	16.0	8.38	6.5	800	222	0.02	0.0016	1.20	1.29	1.19	2.68	0.280	0.231	80%	487	11	468
	StDev	7.5	0.16	2.6	32387	94	0.12	0.0011	0.88	0.51	0.49	1.14	0.126	0.098	0.09	131	19	146
	Minimum	0.0	8.03	5.3	10	92	0.02	0.0007	0.20	0.41	0.39	0.92	0.033	0.022	67%	229	5	161
	Maximum	21.0	8.57	12.8	99000	376	0.38	0.0045	3.30	1.99	1.97	5.29	0.438	0.350	94%	654	68	647
CLT-2A	**Mean**	16.0	8.32	4.3	3830	189	0.10	0.0055	0.19	1.35	1.25	1.54	0.222	0.174	73%	462	9	453
	Median	19.0	8.29	3.6	840	188	0.04	0.0032	0.10	1.45	1.40	1.59	0.198	0.143	76%	482	8	475
	StDev	7.2	0.14	3.2	7566	26	0.15	0.0072	0.22	0.46	0.39	0.37	0.112	0.119	0.18	60	5	60
	Minimum	4.0	8.15	0.6	10	151	0.02	0.0003	0.10	0.55	0.53	0.87	0.096	0.031	32%	344	4	336
	Maximum	24.0	8.54	9.7	24000	227	0.52	0.0245	0.80	1.91	1.65	2.01	0.458	0.421	92%	543	20	535
CLT-3	**Mean**	14.9	8.33	6.6	17174	184	0.06	0.0033	0.58	1.25	1.19	1.82	0.221	0.144	65%	459	32	428
	Median	17.0	8.33	6.1	1400	204	0.02	0.0016	0.35	1.16	1.14	1.58	0.180	0.118	67%	480	16	465
	StDev	7.4	0.20	2.2	35199	54	0.09	0.0063	0.75	0.46	0.45	1.05	0.121	0.079	0.09	118	47	124
	Minimum	0.0	7.92	4.2	10	83	0.02	0.0006	0.10	0.62	0.60	0.82	0.069	0.039	45%	162	11	146
	Maximum	23.0	8.67	10.0	95000	256	0.28	0.0232	2.80	2.12	2.10	4.92	0.445	0.310	77%	590	178	561
CLT-7	**Mean**	16.2	8.40	7.5	15082	190	0.07	0.0051	0.54	1.21	1.14	1.75	0.305	0.143	57%	499	43	456
	Median	19.0	8.42	6.8	1550	203	0.02	0.0023	0.30	1.19	1.15	1.48	0.198	0.113	58%	506	31	470
	StDev	7.5	0.14	2.2	24662	51	0.08	0.0074	0.73	0.46	0.46	0.95	0.303	0.071	0.15	112	39	105
	Minimum	0.0	8.09	5.0	10	92	0.02	0.0008	0.10	0.41	0.18	0.76	0.059	0.031	16%	265	8	199
	Maximum	24.0	8.59	11.2	64000	242	0.24	0.0281	2.80	2.12	1.88	4.57	1.250	0.274	75%	670	146	586
CLT-4	**Mean**	13.6	8.32	6.4	1401	224	0.09	0.0019	1.43	1.47	1.38	2.90	0.319	0.254	79%	518	31	487
	Median	16.0	8.33	5.9	350	225	0.02	0.0016	1.10	1.34	1.29	2.94	0.355	0.283	84%	535	18	523
	StDev	7.1	0.10	1.4	2456	101	0.15	0.0015	1.16	0.54	0.49	1.56	0.139	0.111	0.12	141	57	173
	Minimum	0.0	8.16	4.7	20	97	0.02	0.0006	0.20	0.75	0.73	0.95	0.064	0.041	59%	319	4	169
	Maximum	20.5	8.44	8.8	7600	387	0.39	0.0049	3.40	2.39	2.17	5.30	0.504	0.371	95%	708	192	704
CLT-5	**Mean**	15.4	8.40	7.9	2180	233	0.10	0.0026	1.26	1.24	1.14	2.50	0.455	0.209	71%	555	43	512
	Median	17.3	8.38	7.8	675	253	0.02	0.0020	0.70	1.16	1.14	1.88	0.326	0.228	76%	534	13	531
	StDev	7.3	0.13	2.0	2792	100	0.19	0.0018	1.31	0.47	0.46	1.71	0.656	0.108	0.23	141	91	185
	Minimum	0.0	8.14	5.6	10	97	0.02	0.0008	0.10	0.67	0.38	0.77	0.050	0.038	10%	305	3	154
	Maximum	22.0	8.60	11.4	7200	389	0.60	0.0068	4.00	1.90	1.87	5.89	2.400	0.360	90%	729	316	719
CLT-6	**Mean**	17.0	8.44	7.6	10	214	0.03	0.0019	0.20	1.12	1.09	1.32	0.082	0.049	58%	413	6	407
	Median	17.0	8.62	7.1	10	174	0.02	0.0015	0.10	1.15	1.13	1.35	0.045	0.029	60%	428	4	424
	StDev	11.3	0.35	3.2	0	71	0.02	0.0017	0.17	0.14	0.16	0.06	0.066	0.041	0.11	66	3	64
	Minimum	9.0	8.04	4.7	10	172	0.02	0.0004	0.10	0.97	0.92	1.25	0.043	0.021	47%	341	4	337
	Maximum	25.0	8.66	11.0	10	296	0.05	0.0038	0.40	1.25	1.23	1.37	0.159	0.096	67%	471	10	461
CLT-10	**Mean**	25.0	8.25	4.5	505	179	0.18	0.0035	0.15	1.83	1.66	1.98	0.381	0.309	81%	318	8	310
	Median	25.0	8.25	4.5	505	179	0.18	0.0035	0.15	1.83	1.66	1.98	0.381	0.309	81%	318	8	310
	StDev		0.27	6.0	672	26	0.21	0.0007	0.07	0.89	0.69	0.96	0.000	0.052	0.14	29	6	35
	Minimum	25.0	8.06	0.2	30	160	0.03	0.0030	0.10	1.20	1.17	1.30	0.381	0.272	71%	297	3	285
	Maximum	25.0	8.44	8.7	980	197	0.32	0.0041	0.20	2.46	2.14	2.66	0.381	0.345	91%	338	12	335

Site CLO-9

This site is located on the outlet of Clear Lake (Figure 23). It was used to determine the hydrologic, sediment and nutrient budget for Clear Lake. The subwatershed size for CLO-9 includes all the subwatersheds previously described (Sites CLT-1-CLT-10). The total area according to the AGNPS computer program is 27,360 acres.

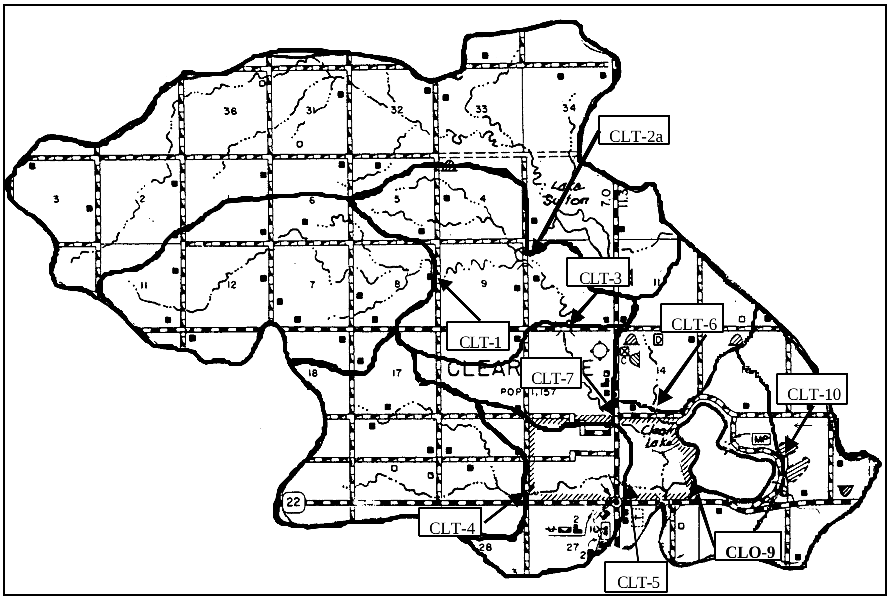


Figure 23

Site CLO-9 should be different, comparatively speaking, due to its location on the outlet of Clear Lake. The water quality of the outlet of Clear Lake is not only determined by how much material was deposited in the lake but also by the amount of this material that was used in the biological processes within the lake.

Clear Lake acts as a sediment and nutrient sink retaining a high percentage of the nutrients and sediment discharged into its basin. The outlet water quality is a function of what has been discharged into the lake. Site CLO-9 was monitored for the same period of time as the other sites previously discussed. No point sources were located within the area of the outlet that may have potentially affected the water quality or loading data. The regression analysis conducted between the instantaneous discharge and stage was very good ($R^2 = 0.97$, n=26, df=25).

As discussed above, the water quality data for the outlet of Clear Lake are a reflection of the water quality of the lake. The maximum fecal coliform concentration recorded at the outlet was 470 colonies/100ml during the course of the investigation. However, the median concentration was 40 colonies/100ml. There were several samples that exhibited concentrations ranging between 10 fecal colonies/100 ml to 80 fecal colonies/100ml. A comparison with the nearest inlake Site CL-2 did not indicate any problems with fecal coliform. The mean coliform concentration for Site CLO-9 of 89 colonies/100ml was lower than at any other site with the exception of Site CLT-6 (Tables 5 and 6).

The suspended solids (TSS) concentrations at Site CLO-9 were relatively low as well (19 mg/L). The lowest mean TSS concentration was recorded at Site CLT-6 (6 mg/L). The mean concentration for Site CLO-9 was well within the range of the other tributary monitoring sites. The median was actually lower at 16 mg/L. The concentrations were consistently within the range of 13 mg/L to 24 mg/L during the course of the summer sampling months. These higher

Table 6. Descriptive Statistics for several physical and chemical parameters collected from the outlet of Clear Lake (Site CLO-9), Deuel County, South Dakota, 1997.

SITE		WTEMP	FPH	DO	FECAL	TALK	AMM	UN-AMM	NO3+2	TKN	Or-Nit	T-Nit	TPO4P	TDPO4P	%TDP	TS	TSS	TDS
CLO-9	**Mean**	18.0	8.86	7.7	89	163	0.05	0.0071	0.24	1.41	1.36	1.65	0.188	0.097	45%	426	19	407
	Median	22.3	8.94	8.2	40	159	0.02	0.0069	0.10	1.33	1.31	1.62	0.159	0.075	42%	409	16	391
	StDev	8.1	0.34	2.2	145	36	0.08	0.0045	0.41	0.40	0.36	0.47	0.110	0.103	0.19	51	11	51
	Minimum	2.5	8.28	3.3	10	104	0.02	0.0011	0.10	0.97	0.95	1.07	0.086	0.019	21%	352	7	338
	Maximum	24.5	9.24	11.2	470	232	0.27	0.0173	1.40	2.09	1.96	2.42	0.438	0.373	85%	530	44	523

Table 7. Total Loadings for the Outlet of Clear Lake (Site CLO-9). Clear Lake, Deuel County, South Dakota, 1997

SITE	Watershed	WATER	TALKAL	TSOL	TSSOL	TDSOL	AMMO	UN-AMM	NO3+2	TKN-N	Org Nitro	Tot Nitro	TPO4P	TDPO4P
	Acres	acre-feet	tons/year	tons/year	tons/year	tons/year	tons/year	tons/year	tons/year	tons/year	tons/year	tons/year	tons/year	tons/year
CLO-9	27,360	28,825	9,071	10,236	394	9,842	9.3	0.1	18.0	44.5	35.3	62.6	2.9	1.2

concentrations during the summer may be due to the higher amounts of organic material suspended in the water. Algae and aquatic plant material may have been transported through the outlet during this time period. Also, some of the incoming solids remained suspended to be discharged from the lake.

Ammonia concentrations were not significantly different from than any of the other tributary monitoring sites. The mean ammonia concentration was 0.05 mg/L, which is within the range of the sites previously discussed (Table 5 and 6). The highest mean for all the tributary sites was collected from Site CLT-10 (0.18 mg/L). Nitrate samples had a maximum concentration of 1.4 mg/L that occurred on July 25, 1997 but this was the only peak in concentrations. The remaining 9 samples did not exceed 0.2 mg/L (Table 6).

Concentrations of phosphorus found at Site CLO-9 are greatly effected by the settling rate of inlake phosphorus and how much is used for plant and animal biomass. The lake acts as a sediment and phosphorus sink retaining material that is transported from the upstream tributary sites. The mean total phosphorus concentration decreased between Site CLT-7 (0.305 mg/L) and Site CLO-9 (0.189 mg/L), a similar reduction in dissolved phosphorus occurred as well (CLT-7 = 0.143 mg/L, CLO-9 = 0.097 mg/L). As the growing season intensifies during the summer, the increase in biomass requires more dissolved phosphorus, i.e. the dissolved phosphorus concentration becomes smaller at the outlet site than at the inlet site. Periodically, during the growing season the outlet concentrations are slightly higher which may indicate that an algal bloom had collapsed in Clear Lake. As the algal bloom was decomposed by bacteria, dissolved phosphorus was released and discharged. There was also a slight drop in the dissolved oxygen level at this time. Also, during most of the sampling year the fraction of dissolved phosphorus was below 50%. The mean fraction of dissolved phosphorus was 45% (Table 6) which is what may be expected at the outlet of a lake. There was only one instance where the fraction of dissolved phosphorus exceeded 80%.

The nutrient and sediment loadings discharged from Site CLO-9 are dependent upon how much of the nutrient and sediment material was retained by the lake. There was a substantial reduction in the amount of suspended solids and total phosphorus but there was a large increase in ammonia loadings between Site CLT-7 and Site CLO-9. The lake is using some of the nitrates earlier in the season as biomass increases, Site CLO-9 ammonia is released during the subsequent breakdown of algae and other vegetation and some of it then leaves the lake through the outlet.

Hydrologic Budgets

The hydrologic load explains how much water entered the lake and how much water left the lake. Theoretically, all inputs of water must equal all outputs during the course of hydrologic cycle. However, monitoring all the possible inputs to a lake is very difficult. In some cases, estimates of the water load to the lake are needed to help balance the equation. The hydrologic inputs to Clear Lake come from many sources; precipitation, tributary run-off, indirect runoff, and groundwater. The period of record used to develop the loadings was March – October, 1997. In order to calculate the precipitation inputs, 1997 rainfall data was taken from the weather station located within the city of Clear Lake. Evaporation, which is an output of water, was not collected at this weather station. The nearest weather station that collected evaporation data was 2 miles northeast of Brookings. The amount of evaporation and precipitation in inches was converted to feet and multiplied by the surface area of Clear Lake (532 acres). In the case of the evaporation data, the monthly pan evaporation rates were multiplied by the Class A monthly land pan coefficients for the midwestern United States to derive a monthly evaporation rate for each lake (Roberts and Stall, 1967; in Fetter, 1988).

The five main inputs into Clear Lake are Subwatershed CLT-7 (input from the northwestern Tributary), CLT-6 (wetland from the north), CLT-10 (wetland from the east), ungauged runoff, and precipitation. The ungauged runoff primarily involves direct runoff from the immediate watershed for Clear Lake. All of these sources of water must be considered in the overall water budget. These small tributaries (ungauged sources) were not monitored but their surface area (drainage area) was calculated using the AGNPS computer program (see AGNPS Report in Appendix A for a discussion on these individual tributaries).

Table 8. HYDROLOGIC BUDGET - Clear Lake

	Surface Area 532 acres	**Volume 2,400 ac-ft**	
Input Sources	**Load (ac-ft)**	**Output Sources**	**Load (ac-ft)**
Precipitation	1,159.8	Evaporation	1,299.2
CLT-7	26,010.8	Outlet (CLO-9)	28,826.0
CLT-6	1,508.3	Groundwater	896.0
Change in Storage (neg.)	-643.7		
CLT-10	452.0		
Ungauged Runoff	2,534.0		

At the end of the monitoring period (November 12, 1997) the level of Clear Lake was 0.06 feet above the spillway. The differences between the beginning (1.27 ft) and ending (0.06 ft) of the monitoring period is 1.21 feet which constitutes 643.7 acre-feet (1.21 * 532 acres) for negative in storage. Change in storage accounts for changes in surface elevation over the study period. A negative change occurs if the lake volume decreases over the study period. A negative change of 643.7 acre-ft occurred for Clear Lake during 1997 (Table 8).

After the estimates of ungauged runoff were added to the Clear Lake inputs, the groundwater had not been added to the hydrologic budget. The total outflow from the outlet and evaporation was 30,125.2 ac-ft. The outflow was still short 896 ac-ft when compared to all of the input sources. The only other output source not yet included in the budget was groundwater. Inputs and outputs to and from groundwater are generally very difficult to assess and the amount of water needed to balance the hydrologic budget seemed low. However, the regression equations used to calculate the daily discharge estimates were very good (CLT-7 R^2 = 0.99, and CLO-9 R^2 = 0.98). This area of South Dakota has been in a wet cycle and the water table has been above normal.

Suspended Solids Budget

Based on the suspended solids loading data collected during 1997 from CLT-7, suspended solids (sediment) do not appear to be an impairment for Clear Lake. According to the data collected, including all of the inputs in Table 6, Clear Lake shows less than 1 acre-foot of sediment entering the lake annually from all documented sources. However, this should not deter the implementation of BMPs within those critical erosion areas identified by AGNPS. Assuming that the sediment is uniform silt, the load was divided by the total pounds of sediment entering the lake (2,001,663.7 pounds) by a factor of 135 pounds per cubic foot (Uniform Silt = 135 lbs/ft^3) (Kuck, 1998). The cubic feet were then converted to acre-feet for a total of 0.34 ac-ft of sediment. There may be more sediment entering Clear Lake from the bedload of a stream. However, all tributary samples collected during this investigation were collected with a suspended sediment sampler (DENR SOP, 1998). This sampling method is much more accurate for calculating sediment loadings than using the simple grab sample method. If the amount of suspended solids entering Clear Lake is doubled to include sediments that may have been missed, the rate of deposition of sediment for Clear Lake would still be less than 0.02 inches per year over the entire surface area of Clear Lake. It is not known how much of the suspended solids are actual inorganic sediment or organic matter (decaying plants and vegetation). Due to the amount of intensive agriculture, some of the suspended solids would be inorganic. However, during the course of the study, Clear Lake accumulated 607 tons of sediment, which constitutes 0.005 inches of sediment over the entire surface area of the lake.

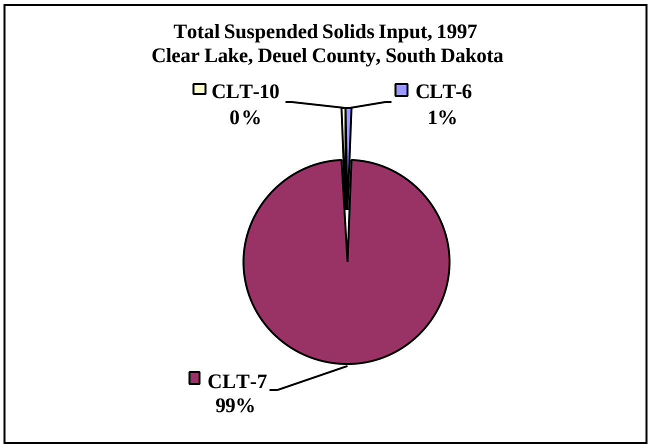


Figure 24

Nitrogen Budget

Based on the data collected during 1997, the inlake volume of total nitrogen in Clear Lake decreased by 3.8 tons, i.e. more nitrogen left the lake than was delivered to it. The majority of the nitrogen that was discharged was ammonia and organic which means that the nitrogen was tied up in plant and algal biomass. During 1997, the lake actually accumulated 1.18 tons of inorganic nitrogen in the form of nitrate+nitrite nitrogen. What happened to the inorganic nitrogen was that it was taken up by the aquatic plants and algae species

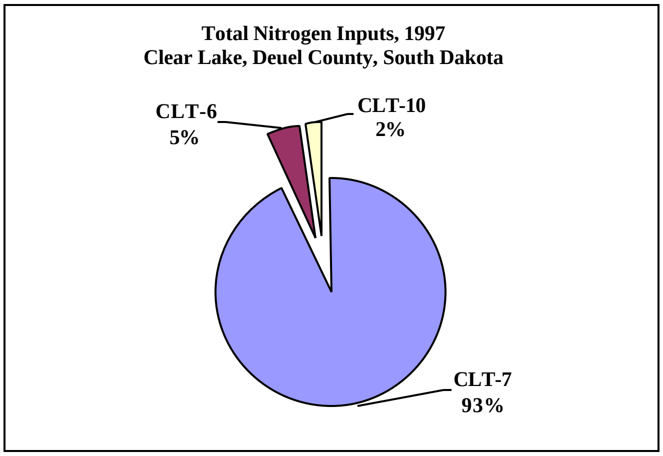


Figure 25

during the creation of more biomass (production). As the year progresses and these plants and algae die off the converted inorganic nitrogen is discharged from the lake as an organic form (decaying plants and algae). Also, a by-product of the biodegradation process is the release of ammonia. Most of the ammonia was discharged during the very early spring runoff due to buildup over the winter and there was another peak discharge of ammonia during the mid to late summer when the algal blooms occur. As the algal blooms collapse, one of the primary byproducts of biodegradation is ammonia. Algae consist of organic nitrogen and other materials and most of the organic nitrogen discharged through the outlet was contained within the algal cells. As some species of blue-green algae are able to convert unusable forms of nitrogen into more usable forms, nitrogen is very difficult to control.

Table 9.

Nitrogen Form	**Total Inputs**	**Total Outputs**
Inorganic	48%	44%
Organic	52%	56%

Phosphorus is more easily managed. Forty-eight percent of the nitrogen delivered to the lake was in the inorganic form (nitrates) whereas 56% of the nitrogen output from Clear Lake was in the organic form (Table 9).

Phosphorus Budget

Phosphorus inputs to Clear Lake during the 1997 sampling season totaled 30,707 lbs. (15.3 tons). Site CLT-7 was responsible for 97% of the total phosphorus delivered to the lake (Figure 26) but only constituted 84% of the hydrologic input (Table 8).

The groundwater contribution to the phosphorus budget was insignificant. Site CLT-6 and CLT-10, which drain small subwatersheds to the north and east of Clear Lake, only contributed 3% of the total phosphorus budget for Clear Lake. The ungauged runoff was also assumed to provide an in insignificant contribution to the lake.

Clear Lake retained 24,822 lbs (12.4 tons) of total phosphorus during 1997. More phosphorus entered the lake than left the lake through external sources (CLO-9a). Ninety-one percent of the phosphorus delivered to the lake was received during the spring season, which is when 85% of the hydrologic load occurred. The total phosphorus loading during the spring is then primarily used by the lake for algal production during the summer. Although the lake discharged a smaller portion of phosphorus during the spring (74%) this is to be expected. There is lag period where the total phosphorus works its way through the Clear Lake system allowing algae to use the bioavailable phosphorus. The material discharged into the lake during the spring

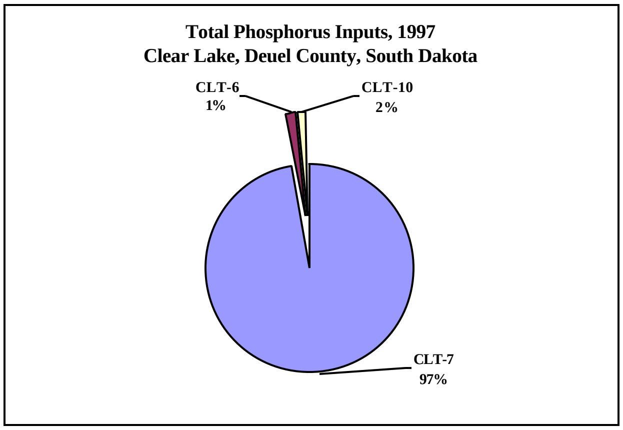


Figure 26

would take some time to work its way to the outlet which is why the loading rate for the outlet is slightly higher during the summer. This also allows phosphorus to settle to the bottom of the lake.

Site CLT-7 delivered 81% of the total dissolved phosphorus load during the spring and 14% during the summer. The outlet of Clear Lake (Site CLO-9) delivered a reduced amount of dissolved phosphorus during the spring (66%). This can be attributed to the Clear Lake ecosystem which would use some of the bioavailable phosphorus. However, the hydraulic residence was so short during 1997 that a large amount of the bioavailable phosphorus was released through the outlet.

Urban Runoff

Urban stormwater runoff was, prior to 1980, considered to be an insignificant source of water quality degradation. However, the completion of the National Urban Runoff Program (NURP) indicated that there has been significant degradation to the water quality of the receiving waters from this stormwater runoff. In 1987, the Clean Water Act required municipalities with a population of 100,000 or more to receive a permit under the National Pollutant Discharge Elimination System (NPDES). This permit emphasizes the use of Best Management Practices (BMPs) to reduce pollutant loadings. Although cities smaller than 100,000 people are not required to obtain a NPDES permit, they can still have a significant impact on the receiving water body and should implement BMPs to improve the water quality of their urban runoff (USEPA, 1992(2)).

During 1998, nine grab samples were collected from nine storm sewer outlets within the city limits of Clear Lake. The following parameters were chosen for laboratory analysis:

Fecal Coliform
Total Phosphorus
Alkalinity
Total Kjeldahl Nitrogen
Dissolved Oxygen
Dissolved Phosphorus
Nitrate
pH
Ammonia
Total Solids
Dissolved Solids
Suspended Solids

There were three locations within the city of Clear Lake where storm sewer samples were collected:

1) Under U.S. Highway 77 near Site CLT-5, two culverts drain the streets of Clear Lake emptying directly into the stream. One drains from the north and the other from the south. Both drain residential, light industrial, and downtown business areas.
2) A small drain tile drains the areas surrounding the city park and enters the main northwestern tributary near Site CLT-7. This site drains primarily residential areas and empties directly into the stream.
3) Two large culverts located directly south of the grain elevator drain most of the downtown area of Clear Lake. These main storm sewers empty into a field directly east of the city of Clear Lake before draining into the northwestern tributary.

Concentrations of Parameters in Stormwater Runoff

All samples collected in 1998 were collected between March and June. Only two samples were collected at each site. The first sample was collected on March 25, 1998 and the last sample was collected on June 15, 1998. High levels of bacteria (fecal coliform) were found at all five sites (Table 10). The National Urban Runoff Program (NURP) reported that urban runoff typically contains coliform densities of 10,000 to 100,000 organisms per 100 ml.

The fecal coliform count per 100 ml ranged from 20 to 61,000, respectively (Table 10). However, all five sites exhibited concentrations exceeding 15,000. There are some potential health risks associated with primary (swimming) and secondary (boating) contact recreation that takes place in water bodies exhibiting high counts of these bacteria (USEPA, 1993). Pet and bird wastes can be sources of increased bacteria. Organic wastes and sanitary sewer overflows can also be a source.

Total phosphorus concentrations ranged from a minimum value of 0.270 mg/L (Site CLT-5 culvert on south side) to a maximum value of 9.13 mg/L (sampled from a drain tile draining out of the city park located near Site CLT-7). The mean total phosphorus concentration from the storm sewer samples was 1.58 mg/L which is significantly larger than any of the tributary sites. Site CLT-5, located within the city limits of Clear Lake, exhibited the highest mean for the Clear Lake tributary sites (0.455 mg/L). In comparison, the mean for the storm sewer sites was 1.58 mg/L, or 3.47 times as high. The total dissolved phosphorus concentrations ranged from a minimum of 0.073 mg/L to a maximum concentration of 7.28 mg/L. The maximum concentration for dissolved phosphorus was also sampled from the drain tile near Site CLT-7. The largest dissolved phosphorus concentration for the tributary sites sampled in 1997 was 0.421 mg/L collected from Site CLT-2a. Urban runoff typically contains high concentrations of nutrient runoff. As explained earlier excessive nutrients encourage undesirable algal blooms. The sources of nutrients in urban runoff arise from chemical fertilizers used on lawns, parks, and golf courses as well as in other chemical forms from roads, sidewalks, parking lots, homes, and commercial sites (Terrene, 1994).

Total suspended solids exhibited very high concentrations from all storm sewer samples collected in 1998. Concentrations ranged from a minimum of 23 mg/L (drain tile near Site CLT-7) to a maximum of 348 mg/L collected from storm sewers draining most of main street in Clear Lake. The outlet for these main street storm sewers is located directly south of the elevator. There were very high concentrations exhibited from every storm sewer site. The mean concentration for suspended solids was 167 mg/L. Again, the mean concentration for the storm sewers was significantly higher than any of the tributary sites sampled in 1997. Suspended solids or sediment (organic and inorganic) are derived from many areas. Sediment loading occurs from soil erosion and runoff from construction sites and other urban land. Urbanization increases the rate of storm water runoff by removing vegetation and changed slopes. The increased rate of runoff transports sediment from erosion, litter and road sanding. Other pollutants such as nutrients and metals attach to the sediment particles and are transported downstream as well (USEPA, 1993; Terrene, 1994).

To determine whether the high total phosphorus concentrations were sediment based, a regression analysis was conducted between total phosphorus and suspended solids concentrations. The analysis indicated that the high concentrations in total phosphorus were not significantly related to the high concentrations of suspended solids (R^2=0.17,n=9,df=8). This means that the nutrient concentrations are derived from other sources besides sediment.

The storm sewer mean ammonia concentration was significantly higher than the mean concentrations from the tributary samples collected in 1997. The mean concentration from the storm sewers was 0.78 mg/L whereas the highest mean concentration from the tributary sites was 0.18 mg/L. However, this mean concentration was biased by one extremely high concentration of 4.85 mg/L. The ammonia concentrations from the city ranged from a minimum concentration of 0.07 mg/L (drain tile near Site CLT-7) to a maximum concentration of 4.85 mg/L which was collected from the same site. The ammonia concentrations from the remaining 4 storm sewer sites were not excessively higher than the tributary concentrations. Urban sources of ammonia are similar to the sources for bacteria and nutrients.

Although dissolved oxygen concentrations were relatively high, ranging from a minimum concentration of 7.8 mg/L to a maximum of 10.6 mg/L (Table 10) there exists a potential for reduced oxygen concentrations due to high levels of nutrients and sediment. Oxygen-demanding matter such as sediment (inorganic and organic), litter, organic wastes, etc. during periods of warmer temperatures, create low oxygen conditions in the receiving water body. In fact, a major urban runoff event into a stream can severely deplete local oxygen supplies. In addition, the water temperature of urban runoff is typically higher than from other forms of runoff due to the heat-absorbing nature of the substrate, i.e. pavement and sidewalks. Higher temperatures further reduce the ability of water to hold as much oxygen.

The pH for the urban samples collected in 1998 ranged from a minimum of 7.92 su to a maximum of 8.26 su (Table 10). These values are not significantly different from the tributary samples collected in 1997.

Other parameters that were not analyzed but are typically present in urban runoff are oil and grease, chlorides, trash and debris, which can all have varying degrees of degradation on the receiving water body. The impervious surfaces of urban areas result in a complete change of hydrology. Paved surfaces absorb less rainfall and increase the velocity of stormwater runoff. This increase in velocity transports sediment and other pollutants more rapidly and with more force, which can result in streambank erosion. With the increased velocity, sediment and other pollutants are not allowed to settle out as they naturally would in a wetland and grassed waterway. The sediment load is completely discharged into the receiving water body which can severely degrade the aquatic habitat.

The local storm sewers have very little watershed area in comparison to the larger 27,360 acre watershed of Clear Lake. However, the paved surfaces of urban areas do not allow any filtering to take place or reduce the velocity of water to allow sediment to drop out. The phosphorus export coefficients (lbs of phosphorus per acre) from urban areas are extremely high in comparison to a typical agricultural watershed. It should be recommended that any future upgrades to the city of Clear Lake storm sewer network include best management practices that will reduce the velocity and improve the quality of water entering the main tributaries associated with the Clear Lake watershed. Stormwater retention basins can be constructed to reduce the impact or reduce the velocity of the water to allow sediment and nutrients to drop out prior to the water entering the main tributaries. Also, a more aggressive street cleaning campaign can reduce the nutrient and sediment loadings to a waterbody. A final alternative that would be easy to carry out is a “drains-to-stream/ lake campaign” in which service clubs such as the Boy Scouts stencil storm drains with “Drains to Stream/Lake”. This logo may help reduce the amount of fertilizers and, oil and grease that are transported from the storm sewer network into the receiving waterbody.

If rerouting of storms sewers or other best management practices are installed, it will significantly reduce or eliminate the loadings from the city to the lake and help in reaching a 20-30% reduction in overall phosphorus loadings to Clear Lake, thereby reducing the intensity and severity of nuisance algal blooms.

Table 10. Urban Storm Sewer Samples Collected from 5 different locations within the city of Clear Lake, 1998.

DATE	SITE	A TEMP	W TEMP	P H	DO	COLIFORM	ALKA-M	TKN	AMMONIA	NITRATE	TPO4	TDPO4	TSOL	TSSOL	TDSOL	VTSS
		(C)	(C)		(mg/L)	(per 100 ml)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
25-Mar-98	CLT-5 North		5.0	8.18	10.40	30	103	1.68	0.26	0.4	0.505	0.088	465	172	293	12
15-Jun-98	CLT-5 North	18	17.0	8.03	8.40	15,000	44	1.39	0.26	0.6	0.290	0.073	161	72	89	16
25-Mar-98	CLT-5 South		5.0	8.11	10.60	20	84	1.55	0.22	0.4	0.390	0.095	399	136	263	16
15-Jun-98	CLT-5 South	18	17.0	8.05	8.40	31,000	46	1.35	0.24	0.8	0.270	0.076	179	72	107	8
15-Jun-98	Elevator north	18	17.0	8.12	7.90	30,000	90	0.97	0.19	1.8	0.602	0.428	262	76	186	10
01-Jun-98	Elevator south	16		7.92		20,000	91	7.15	0.83	1.4	1.8	0.84	586	348	238	60
15-Jun-98	Elevator south	18	17	8.03	7.8	35,000	95	0.98	0.13	1.3	0.92	0.128	522	340	182	48
01-Jun-98	Park Tile	16		8.00		61,000	117	9.95	4.85	1.6	9.13	7.28	513	260	253	32
15-Jun-98	Park Tile	18	16	8.26	8	78,00	180	1.82	0.07	0.9	0.36	0.319	373	23	350	4

Clear Lake Inlake Water Quality Discussion

The beneficial uses for Clear Lake and the standards pertaining to these uses were discussed previously and will not be included here.

Water Temperature

This 532-acre (215.3 ha) lake is very shallow and windswept lake (Mean Depth = 4.5 ft) (Stueven et al., 1996) which does not allow thermal stratification to take place. Surface temperatures ranged between 0^{o}C in the winter to a maximum temperature of 25.5^{o}C in the summer. There was no significant difference between the two monitoring sites (Site CL-1 mean = 9.9^{o}C and Site CL-2 mean = 9.7^{o}C) (Figure 27).

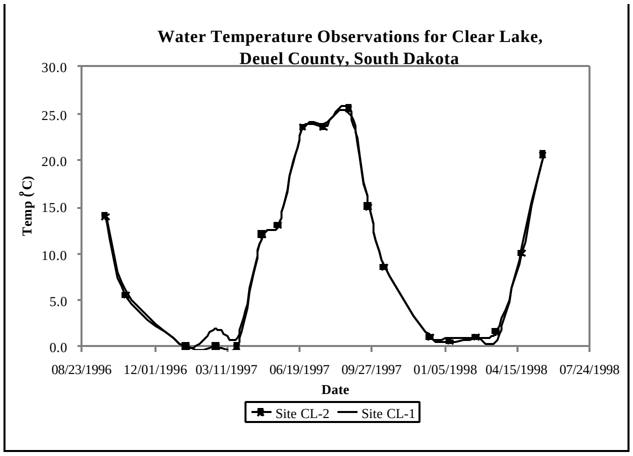


Figure 27

Dissolved Oxygen

There was no significant difference between the two monitoring sites. The average concentrations for the two inlake sites were 8.67 and 7.88 mg/L, respectively. The range of dissolved oxygen values for Site CL-1 were 1.20 –18.10 mg/l and for Site CL-2 were 1.25-11.60 mg/L. The dissolved oxygen data for Clear Lake did not exhibit any incidences of anoxia during the study. Although during the winter of 1996-97 lower concentrations of oxygen were documented. The lowest concentrations for both sites were collected on February 24, 1997. This was during the 1996-97 winter which exhibited extreme depths of snow. As can be seen in Figure 28, concentrations of dissolved oxygen dropped severely during the winter and did not climb back to normal levels until the month of March'97. This was due primarily to sunlight not being able to penetrate the snow

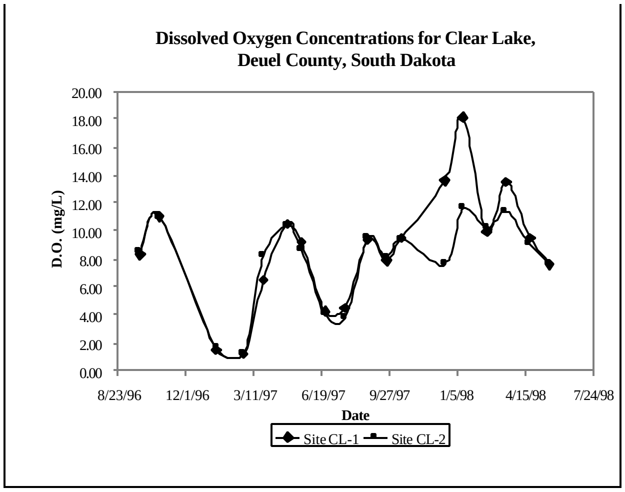


Figure 28

and reducing rates of photosynthesis for algae which is usually facilitated by lack of snow on the ice as it was during the winter of 1997-98 (Figure 29). With the lower temperatures water can hold more oxygen and algae underneath the ice can conduct photosynthesis producing oxygen. However, when there is an excessive depth of snow on the ice the algae is prevented from producing oxygen through photosynthesis resulting in lower concentrations of oxygen and corresponding fish kills due to the lack of oxygen (winterkill). This is especially true with very shallow lakes such as Clear Lake where the mean depth is 4.5 feet.

A similar phenomenon can occur during the summer in which higher temperatures do not allow water to hold as much oxygen. During a collapsing algal bloom in which the algae begin to die off there is a reduction in the photosynthetic rate, i.e. reduction in oxygen production. This lack of oxygen results in a summer fish kill that can be primarily linked to the high levels of nutrients and the resulting algal blooms. Clear Lake did exhibit reduced levels of oxygen during the summer of 1997 (Figure 28). Exceedances of the dissolved oxygen standard were discussed earlier in the water quality standards section.

pH

Clear Lake exhibited no significant differences between the two monitoring sites. The average pH measurements for each site was 8.40 and 8.36, respectively (Table 11). The minimum value was 7.51 su sampled from Site CL-1 on February 24,1997. The maximum value of 9.30 su was recorded as an exceedance of the water quality standards. This value was recorded from Site CL-2 on August 26,1997. The pH from Site CL-1 was 9.16 on this same date which was also an exceedance of the water quality standards. There were 4 other instances in which the pH standard of 9.00 su was exceeded. Please see the water quality standards section for further discussion. The only plausible explanation for these higher pH readings is that increased photosynthesis and the resulting high uptake of carbon dioxide by the summer algae bloom drove the pH up. The predominant chemical species were HCO_3^- and CO_3^{2-} as a result of the uptake of CO_2 (Carbon Dioxide) by the algae. After the algal growth occurs, rates of photosynthesis may decrease and the lake is allowed to equilibrate and pH shifts back down below 9.00 to the 8.00 range where the predominant carbonate species is the bicarbonate ion (HCO_3^-). Clear Lake usually recovers quickly in these

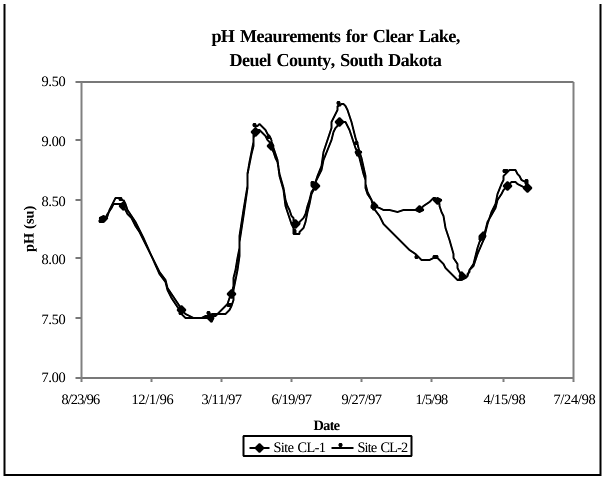


Figure 29

situations as a result of an adequate buffering capacity. There was also slight drop in the total alkalinity and dissolved solids concentrations during the periods when the higher pH readings occurred (Figure 30 and 31). These two parameters play a role in regulating or buffering the pH. When their concentrations decrease the pH can increase.

Alkalinity

Lakes within the State of South Dakota usually range from 150 to 200 mg/L. The minimum value for Clear Lake was 148 mg/L collected from Site CL-2 and the maximum value of 204 mg/L was collected from Site CL-1. No significant differences were exhibited between sites. The trend towards increasing alkalinity during the winter months was exhibited by Clear Lake. This may be an indication that during the winter months groundwater is more of an influence than during the rest of the year (Figure 31). Interestingly the pH dropped during periods when alkalinity increased (Figure 30).

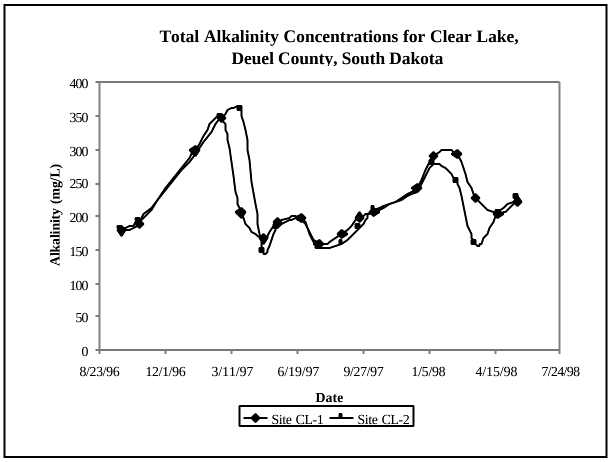


Figure 30

Fecal Coliform

Fecal coliform is used as an indicator of human or animal wastes. There were 36 inlake fecal coliform samples collected during the project (9/24/96 – 5/20/98). Of the 36 samples only six samples exceeded 10 colonies per 100 ml. The maximum concentration exhibited was 110 per 100 ml which was collected from Site CL-2. The mean concentrations for Sites CL-1 and CL-2 were 15 and 19 colonies per 100 ml, respectively. No exceedances occurred for this lake.

Table 11. **Descriptive Statistics for Two Inlake Monitoring Sites from Clear Lake, Deuel County, South Dakota, 1996-98.**

		Un-Chl-a mg/m^3	Cor-Chl-a mg/m^3	WT ^{o}C	DO mg/L	FpH su	COLIFORMS /100 ml	TALK mg/L	TS mg/L	TDS mg/L	TSS mg/L	VTSS mg/L
CL-1 Surface	Mean	60.9	59.0	9.9	8.67	8.40	15	222	531	503	26	10
	Median	36.2	33.2	9.5	9.30	8.45	10	204	486	463	15	7
	Minimum	4.0	3.6	0.0	1.20	7.51	10	159	350	337	3	1
	Maximum	345.1	352.6	25.0	18.10	9.16	70	347	763	749	80	18
	StDev	80.0	82.2	9.0	4.20	0.49	15	53	115	123	26	7
CL-2 Surface	Mean	52.2	50.6	9.7	7.88	8.36	19	220	473	444	27	11
	Median	29.6	26.4	9.3	8.60	8.37	10	201	465	418	16	8
	Minimum	2.3	0.7	0.0	1.25	7.53	10	148	124	121	3	1
	Maximum	191.0	199.4	25.5	11.60	9.30	110	359	764	756	96	24
	StDev	54.9	56.7	9.1	3.17	0.55	27	64	138	137	30	8

Table 11 **cont.**		SECCHI feet	CONDUCT µmhos	AMM mg/L	UN-AMM mg/L	NO3+2 mg/L	TKN mg/L	O-N mg/L	T-N mg/L	TP mg/L	TDP mg/L

Total Solids

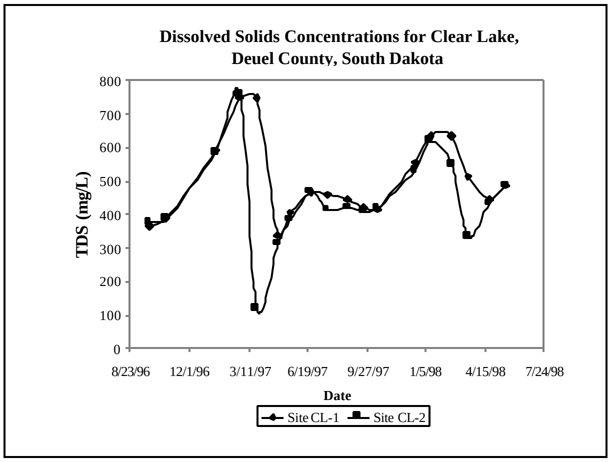


Figure 31

The dissolved solids concentrations in Clear Lake averaged 503 mg/L for Site CL-1 and 444 mg/L for Site CL-2 (Table 11). The concentrations in Clear Lake ranged from a minimum of 121 mg/L from Site CL-2 to a maximum concentration of 756 mg/L which was also collected from Site CL-2 (2/24/97). There was very little change in total dissolved concentrations from year to year. Significant differences were not exhibited between sites.

Total suspended solids for Site CL-1 averaged 26 mg/L whereas Site CL-2 averaged 27 mg/L. The maximum concentrations were 80 mg/L and 96 mg/L for Sites CL-1 and CL-2, respectively. The maximum concentrations occurred during the month of October'1997. The concentrations also exhibited more variability during this time period as well. Algae, organic matter and fine particles suspended off the bottom due to shallowness of the lake increased the concentrations. Although the relationship between these two variables was not significant, in certain instances the concentrations of suspended solids increased with increasing chlorophyll *a* concentrations. This was observed when the maximum concentrations occurred in the month of October 1997. A fall algal bloom occurred increasing the chlorophyll *a* concentrations which resulted in a slight increase in suspended solids.

Ammonia (total and un-ionized ammonia)

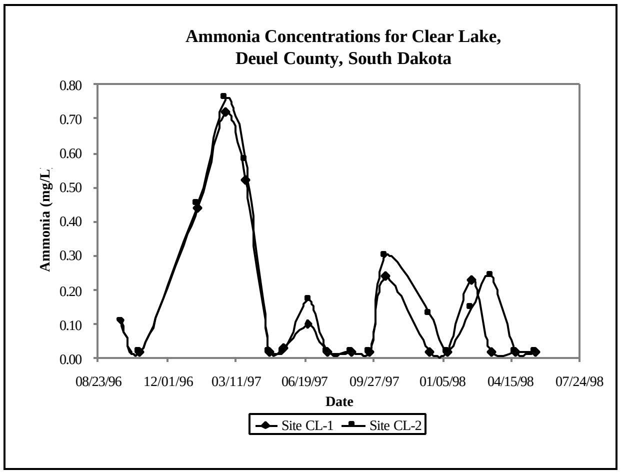


Figure 32

Bacterial decomposition of organic matter is the primary source of ammonia in lakes and streams. High ammonia concentrations can be used to demonstrate organic pollution. The inlake samples averaged 0.14 mg/L and 0.17 mg/L for each site, respectively. As is indicated by the mean concentrations, Site CL-2 was slightly higher. The standard deviation (0.14 mg/L) for all ammonia samples was greater than 50% of the overall mean of 0.17 mg/L indicating large variability in the data. The higher ammonia concentrations that occurred during the spring of 1997 were a by-product of the almost complete use of all the oxygen.

Increases in the un-ionized ammonia concentrations occurred during the summer of 1997 (Table 11). Concentrations of un-ionized ammonia usually increase during the summer with higher water temperatures and when the pH increases as a result of photosynthesis and other factors. The range of concentrations for Clear Lake was a maximum of 0.0130 mg/L collected from Site CL-2 on June 24, 1997 and a minimum of 0.0001 mg/L calculated from samples collected during the winter at Site CL-2.

Nitrate and Nitrite

Nitrate+Nitrite (NO_{3+2}) are inorganic forms of nitrogen that are most easily assimilated by algae and other aquatic plants. The process that converts nitrate and nitrite into free nitrogen usually takes place in the lower strata of lakes. This process also increases with increasing temperature and decreasing pH. There were no significant differences exhibited between sites. The average concentration of nitrate/nitrite for Site CL-1 was 0.17 mg/L whereas Site CL-2 averaged 0.19 mg/L. There was an increase in concentrations in winter and during the spring when concentrations increased to 1.0. This corresponds to increases in other nitrogen species such as ammonia. As the ammonia concentrations increased due to biodegradation, some of the ammonia was converted to the nitrate+nitrate through the process known as nitrification.

Total Kjeldahl Nitrogen/Organic Nitrogen

Kjeldahl nitrogen is used to calculate both organic nitrogen and total nitrogen. The organic nitrogen concentration mean for both inlake sampling sites was 1.72 mg/L and 1.63 mg/L, respectively. The highest concentration of organic nitrogen (2.71 mg/L) was sampled from Site CL-1 on January 12,1998. This may have been due to an algae bloom under the ice during the winter. In addition, nitrogen samples usually exhibited higher concentrations due to the amount of organic matter (algae) in this shallow lake.

Total Nitrogen

The maximum total nitrogen concentrations found in Clear Lake during the course of the study were 3.32 mg/L at CL-1 and 3.21 mg/L at CL-2 sampled on March 25,1997. There were no significant differences exhibited between the two sampling sites. The means for the surface and bottom samples were 2.04 mg/L and 1.99 mg/L, respectively.

Total Phosphorus

As with the nutrient and solids parameters discussed thus far, there were no significant differences exhibited by total phosphorus levels (Figure 33). Inlake phosphorus concentrations in Clear Lake averaged 0.167 mg/L (median 0.174 mg/L) for Site CL-1 and 0.169 mg/L (median 0.146 mg/L) for Site CL-2 (Table 11). The minimum and maximum concentrations of 0.023 mg/L and 0.335 mg/L for total phosphorus were both recorded from Site CL-2.

Trends for Clear Lake phosphorus concentrations indicated a reduction in phosphorus concentrations diluted by increases in hydrologic loadings. Following the spring runoff, total phosphorus concentrations increased with successive decreases in hydrologic loadings. After the increases occurred they fluctuated during the course of fall and winter, depending on the influx of groundwater and the presence of algae and other aquatic organisms which play a role in regulating inlake phosphorus concentrations.

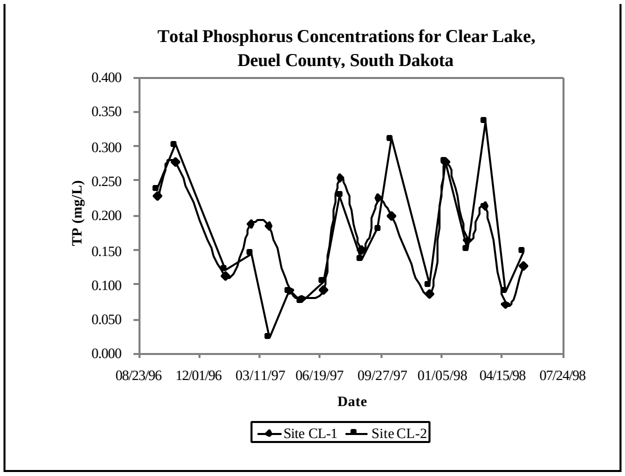


Figure 33

Total Dissolved Phosphorus

Dissolved phosphorus average concentrations were 0.057 mg/L and 0.061 mg/L for Sites CL-1 and CL-2, respectively. The minimum concentration was 0.013 mg/L sampled from Site CL-2. Concentrations followed the same general trend as TP decreasing during the major runoff period for both sites and increasing once this runoff slowed (Figure 34). The maximum concentration, which was collected from Site CL-2, reached 0.210 mg/L. A regression analysis was conducted to determine the relationship of dissolved phosphorus and suspended solids. No relationship (R^2=0.02,n=36,df=35) existed between these two variables from the data collected in 1997-98. However, there was a slight relationship between total phosphorus and suspended solids (R^2=0.35,n=36, df=35). The average concentration of all the inlake dissolved phosphorus samples was 0.059 mg/L, which is almost more than the amount necessary to stimulate algal growth.

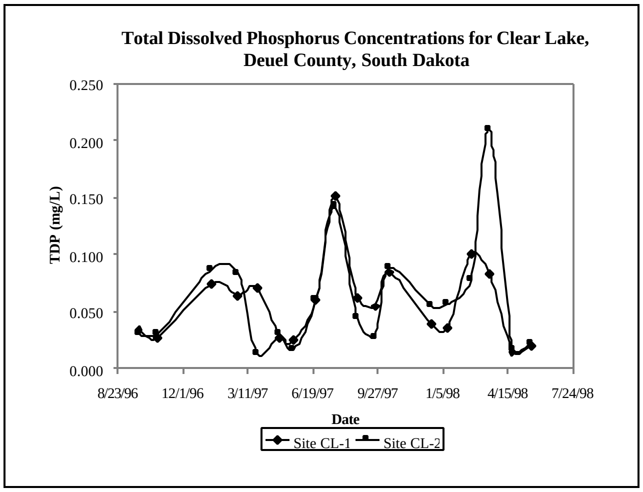


Figure 34.

Limiting Nutrient for Clear Lake

Blue green algae require a certain amount of nitrogen and phosphorus to develop and maintain a bloom. Depending on how much of these nutrients are available for uptake these blooms can be intense and severe and restrict the attainment of some of the beneficial uses for Clear Lake. If either phosphorus or nitrogen is reduced to an amount which can significantly reduce the severity of these blooms, it is known as the limiting nutrient for Clear Lake. In cases where the amount of nitrogen is limiting, blue-green algae can fix atmospheric N_2 (nitrogen) provided there is enough phosphorus available to sustain their growth (Wetzel, 1983). This is why, when nitrogen may be the limiting factor, it is easier to control the severity of algal blooms through phosphorus management.

Clear Lake has relatively moderate dissolved phosphorus concentrations that are greatly affected by the amount of surface water loading delivered from main northwest inlet. Also, during the course of this project, the mean total phosphorus concentrations were nearly ten times the concentration necessary to stimulate algal blooms. Due to these high concentrations of phosphorus, the ratio of 10:1 was used to determine the limiting factor. If the ratio of nitrogen divided by phosphorus, is greater than 10 for (TN/TP), the lake is assumed to be phosphorus limited for the respective parameters (USEPA, 1990(2)). A ratio of less than 10 assumes the lake is nitrogen limited.

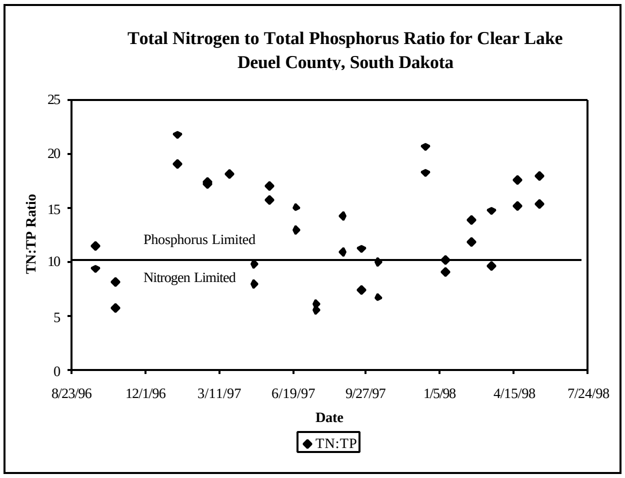


Figure 35

The mean ratio from the inlake samples collected during the course of the study was 15.8. Figure 35 indicates that Clear Lake is predominantly limited by phosphorus during most times of the year. The highest TN:TP ratio observed during the project was 115.7 from samples collected on March 25, 1997.

Clear Lake Algal Communities (1997-1998)

In recent decades, Clear Lake has undergone considerable siltation and nutrient enrichment. The former has reduced average lake depth to less than five feet while the latter process has resulted in greatly diminished water clarity produced mainly by the growth and decay of large standing crops of algae. Recent algal densities and chlorophyll *a* levels were among the highest recorded for 115 state lakes monitored by DENR.

Clear Lake has reached an advanced stage of eutrophication where nutrient limitations for algal growth have been virtually removed. Clear Lake algal densities remained high over nearly the entire annual cycle in 1997 and 1998 and were apparently mostly limited by the availability of light and self-shading effects. There are other factors also involved in the development of an algal bloom such as temperature and water clarity among others. However, nutrients are much more easily managed than any of these other factors.

Population succession in Clear Lake algae communities was intense throughout the year and blooms of successive populations followed one another in rapid sequence including in the winter months under ice. The patterns of succession between years were apparently controlled by meteorological conditions such as the unusually mild winter of 1997-98. During the previous spring and summer of 1997 algal populations may have been affected (moderately reduced) by the development of dense stands of aquatic vegetation (mainly sago pond weed) throughout the lake.

Trophic State Index (Clear Lake)

Carlson's (1977) Trophic State Index (TSI) is an index that can be used to measure the relative trophic state of a waterbody. The trophic state is a description of how much production occurs in the waterbody. The smaller the nutrient concentrations in a waterbody, the lower the trophic level. As the nutrient levels increase, the waterbody becomes more eutrophic or even hypereutrophic. Those lakes with few nutrients may be found in montane areas (Black Hills) and are termed oligotrophic. The majority of lakes in South Dakota are in the eutrophic to hypereutrophic range as a result of excessive nutrient input. Table 12 describes the different numeric limits for the various levels of Carlson's Index.

Table 12. Trophic Index Levels.

Trophic Level	**Numeric Range**
Oligotrophic	0 -- 35
Mesotrophic	36 -- 50
Eutrophic	51 -- 64
Hyper-eutrophic	65 -- 100

Table 13. Average Summer Trophic State Index Levels for Clear Lake.

Parameter ➡	**TSI Secchi Disk**	**TSI Phosphorus**	**TSI Chlorophyll *a***
Average	**69.89**	**77.45**	**64.29**
Median	**67.90**	**77.71**	**64.41**
Minimum	**65.12**	**69.54**	**51.80**
Maximum	**78.66**	**84.04**	**72.57**
StDev	**5.14**	**5.42**	**7.38**

Three different parameters are used to determine the average trophic state of a waterbody: 1) secchi disk, 2) total phosphorus, and 3) chlorophyll *a*. TSI levels for all of the water quality data available for Clear Lake are indicated on Table 13 and Figure 36.

The mean and median of secchi depth and chlorophyll *a* are both on the edge between eutrophic and hyper-eutrophic. The total phosphorus TSI is in the high end of the hyper-eutrophic scale. This is indicative of the excessive amounts of nutrients in Clear Lake.

Over the years in which data was available for Clear Lake, the mean trophic status is 65, which is the lower end of the hyper-eutrophic index.

Chlorophyll *a*

Statistical analysis was used on the data collected during the project to determine if there was a significant relationship between Sites CL-1 and CL-2. No significant differences were found between the sites. However, the chlorophyll *a* concentrations were extremely variable throughout the course of the study. In fact, the standard deviation, which is a measure of the distribution of the observations around the mean, is greater than the means of Sites CL-1 and CL-2. The means were 60.9 mg/m^3 (stdev=80.0) and 59.0 mg/m^3 (stdev=82.2) for Sites CL-1 and CL-2, respectively.

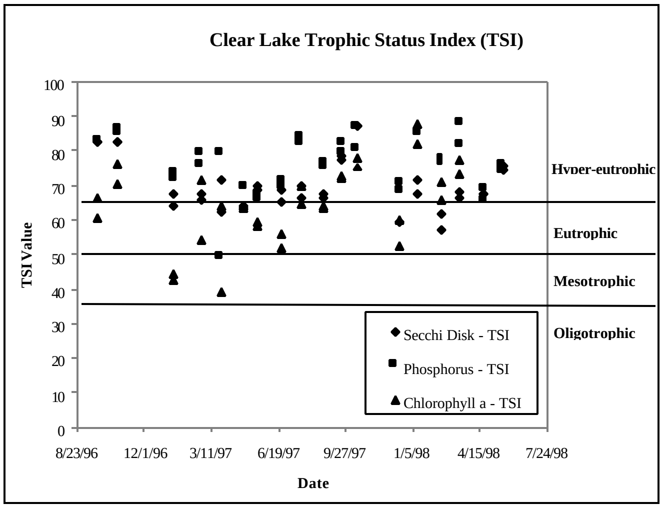


Figure 36

The chlorophyll *a* concentrations for Clear Lake ranged from a minimum of 2.3 mg/m^3 sampled on March 25, 1997 to a maximum of 345.1 mg/m^3 sampled on January 12, 1998. Chlorophyll *a* concentrations were typically higher during the late summer and early fall than at any other time period during the sampling year. The exception to this was the maximum concentration that was observed during the month of January. In this particular instance a winter bloom of large-bodied flagellated *Cryptomonas* spp., *Synura uvella*, and *Glenodinium* spp. caused a spike in the chlorophyll *a* concentration. The numbers blue-green, green and diatom algae were relatively insignificant contributors of chlorophyll at this time.

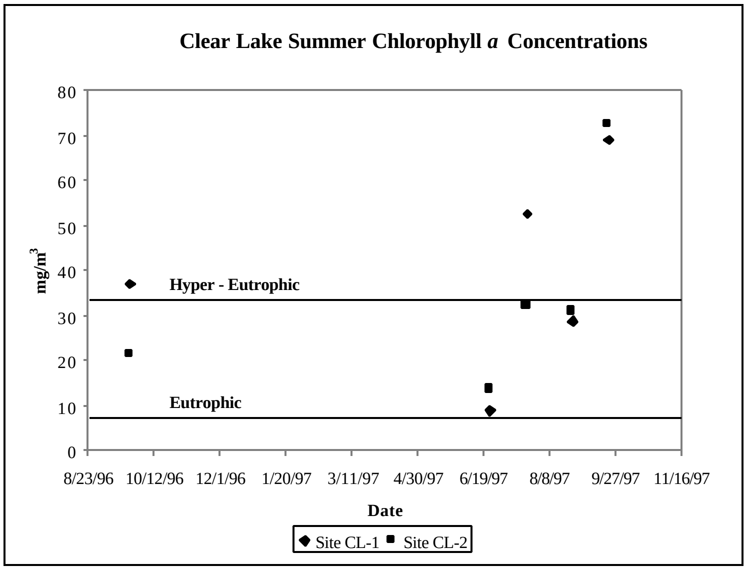


Figure 37

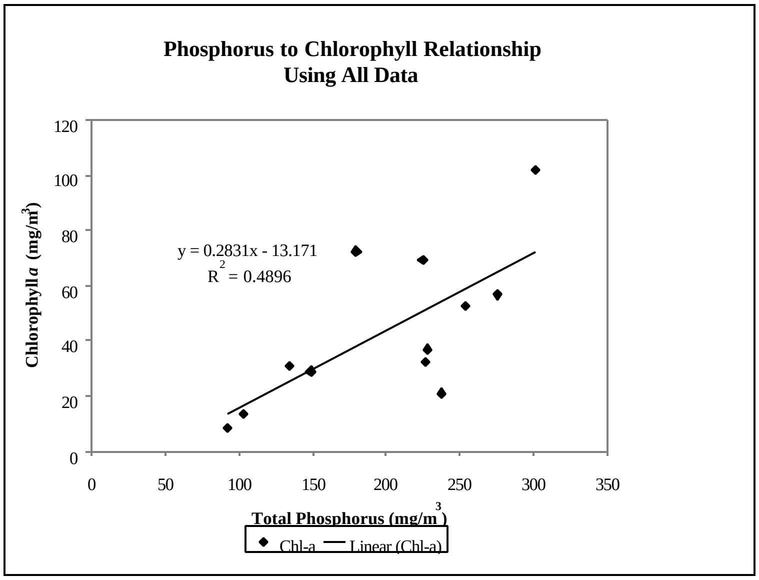


Figure 38

Although chlorophyll *a* is an important parameter for Clear Lake, the extent of algae blooms depends to a large degree on the nutrient content of the lake. Chlorophyll *a* and total phosphorus may be expected to have a direct relationship in regard to increasing concentrations. Typically, as total phosphorus increases so does chlorophyll *a*. However, as shown in Figure 38, there seems to be only a slight relationship between phosphorus and chlorophyll *a* for all the data collected during the project (R^2 value of 0.49). The fact that the lake may not always be phosphorus limited; the fixation of nitrogen by blue-green algae; and influence of resuspended sediments, may be some of the reasons for the lower R^2 value.

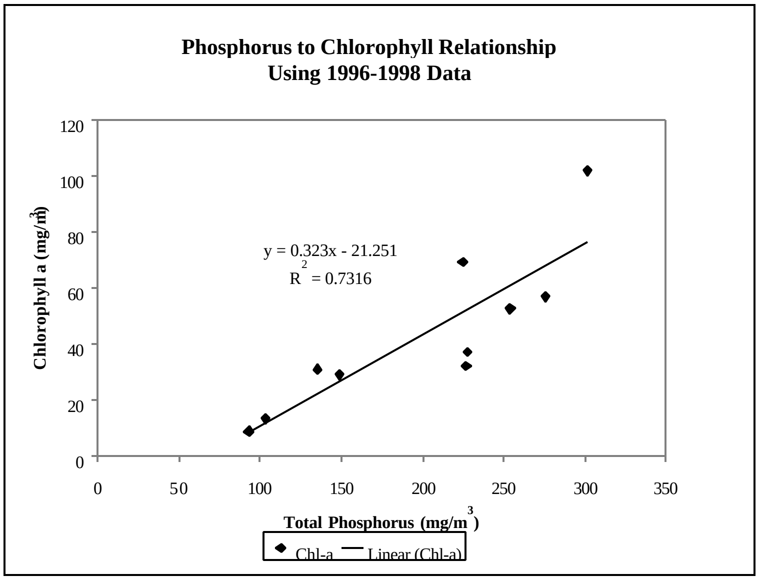


Figure 39

After reviewing the data it was determined that there were two data points which were considered to be outliers. The chlorophyll *a* and total phosphorus concentrations collected from Site CL-2 for the dates of September 24, 1996 and September 22, 1997 were not consistent with the remaining data points. After conducting the regression analysis on this adjusted data set the R^2 value improved to 0.73 that indicates a fairly significant relationship (Figure 39).

To normalize the distribution of the data, a log transformation of the total phosphorus and chlorophyll *a* concentrations was also conducted. This transformation increased the relationship significantly (R^2=0.85,df =9,n=10) (Figure 40).

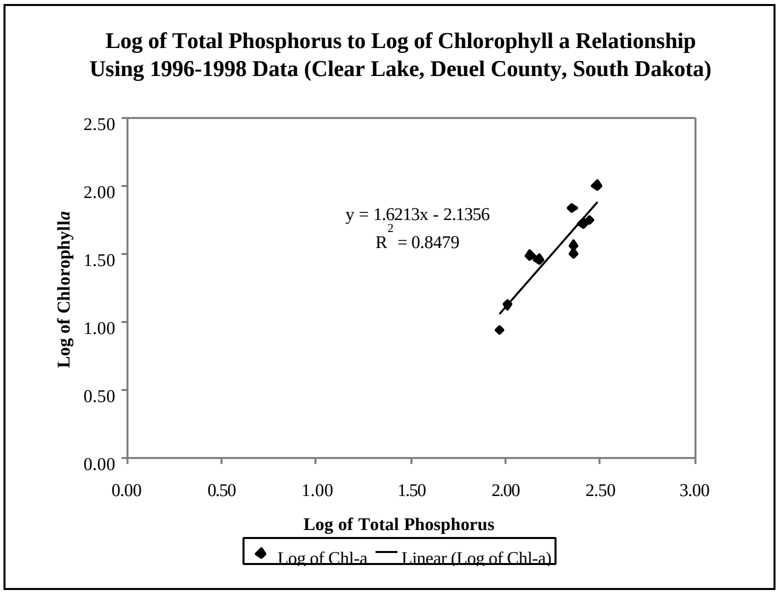


Figure 40

The relationships between phosphorus and chlorophyll *a* can be used to estimate the reduction in chlorophyll *a* that could be attained by reducing inlake phosphorus concentrations. The better the relationship the more confident lake managers can be in expected results. When applying the regression derived from the data previously discussed it is important to note that the predictions should be made within the range of data used in the analysis. It may skew the results if recommendations are made outside of this range of data. The total phosphorus concentrations applied to the regression analysis ranged from 0.093 mg/L to 0.302 mg/L. The chlorophyll *a* concentrations ranged from 8.71 mg/m^3 to 101.84 mg/m^3. This data set and the resulting regression analysis will be used in the next section for the reduction-response model. The equation for the line in Figure 40 will be used to predict chlorophyll *a* from inlake phosphorus concentrations. The line equation (Equation 1) is shown below:

{Equation 1} $Log(Y) = 1.6213 - (Log(X) \times 2.1356)$ (Clear Lake Data Only)

Y = predicted chlorophyll *a* concentration

X = phosphorus concentration

Reduction/Response Model (Clear Lake)

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

1) $\left[\overline{P}\right]l$ = Average inlake total phosphorus concentration

2) $\left[\overline{P}\right]i$ = Average concentration of total phosphorus which flows into the lake

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

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

Data collected during the project (1996 - 1998) provided enough information to estimate $\left[\overline{P}\right]l$, $\left[\overline{P}\right]i$, and $\overline{T}_w$. In order to estimate the residence time of total phosphorus ($\overline{T}_p$) it was necessary to back calculate Equation 2 below, and solve for $\overline{T}_p$ by forming Equation 3 (Wittmuss, 1996).

{Equation 2} $$\left[\overline{P}\right]l = \left[\frac{\overline{T}_p}{\overline{T}_w}\right]\left[\overline{P}\right]i$$

{Equation 3} $$\left(\overline{T}_p\right) = \frac{\left[\overline{P}\right]l}{\left[\overline{P}\right]i}\left(\overline{T}_w\right)$$

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

$\left[\overline{P}\right]l$ was determined by averaging all of the surface total phosphorus samples from 1996-98 collection period.

$\left[\overline{P}\right]i$ was determined by adding all of the input loadings for total phosphorus in milligrams and dividing that number by the total number of liters that entered the lake. The values for both of these numbers came from tributaries, groundwater, and the atmosphere.

$\overline{T}_w$ was determined by averaging the total volume of Clear Lake (2,400 acre-feet) by the total inputs of water into the lake (28,828 acre-feet/days of discharge measurements).

$$\overline{T}_w = {}^{2{,}400\,acre-feet}\Big/_{28{,}828\,acre-feet/235\,days} = 19.6 \text{ days} = 0.054 \text{ year}$$

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

$$\left[\overline{P}\right]l \;=\; 0.168 \text{ mg/L} \qquad\qquad \left[\overline{P}\right]i \;=\; 0.404 \text{ mg/L}$$

By placing the numbers in the proper places as discussed in Equation 3, $\overline{T}_p$ would be:

$$\left(\overline{T}_p\right)=\left[\frac{0.168}{0.404}\right](0.054) \;=\; 0.0225 \text{ years } \;=\; 8 \text{ days}$$

Referring back to Equation 2, reducing the inputs of total phosphorus, the equation would estimate the reduction of inlake total phosphorus. This is assuming constant inputs of water. Theoretically, the retention time for total phosphorus should also be reduced. With only one year of sampling, there is no way to estimate the reduction in the retention time of total phosphorus. The $\overline{T}_p$ constant (0.0225) derived from the data will be used in Equation 2. After estimating the amount of reduction of inlake phosphorus after a reduction of input phosphorus, Equation 1 (page 59) can be used to see the reduction of chlorophyll *a*. As can be seen in Table 14, a 20% reduction in phosphorus inputs to Clear Lake will reduce the inlake chlorophyll *a* concentration by an estimated 30%. The 20% reduction would also lower the chlorophyll TSI value well below the hyper-eutrophic line (Figure 41). As stated above, this is considering no reduction in the retention time of total phosphorus. If the retention time is lowered, the lake should experience even lower inlake concentrations and lower chlorophyll *a* concentrations. As the input concentrations of phosphorus are lowered, the lake will see algal blooms that are less intense and of a shorter duration. These tables and graphs are predictive on the data collected during the study. Actual changes can be expected to differ depending on runoff values and the extent of change that occurs in the volume of water passing through Clear Lake.

Table 14. Effects of Reducing Phosphorus to Clear Lake

Percent Reduction of Phosphorus Inputs	Input Phos Concentration	InLake Phos Concentration[1]	Chlorophyll *a* Concentration	Percent Reduction of Chlorophyll *a* Concentration	Phosphorus TSI	Chlorophyll TSI
0%	0.404	0.168	29.67	0%	78.07	63.83
10%	0.363	0.151	25.01	16%	76.55	62.15
20%	0.323	0.134	20.66	30%	74.85	60.28
30%	0.283	0.118	16.64	44%	72.93	58.15
40%	0.242	0.101	12.96	56%	70.70	55.70
50%	0.202	0.084	9.64	67%	68.07	52.80
60%	0.161	0.067	6.72	77%	64.85	49.25
70%	0.121	0.050	4.21	86%	60.70	44.68
80%	0.081	0.034	2.18	93%	54.85	38.23

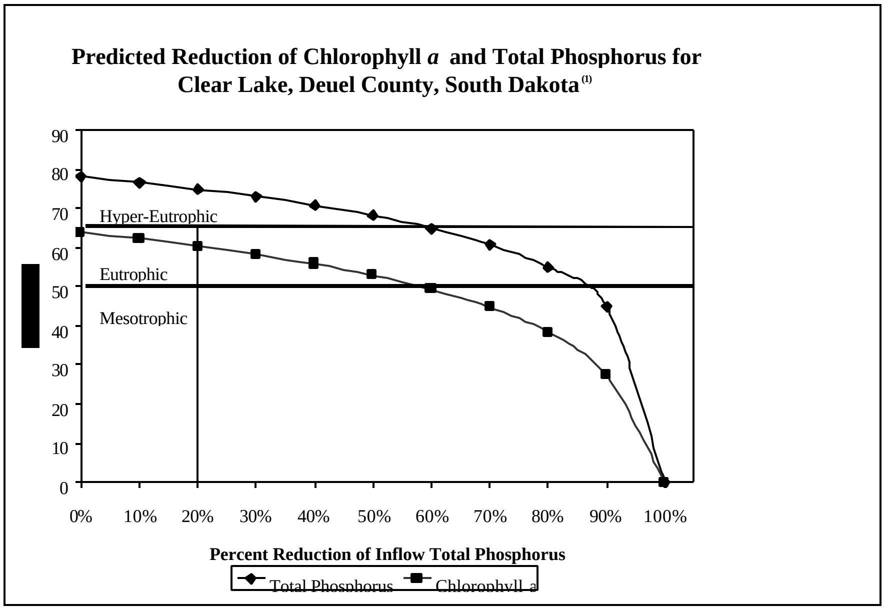


Figure 41

90%	0.040	0.017	0.71	98%	44.85	27.20

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[1] Inlake phosphorus concentrations must be converted from mg/L to mg/m^3 before using Equation 1 to predict chlorophyll *a*.

(1) - A total phosphorus inflow concentration of 0.404 mg/L for the reduction/response model was derived by using total phosphorus load divided by the total hydrologic load delivered to Clear Lake. Reduction/Response model was based on the Total Phosphorus/Chlorophyll a Relationship from 1996-1998 data (R^2=0.85,n-10,df=9).

Aquatic Plant Survey

An aquatic plant survey was conducted for Clear Lake during August of 1997. This plant survey indicated heavy growth of the plant species *Potamogeton pectinatus* commonly known as sago pondweed. Almost the entire surface area (>90% coverage) of the lake was covered with this species. Due to the shallow depth and the hyper-eutrophic condition of the lake there was only one dominant species of aquatic plants. Sago pondweed can tolerate a wide range of water quality conditions. Sago pondweed is common in ponds, lakes, and slow streams in nonacid waters. In fact, P. pectinatus is found in more brackish waters than is tolerated by other Potamogeton species or most other genera of freshwater plants.

In a very site-specific area, located near the outlet where a gravel bottom was the predominant substrate one species of the macroalgae *Chara* was present. *Chara* spp. are usually indicators of good water quality. In the southwestern section of the lake near the outlet these algae were very common which may be an indication of groundwater springs located in this area (Figure 42). The predominant substrate for the remaining area of the lake is primarily uniform silt. This common substrate and the impaired water quality reduce the ability of certain other aquatic plant species to colonize any other areas in the lake resulting in the presence of one dominant aquatic plant species-*Potamogeton pectinatus*.

If the depth of Clear Lake is increased through dredging, the aquatic plant situation may improve. The depth of the lake would have to increase dramatically in certain areas before this would take place. However, if the water quality improves, the species diversity of aquatic plants may improve as well.

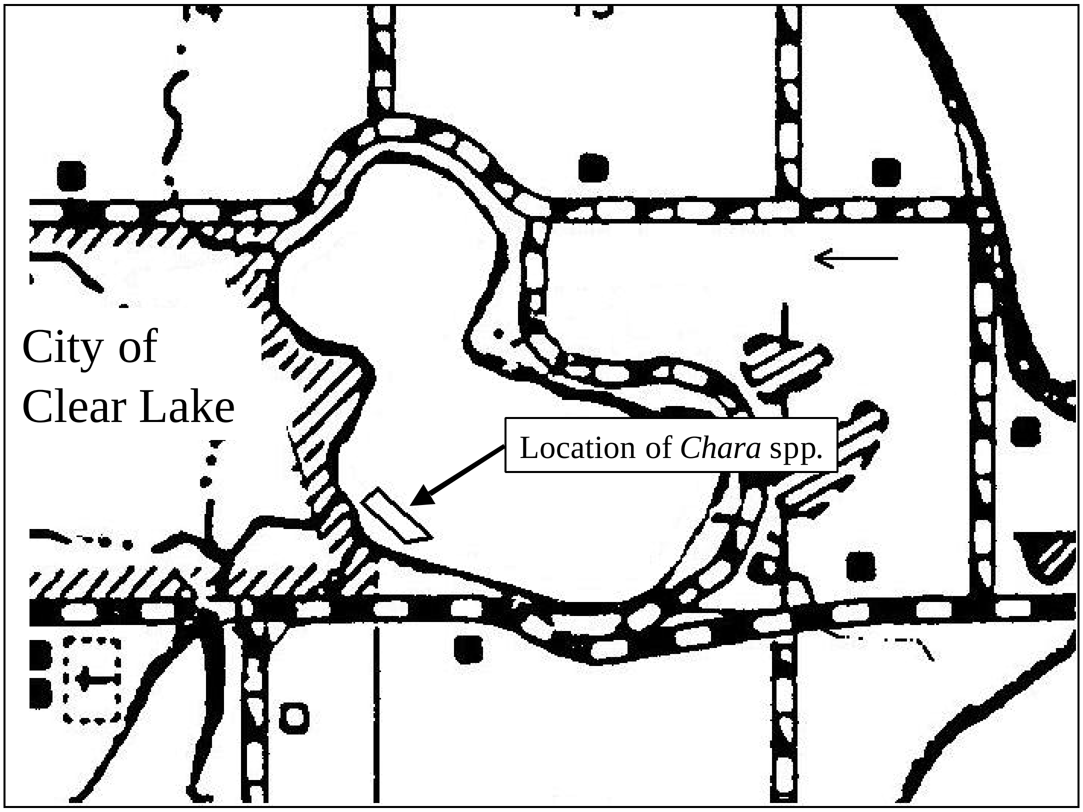

Figure 42. Location of *Chara* spp within Clear Lake, Deuel County, South Dakota.

Clear Lake Sediment Survey

An inlake sediment survey was performed on Clear Lake to determine the depth of loose sediment on the bottom of the lake. Figure 43 contains a contour map which shows the depth of the sediment on the lake bottom. The results of the survey estimated 2.48 million cubic yards of sediment are on the bottom of the lake. This correlates to an average sediment depth of 2.9 feet over the entire 532 acre surface area of the lake.

The north bay of the lake has the deepest and largest area of sediment deposits. Dredging to remove the entire 2.48 million cubic yards of sediment will probably be too costly. Partial lake dredging will provide an affordable option that will still provide benefits to the lake and its users. The removal of 750,000 cubic yards of sediment would increase the depth of the lake by 4 feet over 116 surface area acres.

Figure 43. Locations of Sediment for Clear Lake, Deuel County, South Dakota.

Agricultural Nonpoint Source Model Executive Summary

This is the executive summary of the AGNPS report. The entire report can be found in Appendix A.

Watershed/Subwatershed Analysis

Sediment – The AGNPS data indicates that the Clear Lake watershed has a very low sediment deliverability rate at the outlet of Clear Lake (0.032 tons/acre/yr). This is equivalent to a load of 867 tons of sediment leaving Clear Lake per year. However, an analysis of the sediment transport and deliverability throughout the watershed indicated that for an average year , approximately 3,084 tons (0.121 tons/acre) of sediment enter Clear Lake. This correlates to a trapping efficiency of 71.9% for Clear Lake which under estimates the status of erosion and sediment deliverability rates throughout the watershed. When a details subwatershed analysis was performed, three(1#308, 4#579, and 6#485) of the ten primary subwatersheds analyzed appeared to have high sediment deliverability rates. These subwatersheds were found to contribute 55% of the total sediment, contain 39.5% of the critical erosion cells while occupying only 28.7% of the watershed area. The suspected source of this sediment is from agricultural lands which have slopes of 4% and greater, and ar currently cropped or have poor vegetative cover. The conversion of this acreage to high residue management system or rangeland should reduce the volume of sediment delivered to Clear Lake.

Nutrients – The AGNPs data indicates that the Clear Lake watershed (at the Clear Lake outlet) has a total nitrogen $_{\text{(soluble+sediment bound)}}$ deliverability rate of 5.58 lbs/acre/yr, and a total phosphorus $_{\text{(soluble+sediment bound)}}$ deliverability rate of 1.18 lbs/acre/yr. However, the mean subwatershed nutrient deliverability rate within the Clear Lake watershed was estimated to be 22.1 lbs/acre for nitrogen and 5.2 lbs/acre for phosphorus. On an annual basis, 77 tons of nitrogen and 18.8 tons of phosphorus are delivered to the lake while only 76 tons of nitrogen and 16.1 tons of phosphorus leave Clear Lake. This correlates to a trapping efficiency of 1.3 % for nitrogen and 14.4% for phosphorus entering Clear Lake. When a detailed subwatershed analysis was performed, four of the ten subwatersheds analyzed appeared to have high nutrient deliverability rates. Subwatersheds 1(#308), 4(#579), 5(#553) and 10(#562) appear to be contributing very high amounts of nutrients especially in the form of water soluble (dissolved) nutrients. The model indicates that these high loads may be related to animal feedlots located near the subwatershed outlets and close to channelized flows. The results also indicated that runoff from fertilized corpland was a significant source of water soluble nuttiness to Clear Lake. These four subwatersheds contribute 51.6% (39.7 tons) of the total nitrogen and 56.4% (10.6 tons)of the total phosphorus load to Clear Lake and only make up 38.3%of the watershed area. The most likely source of nutrients is from animal feeding operations located near stream channels and runoff from fertilized cropland.

Critical NPS Cells

Sediment – An analysis of individual cell sediment yields indicated that out of the 684 cells found within the Clear Lake watershed, 95 had sediment erosion yield greater than 9.0 tons/acre $_{(25\ \text{year event})}$. This is approximately 13.9% of the cells found within the entire watershed. The suspected primary source of elevated sedimentation within the critical cells is from agricultural lands which have landslopes of 4% or greater which are utilized as cropland (high C-factor). The AGNPS model was run with reduced C-factors to simulate conservation tillage practices to determine the amount of sediment that could be retained. The C-factors were changed on 26 cells (1040 acres) to a value that would simulate a change from conventional tillage to no-till practices. The C-factors were also changed on 30 cells (1200 acres) to a value that would simulate a change from conventional tillage to minimum tillage practices. Installing these practices will reduce the amount of sediment entering Clear Lake annually from 3084 tons to 2034 tons (34% reduction.

Nutrients – An analysis of individual cell nutrient yields indicated that out of the 684 cells found within the watershed, 63 had sediment bound nitrogen yields greater than 10.0 lbs/acre and sediment bound phosphorus yields greater than 5.0 lbs/acre. This is approximately 9.2% of the cells within the watershed. An analysis of individual cell nutrient yields also indicated that 11 cells had water soluble nitrogen yields greater than 10.0 lbs/acre and 6 cells with water soluble phosphorus yields greater than 5.0 lbs/acre. This indicates that sediment bound nutrients are the majority of the total nutrients that enter the lake. The suspected source of the elevated water soluble nutrient levels found within the Clear lake watershed is likely due to animal feeding operations located adjacent to intermittent streams. The identified critical NPS cells should be given high priority when installing any future BMPs.

Feeding Area Evaluation

A total of 25 animal feeding areas were evaluated as part of the study. Of these, sixteen were found to have an AGNPS rating of 50 or greater and ten had an AGNPS rating of 60 or greater. An analysis to evaluate the impact of feeding areas was also performed. When the model was run with the ten feeding areas with an AGNPS rating>60 taken out of the watershed, the dissolved phosphorus load into Clear Lake was reduced from 12.5 tons to 11.3 tons (9.6% reduction). For this same scenario the dissolved nitrogen load into Clear Lake was reduced from 63.7 tons to 56.9 tons (10.7% reduction). These 10 feeding areas locate within cells #249, #253, #312, #361, #376, #399, #490, #619, #639, and #660 appear to be contributing significant levels of nutrients to the watershed. It is recommended that these ten animal feeding areas be evaluated for potential operational or structural modifications in order to minimize future nutrient releases.

Conclusions – It is recommended that the implementation of appropriate BMPs be targeted to the critical subwatersheds, critical cells and priority animal feeding areas. However, due to the high rate of sediment erosion found within subwatersheds #308, $485, and #579 and their high deliverability rates, initial efforts to reduce sediment should be targeted to these subwatersheds. Feeding areas with an AGNPS rating greater than 60 should be evaluated for potential operational or structural modifications in order to minimize future nutrient releases. These feeding areas appear to be contributing significant nutrients to the watershed and should be given a priority. It is recommended that any targeted cell should be field verified prior to the installation of any BMPs. This methodology should produce the most cost effective treatment plan in reducing sediment and nutrient loads to Clear Lake.

If you have any questions concerning this study, please contact the Department of Environment and Natural Resources at 605-773-4254.

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CONCLUSIONS

Water Quality Standards

During the project there were no exceedances of the water quality standards for the tributary samples.

The inlake water quality standards for Clear Lake were exceeded a total of 13 times. There were five documented exceedances of the pH standard 9.0 su for Clear Lake. Most of the pH exceedances can be attributed to algal blooms or the extensive aquatic plant growth documented for Clear Lake during the summer. There were eight dissolved oxygen observations that exceeded the standard of 5.00 mg/L. Both inlake sites exhibited four of these exceedances on the exact same dates. Four of the 8 occurred during January and February of 1997 during snow cover and reduced photosynthetic rates. The other four occurred during the summer of 1997 due to the shallow nature of Clear Lake, high temperatures and excessive rates of biodegradation during this time period. There was one exceedance of the temperature standard for Clear Lake.

Seasonal Water Quality

Many of the water quality parameters increased in concentration during the spring runoff. During the spring runoff (March – May), when greater than 80% of the runoff occurred for some of the tributary sites, the concentrations for nutrients and suspended solids concentrations increased. These higher concentrations can be attributed to the much higher flows that occurred during this sampling period. Typically, each tributary's sample concentrations exhibited a variety of seasonal trends. Site CLT-1 (northwestern tributary) exhibited the maximum concentrations during the spring and, as the sampling year continued, the samples decreased in concentration. However, this was highly dependent upon the individual parameter. Nutrients were typically higher in the spring with periodic spikes occurring during the year, which may have been due to fertilizer and animal waste runoff. The higher concentrations also may have been due to overland flow across frozen ground. Dissolved nutrients are able to adsorb to any soil particle and there is very little nutrient demand by the vegetation due to the early time of the year.

Tributary Sampling

Site CLT-1 is located in the far upper reaches of the watershed and drains 3,840 acres (Figure 44). This site exhibited the highest nitrate+nitrite concentrations with very high fecal coliform concentrations. Phosphorus concentrations were also very high although the suspended solids concentrations were relatively low. Compared to the other downstream monitoring sites within this northwestern drainage this site exhibited the highest percentage of dissolved phosphorus fraction (79%), i.e. there was much more dissolved phosphorus than particulate phosphorus. The higher concentrations at Site CLT-1 for nitrate resulted in very high export coefficients per unit area (lbs/acre/yr) for nitrogen. However, the phosphorus and sediment export coefficients were moderately high.

Site CLT-2a monitored a large subwatershed draining 9,000 acres from the northwest (Figure 44). The monitoring site was located on the outlet of Lake Sutton. Lake Sutton serves as a nutrient and sediment trap for this subwatershed so excessive concentrations (in comparison to the other monitoring sites) for these parameters were not observed. However, the AGNPS computer model identified four highly rated livestock feeding areas, 24 critical nutrient cells (40 acres each), and 28 critical erosion cells.

Site CLT-3 monitored the same tributary as CLT-1 and 2a (Figure 44) and it also included an additional 3,000 acres. Dissolved phosphorus concentrations were slightly lower compared to Site CLT-1. The highest fecal coliform mean was observed from this tributary site, however. Higher phosphorus export coefficients (TP lbs per acre) were exhibited at this site compared to the two upstream monitoring sites even though the concentrations were less. AGNPS identified 2 livestock feeding areas rated greater than 50 in the 3,000 acres located between Sites CLT-1 and 2a. It also identified 11 critical nutrient cells (40 acres each) and 13 critical erosion cells in this addition 3,000 acres.

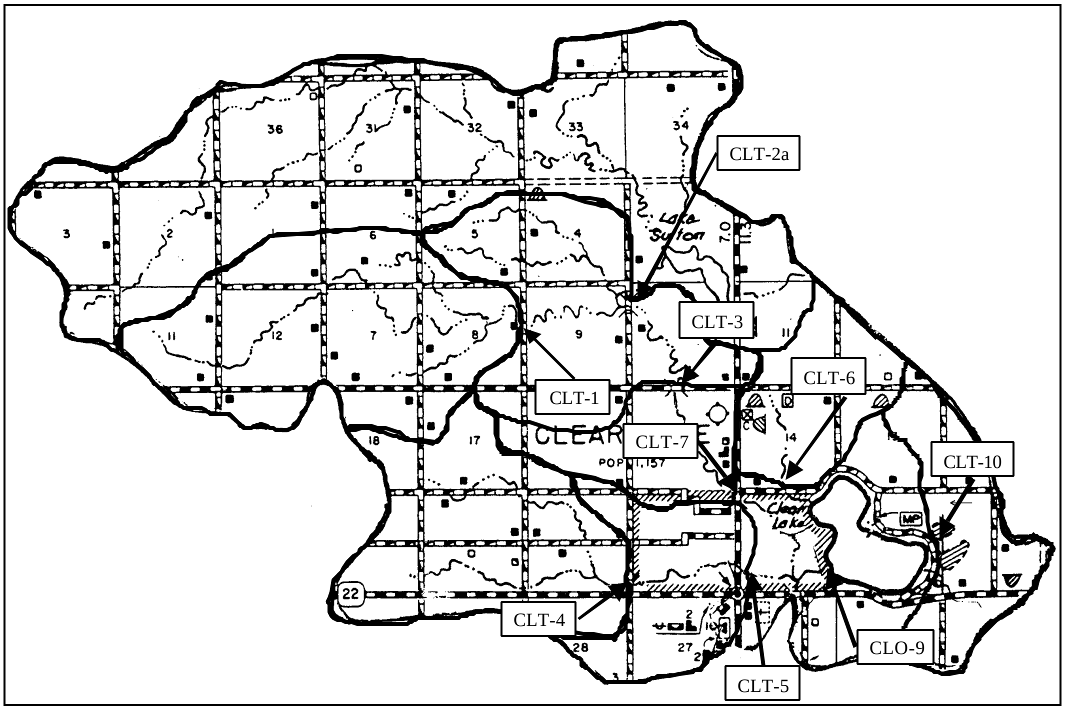

Figure 44. Clear Lake and Clear Lake Watersheds and Tributary Monitoring Sites.

Site CLT-7 was located downstream of Site CLT-3 and monitored an additional 880 acres for a total subwatershed area of 16,720 acres (Figure 44). This site also exhibited a higher fraction of particulate phosphorus (sediment-bound) which indicated that the source for most of the dissolved fraction was located upstream of Site CLT-3. The fecal coliform concentrations were slightly less compared to the upstream sites. With the larger volume of water flowing at this final downstream site, the export coefficients (lbs per acre) were slightly higher than the upstream sites. The sources of these higher export coefficients were located upstream as identified in the subwatersheds of Site CLT-1, 2a, and 3.

Site CLT-6 is a small subwatershed north of Clear Lake draining 1,000 acres (Figure 44). The water quality or loadings data did not indicate any significant problems with this watershed although the AGNPS computer model did identify one livestock feeding operation rated greater than 50 (scale = 0-100) and two critical erosion cells.

Site CLT-10 is located directly east of Clear Lake and drains approximately 2,880 acres of the southeastern portion of the watershed. Even though this site was located on the outlet of a wetland, which serves as a nutrient and sediment trap, high phosphorus concentrations were observed. The small watershed and the very low volume of water discharged into Clear Lake by this tributary resulted in very low phosphorus and sediment export coefficients. AGNPS did identify four livestock feeding areas rated greater than 50 (scale =0-100), six critical nutrient cells (40 acres each), and seven critical erosion cells in this watershed.

Site CLT-4 drains a small subwatershed (3,000 acres) from the west of Clear Lake (Figure 44). Only during times of extreme flooding does this drainage enter the lake. Most of the time this drainage basin bypasses Clear Lake and enters Hidewood Creek which is the outlet of Clear Lake. AGNPS identified two livestock feeding areas rated at 17 and 18. However, it also identified eight critical nutrient cells and 15 critical erosion cells. Site CLT-4 exhibited high levels of phosphorus and nitrogen but only moderate levels of fecal coliform bacteria. This indicates that there may be some livestock grazing upstream, but there is also some erosion and cropland runoff which may also be a source for these higher levels of nutrients

Site CLT-5 is located downstream of Site CLT-4 (Figure 44). It drains 800 acres in addition to the 3,000 acres located upstream of Site CLT-4. This site exhibited the highest concentration of total phosphorus and nitrogen. Water quality at this site is effected by the sources identified above Site CLT-4 as well as the storm sewers from the city of Clear Lake and the golf course located just upstream of this monitoring site. All of these sources contributed to the high concentrations of nutrients and sediment at Site CLT-5 (the maximum TSS concentration of 316 mg/L was collected from this site).

Site CLO-9 is the outlet of Clear Lake (Figure 44). This lake acts a retention basin for the sediment and nutrient loadings discharged from all of the input sources. Concentrations of total phosphorus and suspended solids were not significantly different from the inlake concentrations. Fecal coliform were very low as were the suspended solids. Dissolved phosphorus concentrations were reduced during the summer to accommodate the inlake nutrient requirements of the vegetation. Ammonia loadings increased during the summer as well, due to the subsequent breakdown of algae and other vegetation.

Comparison of Water Quality Data and AGNPS Modeling

The AGNPS computer modeling conducted on the Clear Lake watershed indicated high sediment and nutrient yield results from the same subwatersheds where water quality data indicated high export coefficients for these same parameters. AGNPS indicated that subwatershed CLT-1 (AGNPS report outlet cell#308) delivered high amounts of sediment to Clear Lake. Site CLT-1 had a moderately high sediment export coefficient at 57 lbs/acre/yr to Clear Lake. High sediment yield was identified in the CLT-4 subwatershed by AGNPS. Although this was relatively high at 84 lbs/acre the water quality data indicated that the sediment yield for CLT-5 was much higher at 314 lbs/acre. This may be a product of the storm sewers and grazing cattle located between CLT-4 and 5. The Site CLT-5 sediment export coefficient was biased because of the extremely high TSS concentration of 316 mg/L that occurred during the spring of 1997. After this occurrence the concentrations were relatively low. Another subwatershed identified as significant for sediment erosion was CLT-6. However, the water quality data contradicted the AGNPS export coefficient. From the water quality data, this subdrainage had a very low sediment export coefficient primarily due to the effect of the local wetland.

In addition to high sediment, high nutrient contributions were identified in other subwatersheds. AGNPS identified these critical subwatersheds as CLT-1, CLT-4, CLT-5, and CLT-10 which appeared to be contributing very high amounts of nutrients especially in the form of water soluble (dissolved) nutrients. The AGNPS model indicated that the high nutrients may be due to animal feedlots and runoff from fertilized cropland.

The water quality data indicated that these same subwatersheds (CLT-1, CLT-4, CLT-5, and CLT-10) were major contributors to the nutrient loading of Clear Lake, with one exception. The water quality data indicated that Site CLT-10 had very low nutrient export coefficients. However, the water quality coefficients were based on insufficient data (two samples) and the outlet site for CLT-10 was also located on a wetland.

Possible sources in these areas of high nutrients and sediment were identified as high slopes and bank erosion due to lack of riparian vegetation, reduced residue management, as well as crop and lawn fertilization. Other sources which were identified as significant were confined and pastured livestock feeding areas.

Another subwatershed of concern was Site CLT-2a which drains 9,000 acres above Lake Sutton. Presently, most or a large percentage of sediments and nutrients that enter Lake Sutton and are trapped. However, once Lake Sutton becomes “silted-in” its capacity for holding nutrients and sediments will be reduced to the point where it will become a major contributor (point source) to Clear Lake.

Hydrologic, Sediment, and Nutrient Loadings

The northwestern tributary (Site CLT-7) flowed continuously during 1997 discharging 26,010 acre-feet of water into Clear Lake, which constituted over 83% of the hydrologic load. Other minor contributors to Clear Lake were Sites CLT-6 (5%), CLT-10 (1%), ungauged runoff (8%), and precipitation (4%).

Site CLT-7 contributed 99% of the total amount of sediment discharged into Clear Lake. Clear Lake accumulated 607 tons of sediment which constitutes only 0.005 inch of sediment over the entire surface area of the lake per year. These figures indicate that erosion (sediment load) from the watershed is not a problem for Clear Lake.

Site CLT-7 contributed over 93% to the overall phosphorus budget for Clear Lake. Clear Lake accumulated 24,822 lbs (12.4 tons) of phosphorus during 1997. Ninety-one percent of the phosphorus discharged into the lake was received during the spring season when 85% of the hydrologic load occurred.

Storm Sewers

Storm sewer samples were collected from three sites within the city of Clear Lake. Each of these samples exhibited extremely high concentrations of nutrients (phosphorus and nitrogen), fecal coliform bacteria, and sediment (total suspended solids).

Inlake

Clear Lake is too shallow (avg. depth < 5.0ft) to undergo stratification. The predominant algal species during the summer was a variety of blue-greens such as *Anabaena* spp., *Aphanizomenon flos-aquae, Aphanocapsa spp,* and *Oscillatoria agardhii.* These blue green algae favor high concentrations of phosphorus. Mean concentration of phosphorus in surface samples from Clear Lake was 0.167 mg/L and 0.169 mg/L for Sites CL-1 and CL-2, respectively. This is considerably higher than the requirement to initiate intense blue-green algal blooms which is 0.02 mg/L. The fraction of dissolved phosphorus for both lakes averaged between 36% and 38%. During spring runoff, nutrient concentrations decreased but then increased during the summer months.

Limiting Nutrient and Trophic State Index (TSI)

Since blue-green algae are only able to assimilate dissolved phosphorus but can assimilate several kinds of nitrogen, a total nitrogen to total phosphorus ratio was used to determine the limiting nutrient. When the total nitrogen to total phosphorus ratio increases to 10:1, blue green algae appear to be phosphorus limited. The average total nitrogen to total phosphorus ratio for Clear Lake was 15.8. Turbidity was a limiting factor in Clear Lake where shallow depth allows resuspension of solids, reducing the amount of available light. The mean total phosphorus trophic status (TSI) was 77 for Clear Lake. The hypereutrophic range of Carlson's Trophic Index begins at 65 indicating that Clear Lake is in the hypereutrophic range.

Chlorophyll *a* and Phytoplankton

The high surface concentrations of chlorophyll *a* indicated extensive blooms or algal increases that occurred throughout the year. The highest chlorophyll *a* concentration of 345.1 mg/m^3 occurred in January. In this particular instance there was a bloom of large-bodied flagellated algae which caused this spike during January. For the most part, concentrations were higher during the late summer and early fall. During 1997, summer chlorophyll *a* peaked during early July and August. The predominant algae present in Clear Lake during the summer samples were large populations of blue-green algae explaining the increase in chlorophyll. *Anabaena* spp., *Aphanizomenon* sp., *Oscillatoria* sp., and *Aphanocapsa* spp. were all present in greater numbers than most other species. The summer chlorophyll *a* concentrations for Clear Lake ranged well within the hypereutrophic range, with TSIs in excess of 65.

Relatively significant relationships were found between summer total phosphorus and chlorophyll *a* concentrations. After analyzing all data available for Clear Lake only the data collected during 1997 was found to exhibit a significant relationship between total phosphorus and chlorophyll *a* ($R^2 = 0.85$). This relationship was then used in the reduction response model for Clear Lake.

Reduction Response Model

A model estimated the effect on Clear Lake of reducing tributary phosphorus in the lake watershed for both Clear Lake. A 20% reduction of tributary loadings to Clear Lake would result in a chlorophyll *a* concentration reduction of 30%. If the reduction could be reached, the TSI ranking for chlorophyll *a* would be reduced to well below the hypereutrophic level for Clear Lake.

Aquatic Plant Survey

An aquatic plant survey was conducted for Clear Lake during August of 1997. This plant survey indicated heavy growth of the plant species *Potamogeton pectinatus,* commonly known as sago pondweed. Almost the entire surface area (>90% coverage) of the lake was covered with this species. Due to the shallow depth and the hyper-eutrophic condition of the lake there was only one dominant species of aquatic plant.

Sediment Survey

A sediment survey indicated that the removal of 750,000 cubic yards of sediment would increase the depth of the lake by 4 feet over 116 surface area acres. This constitutes 22% of the total surface area of Clear Lake.

RESTORATION ALTERNATIVES

Because of the soluble nature of nitrogen it is very difficult to remove it from a lake and watershed system. Phosphorus will not pass through groundwater as readily as nitrogen, as it sorbs on to soil and other substrates. Phosphorus is also considered the limiting nutrient when blue-green algae bloom. For these reasons the sponsors should concentrate on the removal of phosphorus from sources entering Clear Lake.

There are a variety of sources of phosphorus that were identified within the Clear Lake watershed. Various treatments and best management practices will need to be implemented in order to attain a 20% reduction in phosphorus loadings. According to the relationship between total phosphorus and chlorophyll *a*, this should result in a 30% reduction of lake Chlorophyll concentrations.

AGNPS Reductions

In order to achieve a chlorophyll *a* reduction a variety of best management practices (BMPs) need to be implemented in the subwatersheds identified in the AGNPS report in Appendix A. According to the AGNPS program, there are 56, 40-acre cells that need to be treated for a combination of sediment and nutrient problems. Twenty-six cells (1040 acres) need to implement a no-tillage practice and 30 cells (1200 acres) need to be converted over to minimum tillage. These cells either have rates of erosion greater than 9.0 tons per acre, or they contribute 10 lbs of sediment-based nitrogen per acre and 5 lbs of sediment-based phosphorus per acre to the overall loadings from the watershed. BMP installation (minimum tillage, no till, and animal waste management systems) on these areas identified in the AGNPS report in Appendix A will create the largest possible reduction in phosphorus loadings to Clear Lake (Table 15).

Table 15. **Agricultural Nonpoint Source Computer Model Reduction Response Results.**

			Percent Reduction in nutrients if:		
	Nutrient	Total AGNPS Loadings	AGNPS Cells with Erosion > 9.0 tons/acre,10 lbs of Nitrogen/acre, 5lbs of phosphorus/acre are treated	10 feeding areas rated > 60 undergo BMP installation	Total Reduction
Clear Lake	Nitrogen (tons)	77.0	10.9%	10.7%	21.6%
	Phosphorus (tons)	18.8	10.6%	9.6%	20.2%

Storm Sewers and Lawn Fertilization

The 20% reduction does not take into consideration any further reductions due to BMP implementation for lawn fertilization and the storm sewers in Clear Lake. The storm sewers drain a significant portion of the city of Clear Lake. As identified in the report, high concentrations of nutrients and sediment are delivered from the streets of Clear Lake. As the storm sewers are periodically upgraded, the possibility of installing sediment traps and sediment retention basins should be explored.

Contributions of phosphorus from the storm sewers via lawn fertilization can be reduced through the use of natural buffers or filter strips or the use of no-phosphate fertilizers, especially on lawns with high slopes located in the subwatershed of Site CLT-5. There are no-P fertilizers available such as CENEX/Land O'Lakes "Clear Lake" fertilizer which is phosphate-free (26-0-7 = N-P-K). A second source of no-P fertilizer is Organic N soybean-based fertilizer (6-0-6) from Renaissance Fertilizers, Edina, Minnesota. Another option is using straight ammonium nitrate fertilizer. These recommendations are for information only and do not imply endorsement by SDDENR.

Those fertilizer recommendations also apply to golf courses. The golf course located streamside in subwatershed Site CLT-5 should reconsider its management practices of fertilization and irrigation. Although no data was collected on the golf course specifically, in general, golf courses use large amounts of fertilizer and a great deal of water to maintain good conditions.

Onsite Wastewater Septic Systems

If cabins or permanent homes develop around Clear Lake it is important that modern individual septic and holding tanks should be installed around Clear Lake. Some type of modernized nutrient abatement procedure will need to be implemented so these areas do not contribute nutrients to the Clear Lake ecosystem.

Dredging

A final option and an opportunity for further inlake phosphorus reductions for Clear Lake is dredging. The contribution of internal phosphorus loading to the nutrient budget of Clear Lake was not calculated. Clear Lake continually receives phosphorus from the northwestern tributary which settles to the bottom, depending upon if it is in the particulate form. The shallow nature of Clear Lake allows this phosphorus to be reused through the resuspension of sediment and uptake by aquatic macrophytes and algae which can be a severe problem in Clear Lake. All of these inlake problems (aquatic macrophytes, blue-green algae blooms, internal loading, and lack of depth) can be solved through dredging. However, this restoration alternative is extremely expensive. The sediment survey indicated that there is 2.48 million cubic yards of sediment contained in the Clear Lake basin. This represents an average sediment depth of 2.9 feet over the entire 532 surface acres of the lake.

The north bay near where the northwestern tributary enters the lake contains the deepest and largest area of sediment. To remove all 2.48 million cubic yards is not economically feasible. Partial lake dredging will provide an affordable option that will still provide benefits to the lake and its users. The removal of 750,000 cubic yards of sediment would increase the depth of the lake by four feet over 116 surface area acres. Although this will increase average depth, aquatic plants can still develop in a depth of eight feet or more due to the anticipated improvement in water clarity. In addition, through the use of dredging, certain patterns can be created in the sediment to increase the fisheries habitat within the lake.

With the nutrient reductions from the watershed and dredging, over time there may be a reduction in the aquatic macrophyte problem. As less and less nutrients become available the growth of aquatic plants and blue-green algae blooms will begin to be limited. However, this would be the optimum situation and, more than likely the aquatic macrophytes will continue to be a problem. To reduce the impact of the aquatic macrophytes the users of the lake may choose to explore the possibility of an aquatic plant harvesting program. The removal of the plants will also help in the reduction of inlake phosphorus concentrations.

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APPENDIX A

PRELIMINARY REPORT ON THE
AGRICULTURAL NONPOINT SOURCE (AGNPS) ANALYSIS OF THE CLEAR LAKE WATERSHED
DEUEL COUNTY, SOUTH DAKOTA

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

MAY 1999

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EXECUTIVE SUMMARY

The entire Clear Lake watershed is located in Deuel County in eastern South Dakota and includes the town of Clear Lake, South Dakota. The size of the Clear Lake watershed and area modeled was 27,360 acres.

In order to further evaluate the water quality status of the Clear Lake watershed, landuse and geo-technical information was compiled. This information was then incorporated into a computer model. The primary objectives of utilizing a computer model on the Clear Lake watershed was to:

1.) Evaluate and quantify Nonpoint Source (NPS) yields from each subwatershed and determine the net loading at the outlet of Clear Lake;
2.) Define critical NPS cells within each subwatershed (elevated sediment, nitrogen, phosphorus); and
3.) Priority rank each animal feeding area and quantify the nutrient loadings from each area.

Based on the results of the computer model, the following conclusions were formulated:

1. <u>Watershed/ Subwatershed Analysis</u>

Sediment - The AGNPS data indicates that the Clear Lake watershed has a very low sediment deliverability rate at the outlet of Clear Lake (.032 tons/acre/year). This is equivalent to a load of 867 tons of sediment leaving Clear Lake per year. However, an analysis of the sediment transport and deliverability throughout the watershed indicated that for an average year, approximately 3,084 tons (.11 tons/acre) of sediment enter Clear Lake. This correlates to a trapping efficiency of 71.9% for Clear Lake which under estimates the status of erosion and sediment deliverability rates throughout the watershed. When a detailed subwatershed analysis was performed, four CL-1 (#308), CL-4 (#579), CL-5 (#553) and CL-6 (#485) of the ten subwatersheds analyzed appeared to have high sediment deliverability rates. These subwatersheds were found to contribute 55% of the total sediment, contain 39.5% of the critical erosion cells while occupying only 28.7% of the watershed area. The suspected source of this sediment is from agricultural lands which have slopes of 4% and greater, and are currently cropped or have poor vegetative cover. The conversion of this acreage to a high residue management system or rangeland should reduce the volume of sediment delivered to Clear Lake.

Nutrients - The AGNPS data indicates that the Clear Lake watershed (at the Clear Lake outlet) has a total nitrogen $_{\text{(soluble + sediment bound)}}$ deliverability rate of 5.58 lbs/acre/year, and a total phosphorus $_{\text{(soluble + sediment bound)}}$ deliverability rate of 1.18 lbs/acre/year. However, the mean subwatershed nutrient deliverability rate within the Clear Lake watershed was estimated to be 5.74 lbs/acre for nitrogen and 1.43 lbs/acre for phosphorus. On an annual basis, 77 tons of nitrogen and 18.8 tons of phosphorous are delivered to the lake while only 76 tons of nitrogen and 16.1 tons of phosphorous leave Clear Lake. This correlates to a trapping efficiency of 1.3% for nitrogen and 14.4% for phosphorous entering Clear Lake. This indicates that most of the nitrogen and phosphorous entering Clear Lake is in the water soluble (dissolved) form.

When a detailed subwatershed analysis was performed, four of the ten subwatersheds analyzed appeared to have high nutrient deliverability rates. Subwatersheds CL-1 (#308), CL-4 (#579), CL-5 (#553) and CL-10 (#562) appear to be contributing very high amounts of nutrients especially in the form of water soluble (dissolved) nutrients. The model indicates that these high loads may be related to animal feedlots located near the subwatershed outlets and close to channelized flows. The results also indicated that runoff from fertilized cropland was a significant source of water soluble nutrients to Clear Lake. These four subwatersheds contribute 51.6% (39.7 tons) of the total nitrogen and 56.4% (10.6 tons) of the total phosphorous load to Clear

Lake and only make up 38.3% of the watershed area. The most likely source of nutrients is from animal feeding operations located near stream channels and runoff from fertilized cropland.

2. Critical NPS Cells

Sediment - An analysis of individual cell sediment yields indicated that out of the 684 cells found within the Clear Lake watershed, 95 had sediment erosion yield greater than 9.0 tons/acre $_{\text{25 year event}}$. This is approximately 13.9% of the cells found within the entire watershed. The suspected primary source of elevated sedimentation within the critical cells is from agricultural lands which have landslopes of 4% or greater which are utilized as cropland (high C-factor). The AGNPS model was run with reduced C-factors to simulate conservation tillage practices to determine the amount of sediment that could be retained. The C-factors were changed on 26 cells (1040 acres) to a value that would simulate a change from conventional tillage to no-till practices. The C-factors were also changed on 30 cells (1200 acres) to a value that would simulate a change from conventional tillage to minimum tillage practices. Installing these practices will reduce the amount of sediment entering Clear Lake annually from 3084 tons to 2034 tons (34% reduction).

Nutrients - An analysis of individual cell nutrient yields indicated that out of the 684 cells found within the watershed, 63 had sediment bound nitrogen yields greater than 10.0 lbs./acre and sediment bound phosphorus yields greater than 5.0 lbs./acre. This is approximately 9.2% of the cells within the watershed. An analysis of individual cell nutrient yields also indicated that 11 cells had water soluble nitrogen yields greater than 10.0 lbs./acre and 6 cells with water soluble phosphorus yields greater than 5.0 lbs./acre. This indicates that sediment bound nutrients are the majority of the total nutrients that enter the lake. The suspected source of the elevated water soluble nutrient levels found within the Clear Lake watershed is likely due to animal feeding operations located adjacent to intermittent streams. The identified critical NPS cells should be given high priority when installing any future BMP's.

3. Feeding Area Evaluation

A total of 25 animal feeding areas were evaluated as part of the study. Of these, sixteen were found to have an AGNPS rating of 50 or greater and ten had an AGNPS rating of 60 or greater. An analysis to evaluate the impact of feeding areas was also performed. When the model was run with the ten feeding areas with an AGNPS rating > 60 taken out of the watershed, the dissolved phosphorous load into Clear Lake was reduced from 12.5 tons to 11.3 tons (9.6% reduction). For this same scenario the dissolved nitrogen load into Clear Lake was reduced from 63.7 tons to 56.9 tons (10.7% reduction). These ten feeding areas located within cells #249, #253, #312, #361, #376, #399, #490, #619, #639, and #660 appear to be contributing significant levels of nutrients to the watershed. It is recommended that these ten animal feeding areas be evaluated for potential operational or structural modifications in order to minimize future nutrient releases.

Conclusions - It is recommended that the implementation of appropriate BMP's be targeted to the critical subwatersheds, critical cells and priority animal feeding areas. However, due to the high rate of sediment erosion found within subwatersheds CL-1 (#308), CL-4 (#579), CL-5 (#553) and CL-6 (#485) and their high deliverability rates, initial efforts to reduce sediment should be targeted to these subwatersheds. Feeding areas with an AGNPS rating greater than 60 should be evaluated for potential operational or structural modifications in order to minimize future nutrient releases. These feeding areas appear to be contributing significant nutrients to the watershed and should be given a priority. It is recommended that any targeted cell should be field verified prior to the installation of any BMP's. This methodology should produce the most cost effective treatment plan in reducing sediment and nutrient loads to Clear Lake.

Potential contributions of sediment from gully, riparian areas, wind and nutrients from septic systems within the Clear Lake watershed were not evaluated as part of the computer modeling assessment phase.

CLEAR LAKE WATERSHED AGNPS ANALYSIS

Due to the lack of site specific water quality data, a computer model was selected in order to assess the Nonpoint Source (NPS) loadings throughout the Clear Lake watershed. The model selected was the Agricultural Nonpoint Source Pollution Model (AGNPS), version 3.65. This model was developed by the USDA - Agricultural Research Service to analyze the water quality of runoff events from watersheds. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand (COD) concentrations in the runoff and sediment for a single storm event for all points in the watershed. Proceeding from the headwaters to the outlet, the pollutants are routed in a step-wise fashion so the flow at any point may be examined. This model was developed to estimate subwatershed or tributary loadings to a waterbody. The AGNPS model is intended to be used as a tool to objectively compare different subwatersheds within a watershed and watersheds throughout a basin.

The entire Clear Lake watershed is located in Deuel County in eastern South Dakota and includes the town of Clear Lake, South Dakota. The size of the Clear Lake watershed and area modeled was 27,360 acres. Initially, the watershed was divided into cells each of which had an area of 40 acres with dimensions of 1320 feet by 1320 feet. The dominant fluid flow direction within each cell was then determined. Based upon the fluid flow directions and drainage patterns, 10 monitored subwatersheds were identified. The AGNPS analysis of the Clear Lake watershed consisted of the collection of 21 field parameters for each cell, the calculation of nonpoint source pollution yields for each cell and subwatershed, impact and ranking of each animal feeding area, and an estimated hydrology runoff volume for each of the storm events modeled.

AGNPS GOALS

The primary objectives of running AGNPS model on the Clear Lake watershed was to:

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

The following is a brief overview of each objective.

OBJECTIVE 1 - EVALUATE AND QUANTIFY SUBWATERSHED NPS LOADINGS

DELINEATION AND LOCATION OF SUBWATERSHEDS

The following AGNPS cells correlate to water quality monitoring sites that were used in the Diagnostic/Feasibility study that was performed in 1996 and 1997;

SUBWATERSHED	DRAINAGE AREA	OUTLET CELL #	DESCRIPTION
1	9000	249	CL-2a
2	3840	308	CL-1
3	15,840	373	CL-3
4	16,720	481	CL-7
5	100	485	CL-6
6	3800	553	CL-5
7	22,400	557	CL-9
8	2840	562	CL-10
9	3000	579	CL-4
10	720	483	non-monitored trib.
Clear Lake Outlet	27,360	587	Watershed Outlet

Clear Lake Subwatershed ***per acre*** loadings (primary drainages)

Outlet cell Number	Drainage Area (acres)	Annual Sed. Yield (tons/acre)	Attached N (lbs/acre)	Dissolved N (lbs/acre)	Total Nitrogen (lbs/acre)	Attached P (lbs/acre)	Dissolved P (lbs/acre)	Total Phosph. (lbs/acre)
249	9000	0.099	0.78	3.51	4.29	0.45	0.63	1.08
308	3840	0.236	1.58	5.26	6.84	0.83	1.13	1.96
373	15840	0.103	0.86	4.55	5.41	0.36	0.88	1.24
481	16720	0.115	0.91	4.59	5.50	0.40	0.88	1.28
483	720	0.045	0.46	4.58	5.04	0.25	1.06	1.31
485	1000	0.152	1.32	3.93	5.25	0.68	0.82	1.50
553	3800	0.172	1.93	7.18	9.11	0.95	1.43	2.38
557	22400	0.019	0.17	4.74	4.91	0.10	0.91	1.01
562	2840	0.113	0.86	5.68	6.54	0.50	1.16	1.66
579	3000	0.213	1.48	7.31	8.79	0.70	1.44	2.14
587	27360	0.032	0.36	5.22	5.58	0.11	1.07	1.18

Clear Lake Subwatershed ***total*** loadings (primary drainages)

Outlet cell Number	Drainage Area (acres)	Annual Sed. Yield (tons)	Attached N (tons)	Dissolved N (tons)	Total Nitrogen (tons)	Attached P (tons)	Dissolved P (tons)	Total Phosph. (tons)
249	9000	887	3.51	15.80	19.31	2.03	2.84	4.86
308	3840	905	3.03	10.10	13.13	1.59	2.17	3.76
373	15840	1632	6.81	36.04	42.85	2.85	6.97	9.82
481	16720	1923	7.61	38.37	45.98	3.34	7.36	10.70
483	720	33	0.17	1.65	1.81	0.09	0.38	0.47
485	1000	152	0.66	1.97	2.63	0.34	0.41	0.75
553	3800	655	3.67	13.64	17.31	1.81	2.72	4.52
557	22400	420	1.90	53.09	54.99	1.12	10.19	11.31
562	2840	321	1.22	8.07	9.29	0.71	1.65	2.36
579	3000	638	2.22	10.97	13.19	1.05	2.16	3.21
587	27360	867	4.92	71.41	76.33	1.50	14.64	16.14
Total Load to Clear Lake		3084	13.3	63.7	77.0	6.3	12.5	18.8

§ - Annual loadings were estimated by calculating the NPS loadings for the cumulation of rainfall events during a average year. This includes a 1 year 24 hour event of 2.1" (E.I. = 24.3), 3 semi-annual rainfall events of 1.6" (E.I. = 13.4) and a series of 11 small rainfall events of .9" (E.I. = 3.8) for a total "R" factor of 106.3 . Rainfall events of less than .9" were modeled and found to produce insignificant amounts of sediment and nutrient yields.

SEDIMENT YIELD RESULTS

The AGNPS model calculated that the sediment delivered from the Clear Lake watershed to Clear Lake is 0.11 tons/acre/year for an estimated annual load. This is equivalent to 3084 tons for an annual load. A comparison of the subwatershed total sediment yield to its aerial size is:

SUBWATERSHED	% OF TOTAL SEDIMENT LOADING	% OF WATERSHED AREA	# OF CRITICAL CELLS
4 (#481)	62.4%	61.1%	62 (65.3%)
5 (#483)	1.1%	2.6%	0
6 (#485)	4.9%	3.7%	2 (2.1%)
7 (#553)	21.2%	13.9%	15 (15.8%)
9 (#562)	10.4%	10.4%	7 (7.4%)
Totals	100%	91.7%	86 of 95 (90.5%)

SEDIMENT ANALYSIS

Subwatersheds CL-1 (#308), CL-4 (#579), CL-5 (#553) and CL-6 (#485) are delivering large amounts of sediment to the watershed. These subwatersheds were found to contribute 55% of the total sediment, contain 39.5% of the critical erosion cells while occupying only 28.7% of the watershed area. The high sediment yields can be attributed to landuse and landslope. The source of this sediment is primarily from agricultural land with slopes greater than 4% and C-Factors > 0.25. The conversion of this acreage to a high residue management system or back to native grasses will reduce the amount of sediment delivered to the watershed. Efforts should be made to target appropriate BMP’s to the 95 critical erosion cells defined on page 22.

An analysis of the sediment transport and deliverability throughout the watershed indicated during an average year, approximately 3084 tons (0.11 tons/acre) of sediment enter Clear Lake and 867 tons (0.032 tons/acre) of sediment leave the lake. This correlates to a trapping efficiency of 71.9% for Clear Lake. Due to the trapping efficiency of the lake, the net watershed sediment deliverability rate at the outlet of Clear Lake of .032 tons/acre/$year_t$ appears to be very low. This low rate under estimates the status of erosion and sediment deliverability rates throughout the watershed, since the mean subwatershed sediment deliverability rate to Clear Lake was estimated to be 0.127 tons/acre.

The impact of sediment erosion derived from gully erosion, riparian areas, shoreline erosion, wind and their deliverability to the watershed was not modeled.

NUTRIENT YIELD RESULTS

The AGNPS data indicates that the Clear Lake watershed (at Clear Lake outlet) has a total nitrogen (soluble + sediment bound) deliverability rate of 5.58 lbs/acre/year (equivalent to 76.3 tons) and a total phosphorus (soluble + sediment bound) deliverability rate of 1.18 lbs/acre/year (equivalent to 16.1 tons). The total nutrient load delivered from the subwatersheds to Clear Lake is estimated to be 77 tons/year of nitrogen and 18.8 tons/year of phosphorus for an estimated annual load. A comparison of the subwatershed total nutrient yield to its aerial size for an annual load is:

SUBWATERSHED (CELL #)	% OF TOTAL NITROGEN YIELD	% OF TOTAL PHOS. YIELD	% OF WATERSHED AREA	# OF CRITICAL NUTRIENT CELLS
4 (#481)	59.7%	56.9%	61.1%	47
5 (#483)	2.4%	2.5%	2.6%	0
6 (#485)	3.4%	4.0%	3.7%	0
7 (#553)	22.5%	24.0%	13.9%	8
9 (#562)	12.0%	12.6%	10.4%	6
Totals	100%	100%	91.7%	61 of 63 (96.8%)

TOTAL NUTRIENT ANALYSIS

Subwatersheds CL-1 (#308), CL-4(#579), CL-5(#553) and CL-10 (#562) appear to be contributing elevated levels of total nutrients (mostly water soluble). This can probably be attributed to the nutrients which are associated with the high sediment yields from these subwatersheds. This is verified by the fact that of the four critical nutrient subwatersheds three, CL-1 (#308), CL-4(#579) and CL-5(#553) of these subwatersheds were identified as critical erosion subwatersheds. Subwatershed CL-10 (#562) is not identified as a critical erosion subwatershed, but it does contain four animal feeding operations that received an AGNPS ranking greater than 50.

The results show that 84% of the total nitrogen and 68% of the total phosphorous load coming into Clear Lake is in the water soluble (dissolved) form. This indicates that animal feeding areas and runoff from fertilized cropland may be a large contributor of nutrients to Clear Lake. Overall, the total nutrients delivered from the Clear Lake watershed is high when adjusted for its watershed size and deliverability system (mean of 5.74 lbs/acre for nitrogen and 1.43 lbs/acre for phosphorus). The most likely source of nutrients is from runoff of cropland and animal feeding operations within the watershed.

OBJECTIVE 2 - IDENTIFICATION OF CRITICAL NPS CELLS (25 YEAR EVENT)

Priority Erosion Cells			**Priority Nitrogen Cells**			**Priority Phosphorous Cells**			**Priority Feeding Areas**	
Cell #	Sediment Yield		Cell #	Nitrogen Yield		Cell #	Phosphorous Yield		Cell #	AGNPS Rating
626	76.29	Tons/acre	3	30.26	Lbs/acre	3	15.13	Lbs/acre	249	60
3	47.37	“	287	22.78	“	287	11.39	“	253	66
18	47.37	“	398	21.69	“	398	10.84	“	312	66
93	25.33	“	519	18.02	“	519	9.01	“	361	87
455	22.66	“	413	17.3	“	413	8.65	“	376	61
287	22.40	“	334	17.17	“	334	8.58	“	399	65
571	21.92	“	393	16.58	“	393	8.29	“	490	72
39	20.60	“	474	16.39	“	474	8.19	“	619	62
41	18.54	“	389	15.83	“	389	7.91	“	639	65
442	16.18	“	273	15.43	“	273	7.72	“	660	63
326	14.61	“	394	15.43	“	394	7.72	“		
398	14.49	“	500	15.43	“	500	7.72	“		
474	14.49	“	41	15.09	“	41	7.55	“		
115	13.90	“	326	14.88	“	326	7.44	“		
116	13.90	“	549	14.32	“	549	7.16	“		
334	13.90	“	343	14.08	“	343	7.04	“		
389	13.90	“	455	13.98	“	455	6.99	“		
418	13.90	“	444	13.69	“	444	6.85	“		
444	13.90	“	515	13.57	“	515	6.79	“		
445	13.90	“	107	13.16	“	107	6.58	“		
413	13.38	“	420	13.16	“	420	6.58	“		
273	12.00	“	365	13.08	“	365	6.54	“		
305	12.00	“	427	13.05	“	427	6.53	“		
362	12.00	“	69	13.03	“	69	6.52	“		
363	12.00	“	99	12.72	“	99	6.36	“		
372	12.00	“	445	12.64	“	445	6.32	“		
392	12.00	“	78	12.39	“	78	6.19	“		
393	12.00	“	24	12.07	“	24	6.03	“		
394	12.00	“	236	12.06	“	236	6.03	“		
395	12.00	“	449	11.99	“	449	6	“		
396	12.00	“	301	11.93	“	270	5.96	“		
420	12.00	“	270	11.92	“	301	5.96	“		
500	12.00	“	253	11.91	“	253	5.95	“		
399	11.50	“	7	11.77	“	7	5.88	“		
427	11.50	“	428	11.77	“	428	5.88	“		
428	11.50	“	269	11.69	“	269	5.84	“		
454	11.50	“	465	11.68	“	465	5.84	“		
478	11.50	“	478	11.54	“	412	5.77	“		
515	11.50	“	412	11.53	“	441	5.77	“		
519	11.50	“	441	11.53	“	478	5.77	“		
523	11.50	“	442	11.53	“	442	5.76	“		
540	11.25	“	53	11.47	“	18	5.73	“		
78	11.00	“	18	11.46	“	53	5.73	“		
79	11.00	“	399	11.36	“	399	5.68	“		
82	11.00	“	203	11.3	“	203	5.65	“		
107	11.00	“	55	11.27	“	55	5.64	“		
108	11.00	“	235	11.25	“	235	5.63	“		
145	11.00	“	182	11.22	“	182	5.61	“		
549	11.00	“	79	11.2	“	79	5.6	“		
310	10.75	“	147	11.1	“	147	5.55	“		
421	10.75	“	36	11.01	“	85	5.51	“		
422	10.75	“	85	11.01	“	114	5.51	“		
501	10.75	“	114	11.01	“	36	5.5	“		
502	10.75	“	115	10.99	“	115	5.49	“		

Priority Erosion Cells	
Cell #	Sediment Yield
343	10.69 “
221	10.23 “
5	10.13 “
118	10.13 “
463	10.13 “
282	10.09 “
24	9.84 “
29	9.84 “
50	9.84 “
448	9.75 “
525	9.75 “
16	9.74 “
69	9.71 “
253	9.71 “
318	9.71 “
380	9.71 “
535	9.71 “
619	9.71 “
87	9.56 “
202	9.56 “
203	9.56 “
234	9.56 “
235	9.56 “
236	9.56 “
333	9.56 “
355	9.56 “
391	9.56 “
178	9.50 “
274	9.50 “
518	9.50 “
570	9.50 “
37	9.29 “
465	9.29 “
489	9.29 “
510	9.29 “
55	9.27 “
269	9.27 “
270	9.27 “
627	9.09 “
20	9.07 “
36	9.07 “

Priority Nitrogen Cells	
Cell #	Nitrogen Yield
108	10.77 “
370	10.66 “
516	10.62 “
93	10.51 “
116	10.4 “
626	10.32 “
66	10.12 “
335	10.1 “
47	10.07 “

Priority Phosphorous Cells	
Cell #	Phosporous Yield
108	5.39 “
370	5.33 “
516	5.31 “
93	5.26 “
116	5.2 “
626	5.16 “
66	5.06 “
335	5.05 “
47	5.04 “

Based upon an evaluation of NPS cell yield data, the following critical cell yield criteria was established:

sediment erosion rate ≥ 9.0 tons/acre
total nitrogen cell yields ≥ 10.0 lbs/acre
total phosphorus cell yields ≥ 5.0 lbs/acre

An analysis of the Clear Lake watershed indicates that there are approximately 95 cells which have a sediment yield greater than 9.0 tons/acre. This is approximately 13.9% of the cells found within the entire watershed. The yields for each of these cells are listed on pages 9 and 10, and their locations are documented on page 22. These critical cells are primarily composed of lands that have a slope of 4% or greater and have a cropping factor (C-factor) of 25 or greater.

The model estimated that there are 63 cells which have a sediment bound nitrogen yield greater than 10.0 lbs./acre and 63 cells with a sediment bound phosphorus yield greater than 5.0 lbs./acre. This is approximately 9.2% of the cells within the watershed. The yields for each of these cells are listed on pages 9 and 10, and their locations are documented on page 23. Based upon a subwatershed area weighted to number of critical cells analysis, the most critical source of nutrients and deliverability are from subwatersheds CL-1 (#308), CL-4(#579), CL-5(#553) and CL-10 (#562). These critical subwatersheds, the critical animal feeding areas and identified critical NPS cells should be given high priority when installing any future BMPs. It is recommended that any targeted cells or feeding areas should be field verified prior to the installation of any BMPs.

OBJECTIVE 3 - PRIORITY RANKING OF ANIMAL FEEDING AREAS (25 YEAR EVENT)

A total of 25 animal feeding areas were identified as potential NPS sources during the AGNPS data acquisition phase of the project. On pages 11 -14 is a listing of the AGNPS analysis of each feeding area. Of these, 16 were found to have an AGNPS ranking of 50 or greater and 10 had an AGNPS ranking of 60 or greater. AGNPS ranks feeding areas from 0 to 100 with a 0 ranked feeding area yielding very little nutrients and 100 ranking yielding large amounts of nutrients.

These ten feeding areas located within cells #249, #253, #312, #361, #376, #399, #490, #619, #639, and #660 appear to be contributing significant levels (AGNPS ranking > 60) of nutrients to the watershed. Feeding areas located in cells #98, #146, #238, #407 and #488 appear to be contributing elevated levels (AGNPS ranking > 50) of nutrients to the watershed. In order to determine the impact of these ten feeding areas, an AGNPS runs was made with these feeding areas removed and then compared to the run where the feeding areas were a part of the watershed. The results of this showed the dissolved phosphorous load into Clear Lake was reduced from 12.5 tons to 11.3 tons (9.6% reduction) annually. For this same scenario the dissolved nitrogen load into Clear Lake was reduced from 63.7 tons to 56.9 tons (10.7% reduction) annually.

It is recommended that these 10 animal feeding areas be evaluated for potential operational or structural modifications in order to minimize future nutrient releases. It is also recommended that all other potential feeding areas within the Clear Lake watershed be evaluated. Other possible sources of nutrient loadings not modeled through this study were those from septic systems and from livestock depositing fecal material directly into the lake or adjacent streams. Overall, based upon the accuracy of the watershed information gathered as part of this study, the total nutrients contributed from animal feeding areas within the Clear Lake watershed is high.

CONCLUSIONS

Sediment

Based upon the AGNPS results, the sediment delivered from the outlet of Clear Lake is 867 tons annually (0.032 tons/acre). This rate is much lower than the calculated subwatershed mean value of 0.127 tons/acre/year. This difference can be attributed to the trapping efficiency (71.9%) of Clear Lake. The net watershed sediment deliverability rate at the outlet of Clear Lake of 0.032 tons/acre/year appears to be very low however, this low rate under estimates the status of erosion and sediment deliverability throughout the watershed. When a detailed subwatershed analysis was performed, four of the ten subwatersheds analyzed appeared to have very high sediment deliverability rates. CL-1 (#308), CL-4 (#579), CL-5 (#553) and CL-6 (#485) were found to be contributing 55% of the total subwatershed sediment loads, contain 39.5% of the critical erosion cells while comprising only 28.7% of the watershed area.

An analysis of individual cell sediment yields indicated that out of the 684 cells found within the Clear Lake watershed, 95 (13.9%) had sediment erosion yields greater than 9.0 tons/acre for a 25 year event. The suspected primary source of elevated sedimentation within the critical cells is from agricultural lands which have land slopes of 4% or greater which are utilized as cropland (high C-factor). In order to determine the amount of reduction in sedimentation from these 95 critical cells, the AGNPS model was run with reduced C-factors. The AGNPS model was run with reduced C-factors to simulate conservation tillage practices to determine the amount of sediment that could be retained.

The C-factors were changed on 26 cells (1040 acres) to a value that would simulate a change from conventional tillage to no-till practices. The C-factors were also changed on 30 cells (1200 acres) to a value that would simulate a change from conventional tillage to minimum tillage practices. Installing these practices will reduce the amount of sediment entering Clear Lake annually from 3084 tons to 2034 tons (34% reduction). Therefore, it is recommended that efforts to reduce sediment should be focused within the identified critical subwatersheds and individual critical erosion cells located throughout the watershed. It is recommended that these areas be targeted for conversion to rangeland or the implementation of a high residue management plan. It is recommended that any targeted cell should be field verified prior to the installation of any best management practices.

Nutrients

The AGNPS data indicates that for a 25 year event, 240 tons of nitrogen and 72 tons of phosphorous are delivered to the lake while only 169 tons of nitrogen and 45 tons of phosphorous leave Clear Lake. This correlates to a trapping efficiency of 29.5% for nitrogen and 37.5% for phosphorous entering Clear Lake. When a detailed subwatershed analysis was performed, four of the sixteen subwatersheds analyzed appeared to have high nutrient deliverability rates. Subwatersheds CL-1 (#308), CL-4(#579), CL-5(#553) and CL-10 (#562) were found to be contributing more than 66% of the total subwatershed nutrient loads while comprising only 29.5% of the watershed area. An analysis of individual cell nutrient yields indicated that out of the 2643 cells found within the watershed, 85 (3.2%) cells had total nitrogen yields greater than 10.0 lbs./acre and 89 (3.4%) cells had total phosphorus yields greater than 3.5 lbs./acre. The AGNPS output showed that most of the nitrogen and phosphorous from the critical cells is in a water soluble form. The model also indicated that the majority of these critical nutrient cells are located on or downstream of animal feeding areas.

The suspected source of the elevated nutrient levels found within the Clear Lake watershed is probably from animal feeding operations. Therefore, it is recommended that efforts to reduce nutrients should be focused within the identified critical subwatersheds, individual critical nutrient cells and priority animal feeding areas located throughout the watershed.

Animal Feeding Areas

A total of 25 animal feeding areas were evaluated as part of the study. Of these, sixteen were found to have an AGNPS rating of 50 or greater and ten had an AGNPS rating of 60 or greater. An analysis to evaluate the impact of feeding areas was also performed. In order to determine the impact of these ten feeding areas, an AGNPS runs was made with these feeding areas removed and then compared to the run where the feeding areas were a part of the watershed. The results of this showed the dissolved phosphorous load into Clear Lake was reduced from 12.5 tons to 11.3 tons (9.6% reduction) annually. For this same scenario the dissolved nitrogen load into Clear Lake was reduced from 63.7 tons to 56.9 tons (10.7% reduction) annually. These ten feeding areas located within cells #249, #253, #312, #361, #376, #399, #490, #619, #639, and #660 appear to be contributing significant levels (AGNPS ranking > 60) of nutrients to the watershed It is recommended that these ten animal feeding areas be evaluated for potential operational or structural modifications in order to minimize future nutrient releases.

It is recommended that efforts to reduce sediment and nutrients be targeted to the installation of appropriate BMPs on cropland (≥ 4% slope), conversion of highly erodible cropland lands to rangeland or CRP, improvement of land surface cover (C-factor) on cropland and rangeland and measures initiated to reduce nutrient runoff from animal feeding areas.

The implementation of appropriate BMPs targeting identified critical cells, priority subwatersheds and priority feeding areas upon the completion of a field verification process should produce the most cost effective treatment plan in reducing sediment and nutrient yields from the Clear Lake watershed.

If you have any questions concerning this study, please contact the Department of Environment and Natural Resources at 605-773-4254.

FEEDING AREA ANALYSIS

Cell #	14
Nitrogen concentration (ppm)	39.7
Phosphorus concentration (ppm)	5.3
COD concentration (ppm)	727.2
Nitrogen mass (lbs)	56.0
Phosphorus mass (lbs)	7.4
COD mass (lbs)	1025.4
Animal feedlot rating number	**29**

Cell #	17
Nitrogen concentration (ppm)	0.9
Phosphorus concentration (ppm)	0.5
COD concentration (ppm)	26.4
Nitrogen mass (lbs)	13.1
Phosphorus mass (lbs)	7.3
COD mass (lbs)	385.7
Animal feedlot rating number	**16**

Cell #	44
Nitrogen concentration (ppm)	25.2
Phosphorus concentration (ppm)	6.8
COD concentration (ppm)	345.5
Nitrogen mass (lbs)	150.1
Phosphorus mass (lbs)	40.3
COD mass (lbs)	2060.5
Animal feedlot rating number	**40**

Cell #	98
Nitrogen concentration (ppm)	155.3
Phosphorus concentration (ppm)	43.3
COD concentration (ppm)	2268.9
Nitrogen mass (lbs)	422.7
Phosphorus mass (lbs)	117.8
COD mass (lbs)	6175.8
Animal feedlot rating number	**54**

Cell #	146
Nitrogen concentration (ppm)	284.8
Phosphorus concentration (ppm)	80.6
COD concentration (ppm)	3327.9
Nitrogen mass (lbs)	587.7
Phosphorus mass (lbs)	166.4
COD mass (lbs)	6867.5
Animal feedlot rating number	**54**

Cell #	238
Nitrogen concentration (ppm)	69.3
Phosphorus concentration (ppm)	18.6
COD concentration (ppm)	1056.4
Nitrogen mass (lbs)	334.3
Phosphorus mass (lbs)	90.1
COD mass (lbs)	5095.7
Animal feedlot rating number	**53**

Cell #	249
Nitrogen concentration (ppm)	68.7
Phosphorus concentration (ppm)	10.7
COD concentration (ppm)	1148.8
Nitrogen mass (lbs)	504.1
Phosphorus mass (lbs)	78.6
COD mass (lbs)	8423.0
Animal feedlot rating number	**60**

Cell #	253
Nitrogen concentration (ppm)	37.4
Phosphorus concentration (ppm)	9.5
COD concentration (ppm)	483.5
Nitrogen mass (lbs)	828.0
Phosphorus mass (lbs)	210.7
COD mass (lbs)	10703.1
Animal feedlot rating number	**66**

Cell #	284
Nitrogen concentration (ppm)	70.9
Phosphorus concentration (ppm)	9.3
COD concentration (ppm)	1472.7
Nitrogen mass (lbs)	200.2
Phosphorus mass (lbs)	26.2
COD mass (lbs)	4158.9
Animal feedlot rating number	**49**

Cell #	312
Nitrogen concentration (ppm)	111.5
Phosphorus concentration (ppm)	27.1
COD concentration (ppm)	1643.9
Nitrogen mass (lbs)	836.5
Phosphorus mass (lbs)	203.1
COD mass (lbs)	12331.3
Animal feedlot rating number	**66**

Cell #	361
Nitrogen concentration (ppm)	142.0
Phosphorus concentration (ppm)	39.5
COD concentration (ppm)	2064.7
Nitrogen mass (lbs)	3010.1
Phosphorus mass (lbs)	836.6
COD mass (lbs)	43756.1
Animal feedlot rating number	**87**

Cell #	375
Nitrogen concentration (ppm)	0.4
Phosphorus concentration (ppm)	0.7
COD concentration (ppm)	60.7
Nitrogen mass (lbs)	0.4
Phosphorus mass (lbs)	0.8
COD mass (lbs)	64.3
Animal feedlot rating number	**0**

Cell #	376

Cell #	382

Nitrogen concentration (ppm)	235.9
Phosphorus concentration (ppm)	66.5
COD concentration (ppm)	3511.5
Nitrogen mass (lbs)	710.0
Phosphorus mass (lbs)	200.2
COD mass (lbs)	10570.2
Animal feedlot rating number	**61**

Cell #	399	
Nitrogen concentration (ppm)		206.8
Phosphorus concentration (ppm)		45.8
COD concentration (ppm)		2896.8
Nitrogen mass (lbs)		924.2
Phosphorus mass (lbs)		204.8
COD mass (lbs)		12946.6
Animal feedlot rating number		**65**

Cell #	477	
Nitrogen concentration (ppm)		12.1
Phosphorus concentration (ppm)		3.7
COD concentration (ppm)		368.0
Nitrogen mass (lbs)		15.1
Phosphorus mass (lbs)		4.7
COD mass (lbs)		460.9
Animal feedlot rating number		**18**

Cell #	490	
Nitrogen concentration (ppm)		76.9
Phosphorus concentration (ppm)		21.3
COD concentration (ppm)		1109.9
Nitrogen mass (lbs)		1147.3
Phosphorus mass (lbs)		317.4
COD mass (lbs)		16549.7
Animal feedlot rating number		**72**

Cell #	592	
Nitrogen concentration (ppm)		60.8
Phosphorus concentration (ppm)		9.5
COD concentration (ppm)		1052.3
Nitrogen mass (lbs)		382.7
Phosphorus mass (lbs)		59.8
COD mass (lbs)		6622.1
Animal feedlot rating number		**57**

Cell #	619	
Nitrogen concentration (ppm)		288
Phosphorus concentration (ppm)		81.6
COD concentration (ppm)		4320
Nitrogen mass (lbs)		763.5
Phosphorus mass (lbs)		216.3
COD mass (lbs)		11452.9
Animal feedlot rating number		**62**

Cell #	660	
Nitrogen concentration (ppm)		166.4
Phosphorus concentration (ppm)		46.5
COD concentration (ppm)		2441.0
Nitrogen mass (lbs)		787.7

Nitrogen concentration (ppm)	110.9
Phosphorus concentration (ppm)	36.5
COD concentration (ppm)	1661.6
Nitrogen mass (lbs)	228.2
Phosphorus mass (lbs)	75.1
COD mass (lbs)	3419.3
Animal feedlot rating number	**45**

Cell #	407	
Nitrogen concentration (ppm)		69.9
Phosphorus concentration (ppm)		10.7
COD concentration (ppm)		937.4
Nitrogen mass (lbs)		495.0
Phosphorus mass (lbs)		75.8
COD mass (lbs)		6636.0
Animal feedlot rating number		**57**

Cell #	488	
Nitrogen concentration (ppm)		45.0
Phosphorus concentration (ppm)		17.0
COD concentration (ppm)		773.8
Nitrogen mass (lbs)		255.7
Phosphorus mass (lbs)		96.9
COD mass (lbs)		4398.1
Animal feedlot rating number		**51**

Cell #	568	
Nitrogen concentration (ppm)		26.1
Phosphorus concentration (ppm)		5.8
COD concentration (ppm)		275.1
Nitrogen mass (lbs)		116.8
Phosphorus mass (lbs)		25.8
COD mass (lbs)		1229.7
Animal feedlot rating number		**31**

Cell	612	
Nitrogen concentration (ppm)		6.7
Phosphorus concentration (ppm)		2.7
COD concentration (ppm)		119.4
Nitrogen mass (lbs)		25.1
Phosphorus mass (lbs)		10.2
COD mass (lbs)		448.6
Animal feedlot rating number		**17**

Cell #	639	
Nitrogen concentration (ppm)		214.5
Phosphorus concentration (ppm)		52.2
COD concentration (ppm)		2681.3
Nitrogen mass (lbs)		1032.9
Phosphorus mass (lbs)		251.4
COD mass (lbs)		12910.9
Animal feedlot rating number		**65**

Phosphorus mass (lbs)	220.1
COD mass (lbs)	11552.1
Animal feedlot rating number	**63**

RAINFALL SPECS FOR THE CLEAR LAKE WATERSHED STUDY

EVENT	RAINFALL	ENERGY INTENSITY
Monthly	.9	3.8
Semi-annual	1.6	13.4
1 year	2.1	24.3
5 year	3.0	52.6
10 year	3.5	73.7
25 year	4.5	127.9
50 year	4.6	133.5
100 year	5.2	174.4

NRCS R_{factor} for the Clear Lake watershed = 70

Annual Loadings Calculations

monthly events = 11 events x 3.8 = 41.8

6 month event = 3 events x 13.4 = 40.2

1 year event = 1 event x 24.3 = 24.3

========

Modeled Cumm. R_{factor} = 106.3

OVERVIEW OF AGNPS DATA INPUTS

OVERVIEW

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

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

PRELIMINARY EXAMINATION

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

1) Detailed topographic map of the watershed (USGS map 1:24,000) (figure 3).
2) Establish the drainage boundaries (figure 4).
3) Divide watershed up into cells (40 acre, 1320 X 1320). Only those cells with greater than 50% of their area within the watershed boundary should be included (figure 5).
4) Number the cells consecutively from one to the number of cells (begin at NW corner of watershed and precede west to east then north to south (figure 5).
5) Establish the watershed drainage pattern from the cells (figure 5).

DATA FILE

Once the preliminary examination is completed, the input data file can be established. The data file is composed of the following 21 inputs per cell (table 1):

<u>Data input for watershed</u> (attachment 1)

1) a) Area of each cell (acres)
   b) Total number of cells in watershed
   c) Precipitation for a ___ year, 24 hour rainfall
   d) Energy intensity value for storm event previously selected

Data input for each cell

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

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

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

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

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

17) **Availability factor**, (table 9) the percent of fertilizer left in the top half inch of soil at the time of the storm. Worst case 100%, water or marsh = 0, urban or residential = 100%.

18) **Point source indicator**: indicator of feedlot within the cell (0 = no feedlot, 1 = feedlot) (attachment 3).

19) **Gully source level**: tons of gully erosion occurring in the cell or input from a sub-watershed (attachment 4).
20) **Chemical oxygen demand (COD) demand**, (table 10) a value of COD for the land use in the cell.
21) **Impoundment factor**: number of impoundment's in the cell (max. 13) (attachment 5)
    a) Area of drainage into the impoundment
    b) Outlet pipe (inches)
22) **Channel indicator**: number which designates the type of channel found in the cell (Table 11)

DATA OUTPUT AT THE OUTLET OF EACH CELL

Hydrology

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

Sediment Output

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

Chemical Output

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

Phosphorus
- Sediment associated mass
- Concentration of soluble material
- Mass of soluble material

Chemical Oxygen Demand
- Concentration
- Mass

PARAMETER SENSITIVITY ANALYSIS

The most sensitive parameters affecting sediment and chemical yields are:
Land slope (LS)
Soil erodibility (K)
Cover-management factor (C)

Curve number (CN)
Practice factor (P)

APPENDIX B

Clear Lake, Deuel County
Inlake Water Quality Data
Phase I 319 Project (FY96)

DATE	TIME	SITE	UNCORRECTED CHLOROP mg/m3	A TEMP (C)	W TEMP (C)	WATER DEPTH (feet)	SECCHI (feet)	PH	DO (mg/l)	CONDUCT (umhos)	FECAL COLIFORM (per 100 ml)	ALKA-M (mg/l)	AMMONIA (mg/l)	ION-AMMON (mg/L)	NITRATE (mg/l)	TKN (mg/l)	ON (mg/l)	TN (mg/l)	TPO4 (mg/l)	TDPO4 (mg/l)	TSOL (mg/l)	TSSOL (mg/l)	TDSOL (mg/L)	VTSS (mg/L)
09/24/1996	1420	CL-1	36.85	18.0	14.5	5.0	0.7	8.34	8.30	420	20	178	0.11	0.00600	0.1	2.03	1.92	2.13	0.228	0.034	438	72	366	
10/22/1996	1245	CL-1	56.62	6.0	6.0	5.0	0.7	8.45	11.00	340	70	189	0.02	0.00074	0.1	2.16	2.14	2.26	0.276	0.027	467	80	387	
01/14/1997	1100	CL-1	4.02	-10.0	0.0	6.0	2.0	7.67	1.50	105	10	298	0.44	0.00135	0.1	2.31	1.87	2.41	0.111	0.074	621	4	589	
02/24/1997	1045	CL-1	64.99	-7.0	2.0	5.5	2.2	7.51	1.20	550	10	347	0.72	0.00227	0.1	3.10	2.38	3.20	0.186	0.064	758	9	749	
03/25/1997	1000	CL-1	30.15	3.0	1.0	2.2	2.8	7.71	6.50	580	10	206	0.52	0.00239	0.4	2.92	2.40	3.32	0.184	0.071	763	16	747	
04/29/1997	1000	CL-1	30.82	12.0	12.0	3.8	2.6	9.07	10.50	350	10	166	0.02	0.00407	0.1	0.79	0.77	0.89	0.091	0.027	350	13	337	
05/20/1997	1115	CL-1	18.43	12.0	13.0	5.0	1.7	8.96	9.20	425	10	191	0.03	0.00530	0.1	1.14	1.11	1.24	0.079	0.024	421	17	404	
06/24/1997	920	CL-1	8.71	24.0	23.5	5.5	2.3	8.30	4.25	590	10	198	0.10	0.00926	0.1	1.30	1.20	1.40	0.093	0.061	477	10	467	
07/22/1997	1020	CL-1	52.60		24.0	5.8	1.7	8.62	4.50	550	10	159	0.02	0.00362	0.1	1.31	1.29	1.41	0.254	0.151	474	16	458	
08/26/1997	1045	CL-1	28.81		26.0	5.5	2.1	9.16	9.40	550	10	174	0.02	0.00903	0.1	1.53	1.51	1.63	0.149	0.062	458	13	445	
09/22/1997	1050	CL-1	69.01	17.0	16.0	5.5	0.9	8.90	7.90	440	10	199	0.02	0.00357	0.1	1.57	1.56	1.67	0.225	0.054	473	52	421	16
10/14/1997	1020	CL-1	95.14	5.6	8.5	5.5	0.6	8.45	9.50	380	30	206	0.24	0.01070	0.1	1.88	1.64	1.98	0.198	0.084	495	80	415	18
12/17/1997	1040	CL-1	20.10	3.3	1.0	4.8	3.5	8.42	13.60	420	10	243	0.02	0.00046	0.3	1.45	1.43	1.75	0.065	0.039	556	3	553	1
01/12/1998	1020	CL-1	345.05	-18.9	1.0	4.1	1.5	8.49	18.10	450	10	291	0.02	0.00054	0.1	2.73	2.71	2.83	0.276	0.035	661	26	635	18
02/17/1998	1110	CL-1	35.51	2.2	1.0	4.1	4.0	7.85	10.00	470	10	293	0.23	0.00145	0.1	1.82	1.59	1.92	0.163	0.100	645	13	632	5
03/17/1998	1100	CL-1	78.06	1.7	0.5	4.3	1.9	8.20	13.50	350	10	228	0.02	0.00027	0.9	2.23	2.21	3.13	0.213	0.083	520	9	511	7
04/21/1998	915	CL-1		11.1	10.5	6.5	2.0	8.62	9.50	440	10	203	0.02	0.00149	0.1	1.13	1.11	1.23	0.070	0.015	456	13	445	5
05/20/1998	1045	CL-1		22.2	20.5	5.8	1.1	8.60	7.60	600	10	223	0.02	0.00282	0.1	2.17	2.15	2.27	0.127	0.020	516	30	486	

DATE	TIME	SITE	UNCORRECTED CHLOROP mg/m3	A TEMP (C)	W TEMP (C)	WATER DEPTH (feet)	SECCHI (feet)	PH	DO (mg/l)	CONDUCT (umhos)	FECAL COLIFORM (per 100 ml)	ALKA-M (mg/l)	AMMONIA (mg/l)	ION-AMMON (mg/L)	NITRATE (mg/l)	TKN (mg/l)	ON (mg/l)	TN (mg/l)	TPO4 (mg/l)	TDPO4 (mg/l)	TSOL (mg/l)	TSSOL (mg/l)	TDSOL (mg/L)	VTSS (mg/L)
09/24/1996	1355	CL-2	21.11	18.0	14.0	5.0	0.7	8.31	8.50	400	10	182	0.11	0.00542	0.1	2.61	2.50	2.71	0.238	0.030	451	76	375	
10/22/1996	1300	CL-2	101.84	6.0	5.5	4.3	0.7	8.49	11.00	340	110	194	0.02	0.00077	0.1	1.64	1.62	1.74	0.302	0.030	478	92	386	
01/14/1997	1145	CL-2	3.35	-10.0	0.0	5.0	2.5	7.54	1.60	10	10	293	0.45	0.00129	0.1	2.20	1.75	2.30	0.121	0.087	622	4	585	
02/24/1997	1110	CL-2	10.72	-7.0	0.0	5.0	2.0	7.53	1.25	350	10	349	0.76	0.00212	0.1	2.40	1.64	2.50	0.144	0.084	764	8	756	
03/25/1997	1045	CL-2	2.35	3.0	0.0	2.0	1.5	7.60	6.20	90	10	359	0.58	0.00190	1	1.66	1.08	2.66	0.023	0.013	124	3	121	
04/29/1997	1030	CL-2	28.48	12.0	12.0	5.0	2.5	9.11	10.40	330	10	148	0.02	0.00438	0.1	0.62	0.60	0.72	0.091	0.030	323	12	311	
05/20/1997	1135	CL-2	16.42	12.0	13.0	5.3	1.8	9.01	8.70	420	10	183	0.02	0.00388	0.1	1.16	1.14	1.26	0.074	0.016	400	17	383	
06/24/1997	945	CL-2	13.40	24.0	23.5	5.0	1.8	8.21	4.00	590	10	196	0.17	0.01302	0.1	1.23	1.06	1.33	0.103	0.061	481	15	466	
07/22/1997	1045	CL-2	32.16		23.5	5.3	2.1	8.62	3.75	530	10	164	0.02	0.00352	0.1	1.29	1.27	1.39	0.227	0.142	426	13	413	
08/26/1997	1105	CL-2	30.82		25.5	5.0	2.0	9.30	9.50	500	10	169	0.02	0.01081	0.1	1.83	1.81	1.93	0.135	0.044	435	16	419	
09/22/1997	1110	CL-2	72.36	17	15	5	1	8.97	8.1	425	20	183	0.02	0.00407	0.1	1.92	1.90	2.02	0.18	0.027	442	34	408	13
10/14/1997	1115	CL-2	125.96	5.6	8.5	5.1	0.5	8.43	9.40	380	70	210	0.30	0.01280	0.1	1.99	1.69	2.09	0.310	0.088	513	96	417	24
12/17/1997	1105	CL-2	9.38	3.3	1.0	4.3	3.5	8.00	7.60	390	10	237	0.13	0.00116	0.1	1.70	1.67	1.80	0.099	0.055	533	4	529	1
01/12/1998	1050	CL-2	190.95	-18.9	0.5	3.8	2.0	8.00	11.60	450	10	278	0.02	0.00017	0.1	2.42	2.40	2.52	0.278	0.057	635	18	617	18
02/17/1998	1045	CL-2	59.97	2.2	1.0	3.7	2.9	7.82	10.20	410	10	252	0.15	0.00089	0.2	1.90	1.75	2.10	0.151	0.077	572	23	549	7
03/17/1998	1030	CL-2	115.91	1.7	1.5	3.8	2.1	8.16	11.40	215	10	156	0.24	0.00321	0.8	2.41	2.17	3.21	0.335	0.210	344	11	333	8
04/21/1998	935	CL-2		11.1	10.0	5.7	2.0	8.73	9.10	425	10	205	0.02	0.00182	0.1	1.26	1.24	1.36	0.090	0.017	445	13	432	7
05/20/1998	1105	CL-2		22.2	20.5	5.2	1.2	8.64	7.60	500	10	227	0.02	0.00305	0.1	2.15	2.13	2.25	0.147	0.021	523	39	484	

Clear Lake, Deuel County
Tributary Water Quality
Phase I 319 Project (FY96)

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP	W TEMP	PH	DO	COLIFORM	ALKA-M	ALKA-P	AMMONIA	UN-AMM	NITRATE	TKN	ON	TN	TPO4	TDPO4	TSOL	TSSOL	TDSOL	VTSS	COLOR
							(C)	(C)		(mg/L)	(per 100 ml)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Clear Lake	5252	30-Oct-96	1130	CLT-1	Kringen	Grab	5	1.0	7.93	12.30	500									0.228	0.181	520	16	467		
Clear Lake	5252	02-Apr-97	1240	CLT-1	Kringen	Grab			8.16		500	92	0	0.38	0.00449	1.2	1.69	1.31	2.89	0.401	0.288	229	68	161		Brown
Clear Lake	5252	08-Apr-97	1140	CLT-1	Kringen	Grab		0.0	8.03	5.50	110	209	0	0.18	0.00158	2.1	1.33	1.15	3.43	0.272	0.242	396	9	387		Brown
Clear Lake	5252	12-May-97	1130	CLT-1	Kringen	Grab		6.5	8.57	12.80	< 10	305	1	0.02	0.00100	2.1	0.41	0.39	2.51	0.033	0.022	568	6	562		Brown
Clear Lake	5252	02-Jul-97	930	CLT-1	Kringen	Grab		16.0	8.27	6.70	99000	137.5		0.02	0.00104	3.3	1.99	1.97	5.29	0.335	0.269	540	12	528		Brown
Clear Lake	5252	21-Jul-97	1030	CLT-1	Kringen	Grab		20.0	8.38	5.40	2500	227	0	0.02	0.00174	1.2	1.53	1.51	2.73	0.299	0.221	485	19	466		Brown
Clear Lake	5252	25-Jul-97	1045	CLT-1	Kringen	Grab		21.0	8.37	5.30		137	0	0.02	0.00182	1.0	1.80	1.78	2.80	0.438	0.350	331	27	304		Brown
Clear Lake	5252	04-Aug-97	900	CLT-1	Kringen	Grab		21.0	8.52	5.80	3700	216	0	0.02	0.00248	0.2	0.72	0.70	0.92	0.287	0.240	367	7	360		Brown
Clear Lake	5252	08-Sep-97	925	CLT-1	Kringen	Grab		16.5	8.46	6.50	800	376	4	0.02	0.00162	1.2	0.90	0.88	2.10	0.149	0.123	586	5	581		Brown
Clear Lake	5252	06-Oct-97	1000	CLT-1	Kringen	Grab	14	13.0	8.28	7.20	12000	267	0	0.02	0.00086	0.6	1.24	1.22	1.84	0.184	0.130	489	19	470	4	Tan
Clear Lake	5252	16-Oct-97	1045	CLT-1	Kringen	Grab		6.5	8.41	10.30	430	352	0	0.02	0.00070	1.7	0.93	0.91	2.63	0.142	0.134	654	7	647	5	Clear
Clear Lake	5313	30-Mar-98	910	CLT-1	Kringen	Grab	3.3	2.5	8.38	10.90	50	271	0	0.02	0.00048	1.7	1.11	1.09	2.81	0.140	0.122	479	5	474	1	Clear
Clear Lake	5313	07-Apr-98	915	CLT-1	Kringen	Grab	4.4	6.0	8.38	9.60	250	229	0	0.02	0.00083	1.6	1.13	1.11	2.73	0.160	0.128	415	12	403	5	Tan
Clear Lake	5313	12-May-98	900	CLT-1	Kringen	Grab	13.3	13.0	8.54	7.30	310	345	1	0.02	0.00151	2.2	1.22	1.20	3.42	0.070	0.036	570	4	566	2	Tan
Clear Lake	5313	10-Jun-98	845	CLT-1	Kringen	Grab	19	13.0	8.34	8.20	10000	351	0	0.02	0.00098	2.7	0.81	0.79	3.51	0.170	0.069	667	51	616	9	Tan
Clear Lake	5313	11-Jun-98	1230	CLT-1	Kringen	Grab	24.4	17.0	8.45	9.30	2840	330	0	0.02	0.00165	2.6	1.41	1.39	4.01	0.121	0.101	611	10	601	5	Tan

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP	W TEMP	PH	DO	COLIFORM	ALKA-M	ALKA-P	AMMONIA	UN-AMM	NITRATE	TKN	ON	TN	TPO4	TDPO4	TSOL	TSSOL	TDSOL	VTSS	COLOR
							(C)	(C)		(mg/L)	(per 100 ml)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Clear Lake	5252	14-Apr-97	1130	CLT-2A	Kringen	Grab		4.0	8.15	9.10	110	151	0	0.02	0.00032	0.8	0.55	0.53	1.35	0.140	0.118	344	8	336		Brown
Clear Lake	5252	12-May-97	1200	CLT-2A	Kringen	Grab		7.5	8.54	9.70	10	192	0	0.02	0.00101	0.1	0.77	0.75	0.87	0.098	0.031	423	11	412		Brown
Clear Lake	5252	16-Jun-97	935	CLT-2A	Kringen	Grab		18.0	8.42	5.50	1000	216	0	0.02	0.00165	0.1	1.46	1.44	1.56	0.381	0.351	492	4	488		Brown
Clear Lake	5252	10-Jul-97	900	CLT-2A	Kringen	Grab		20.5	8.28	3.75	530	174.5	0	0.02	0.00146	0.1	1.43	1.41	1.53	0.203	0.158	509	20	489		Brown
Clear Lake	5252	21-Jul-97	1100	CLT-2A	Kringen	Grab		21.0	8.35	2.10	24000	183	0	0.09	0.00786	0.1	1.74	1.65	1.84	0.458	0.421	482	9	473		Brown
Clear Lake	5252	04-Aug-97	1045	CLT-2A	Kringen	Grab		24.0	8.53	2.20	2000	214	0	0.02	0.00305	0.1	0.92	0.90	1.02	0.211	0.155	509	7	502		Brown
Clear Lake	5252	28-Aug-97	915	CLT-2A	Kringen	Grab		23.0	8.21	0.60	8900	155	0	0.11	0.00815	0.1	1.73	1.62	1.83	0.203	0.142	402	12	390		Brown
Clear Lake	5252	08-Sep-97	950	CLT-2A	Kringen	Grab		20.0	8.23	1.00	760	176	0	0.06	0.00379	0.1	1.65	1.59	1.75	0.192	0.131	433	7	426		Brown
Clear Lake	5252	06-Oct-97	1020	CLT-2A	Kringen	Grab		14.0	8.29	3.50	920	203	0	0.52	0.02452	0.1	1.91	1.39	2.01	0.181	0.143	481	4	477	3	Tan
Clear Lake	5252	20-Oct-97	950	CLT-2A	Kringen	Grab		8.0	8.22	5.80	70	227	0	0.13	0.00334	0.3	1.32	1.19	1.62	0.150	0.088	543	8	535	4	Tan
Clear Lake	5313	30-Mar-98	945	CLT-2A	Kringen	Grab	3.3	3.0	8.33	9.60	< 10	179	0	0.02	0.00044	0.4	1.23	1.21	1.63	0.120	0.057	412	9	403	3	Tan
Clear Lake	5313	07-Apr-98	945	CLT-2A	Kringen	Grab	4.4	7.0	8.35	9.20	230	205	0	0.02	0.00064	0.3	1.82	1.60	1.92	0.085	0.028	468	14	454	< 1	Brown
Clear Lake	5313	12-May-98	945	CLT-2A	Kringen	Grab	13.3	15.5	8.42	5.10	240	228	0	0.03	0.00209	0.1	1.27	1.24	1.37	0.383	0.122	485	9	476	9	Brown
Clear Lake	5313	10-Jun-98	915	CLT-2A	Kringen	Grab	20	14.0	8.37	6.00	300	210	0	0.02	0.00112	0.1	1.26	1.24	1.36	0.143	0.106	523	5	518	4	Tan
Clear Lake	5313	11-Jun-98	1250	CLT-2A	Kringen	Grab	24.4	19.0	8.50	9.20	20	207	0	0.02	0.00209	0.1	1.38	1.36	1.48	0.161	0.122	518	14	504	7	Tan

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP (C)	W TEMP (C)	PH	DO (mg/L)	COLIFORM (per 100 ml)	ALKA-M (mg/L)	ALKA-P (mg/L)	AMMONIA (mg/L)	UN-AMM (mg/L)	NITRATE (mg/L)	TKN (mg/L)	ON (mg/L)	TN (mg/L)	TPO4 (mg/L)	TDPO4 (mg/L)	TSOL (mg/L)	TSSOL (mg/L)	TDSOL (mg/L)	VTSS (mg/L)	COLOR
Clear Lake	5252	02-Apr-97	1110	CLT-3	Kringen	Grab			8.08		70	83	0	0.19	0.00187	0.8	0.87	0.68	1.67	0.208	0.145	162	16	146		Brown
Clear Lake	5252	09-Apr-97	1130	CLT-3	Kringen	Grab		0.0	7.92	9.80	< 10	139	0	0.10	0.00068	0.9	0.96	0.86	1.86	0.159	0.118	308	12	296		Brown
Clear Lake	5252	13-May-97	940	CLT-3	Kringen	Grab	11	6.0	8.48	10.00	30	201	0	0.02	0.00079	0.2	0.62	0.60	0.82	0.069	0.039	454	11	443		Brown
Clear Lake	5252	16-Jun-97	1015	CLT-3	Kringen	Grab		17.0	8.67	4.40	250	225	2	0.02	0.00259	0.1	1.40	1.38	1.50	0.192	0.117	527	27	500		Brown
Clear Lake	5252	02-Jul-97	1000	CLT-3	Kringen	Grab		16.0	8.27	6.30	81000	104		0.02	0.00104	2.8	2.12	2.10	4.92	0.418	0.310	456	35	421		Brown
Clear Lake	5252	09-Jul-97	940	CLT-3	Kringen	Grab		19.5	8.40	7.30	1400	192	0	0.02	0.00176	0.1	1.54	1.52	1.64	0.129	0.086	523	12	511		Brown
Clear Lake	5252	21-Jul-97	1130	CLT-3	Kringen	Grab		20.5	8.34	4.60	95000	224	0	0.28	0.02315	0.3	2.00	1.72	2.30	0.350	0.246	590	32	558		Brown
Clear Lake	5252	25-Jul-97	1130	CLT-3	Kringen	Grab		21.0	8.35	4.20		144	0	0.02	0.00175	0.4	1.11	1.09	1.51	0.445	0.201	466	178	288		Brown
Clear Lake	5252	04-Aug-97	1130	CLT-3	Kringen	Grab		23.0	8.53	5.80	4700	229	0	0.02	0.00287	0.1	0.81	0.79	0.91	0.248	0.192	489	15	474		Brown
Clear Lake	5252	08-Sep-97	1015	CLT-3	Kringen	Grab		20.0	8.32	4.70	1400	208	0	0.02	0.00153	0.2	1.20	1.18	1.40	0.167	0.112	470	14	456		Brown
Clear Lake	5252	06-Oct-97	1050	CLT-3	Kringen	Grab	14	13.5	8.27	6.10	4700	206	0	0.02	0.00087	0.5	1.39	1.37	1.89	0.162	0.096	492	16	476	4	Brown
Clear Lake	5252	20-Oct-97	1015	CLT-3	Kringen	Grab		7.0	8.31	9.15	350	256	0	0.02	0.00058	0.5	0.95	0.93	1.45	0.109	0.067	574	13	561	6	Brown
Clear Lake	5313	30-Mar-98	1030	CLT-3	Kringen	Grab	3.3	3.0	8.36	10.40	10	195	0	0.02	0.00047	0.6	1.17	1.15	1.77	0.122	0.064	426	9	417	9	Brown
Clear Lake	5313	07-Apr-98	1040	CLT-3	Kringen	Grab	4.4	6.5	8.38	9.40	80	213	0	0.02	0.00065	0.5	0.96	0.94	1.46	0.113	0.057	471	16	455	1	Brown
Clear Lake	5313	12-May-98	1020	CLT-3	Kringen	Grab	13.3	15.0	8.46	7.20	1100	251	0	0.02	0.00146	0.3	0.48	0.46	0.78	0.154	0.093	528	8	520	4	Brown
Clear Lake	5313	10-Jun-98	940	CLT-3	Kringen	Grab	21.1	14.0	8.42	7.90	720	239	0	0.02	0.00125	0.3	1.10	1.08	1.40	0.118	0.070	560	19	541	7	Brown
Clear Lake	5313	11-Jun-98	1315	CLT-3	Kringen	Grab	24.4	19.0	8.51	10.40	3300	240	0	0.02	0.00213	0.3	1.35	1.33	1.65	0.146	0.092	597	16	581	3	Brown

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP (C)	W TEMP (C)	PH	DO (mg/L)	COLIFORM (per 100 ml)	ALKA-M (mg/L)	ALKA-P (mg/L)	AMMONIA (mg/L)	UN-AMM (mg/L)	NITRATE (mg/L)	TKN (mg/L)	ON (mg/L)	TN (mg/L)	TPO4 (mg/L)	TDPO4 (mg/L)	TSOL (mg/L)	TSSOL (mg/L)	TDSOL (mg/L)	VTSS (mg/L)	COLOR
Clear Lake	5252	30-Oct-96	1030	CLT-4	Kringen	Grab	5	1.0	7.92	11.80	960									0.322	0.261	552	15	497		
Clear Lake	5252	01-Apr-97	1300	CLT-4	Kringen	Grab			8.16		20	97	0	0.37	0.00437	1.4	2.39	2.02	3.79	0.504	0.297	361	192	169		Brown
Clear Lake	5252	07-Apr-97	1115	CLT-4	Kringen	Grab		0.0	8.19	7.60	40	166	0	0.39	0.00493	2.3	1.53	1.14	3.83	0.390	0.369	319	11	308		Brown
Clear Lake	5252	14-May-97	915	CLT-4	Kringen	Grab		7.0	8.42	7.00	210	290	0	0.02	0.00074	0.2	0.75	0.73	0.95	0.084	0.041	526	6	520		Brown
Clear Lake	5252	02-Jul-97	830	CLT-4	Kringen	Grab		15.0	8.23	5.70	7600	120		0.02	0.00089	3.4	1.90	1.88	5.30	0.446	0.371	544	19	525		Brown
Clear Lake	5252	08-Jul-97	1000	CLT-4	Kringen	Grab		17.0	8.44	7.60	550	264	0	0.02	0.00161	0.5	1.35	1.33	1.85	0.152	0.102	659	18	641		Brown
Clear Lake	5252	21-Jul-97	900	CLT-4	Kringen	Grab		20.0	8.40	5.00	2500	203	0	0.02	0.00181	2.5	2.19	2.17	4.69	0.415	0.314	646	19	627		Brown
Clear Lake	5252	25-Jul-97	900	CLT-4	Kringen	Grab		20.5	8.31	4.70		117	0	0.02	0.00155	2.5	1.32	1.30	3.82	0.319	0.268	358	18	340		Brown
Clear Lake	5252	05-Aug-97	1015	CLT-4	Kringen	Grab		19.0	8.41	5.90	350	247	0	0.02	0.00173	0.3	0.86	0.84	1.16	0.395	0.342	440	17	423		Brown
Clear Lake	5252	09-Sep-97	905	CLT-4	Kringen	Grab		16.0	8.35	5.40	140	387	0.4	0.02	0.00124	0.4	1.15	1.13	1.55	0.252	0.221	620	6	614		Brown
Clear Lake	5252	15-Oct-97	1030	CLT-4	Kringen	Grab	17	7.5	8.30	8.75	1200	350	0	0.02	0.00059	0.8	1.29	1.27	2.09	0.248	0.219	708	4	704	3	Tan
Clear Lake	5313	26-Mar-98	1030	CLT-4	Kringen	Grab		1.0	8.28	10.80	30	134	0	0.04	0.00087	1.2	1.49	1.45	2.69	0.312	0.223	294	26	268	10	Tan
Clear Lake	5313	08-Apr-98	850	CLT-4	Kringen	Grab	4.4	3.5	8.36	11.10	< 10	230	0	0.02	0.00049	1.3	1.15	1.13	2.45	0.130	0.109	479	3	476	3	Tan
Clear Lake	5313	13-May-98	845	CLT-4	Kringen	Grab	17.2	12.0	8.39	6.60	150	376	0	0.02	0.00101	0.5	1.42	1.40	1.92	0.170	0.139	599	9	590	6	Clear
Clear Lake	5313	11-Jun-98	730	CLT-4	Kringen	Grab	21.1	14.5	8.42	6.70	6800	273	0	0.02	0.00130	1.1	1.38	1.36	2.48	0.270	0.181	585	49	536	9	Brown

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP (C)	W TEMP (C)	PH	DO (mg/L)	COLIFORM (per 100 ml)	ALKA-M (mg/L)	ALKA-P (mg/L)	AMMONIA (mg/L)	UN-AMM (mg/L)	NITRATE (mg/L)	TKN (mg/L)	ON (mg/L)	TN (mg/L)	TPO4 (mg/L)	TDPO4 (mg/L)	TSOL (mg/L)	TSSOL (mg/L)	TDSOL (mg/L)	VTSS (mg/L)	COLOR
Clear Lake	5252	30-Oct-96	1055	CLT-5	Kringen	Grab	5	1.0	7.96	11.80	900									0.332	0.245	531	28	432		
Clear Lake	5252	01-Apr-97	1430	CLT-5	Kringen	Grab			8.31		20	97	0	0.31	0.00515	1.2	0.69	0.38	1.89	2.400	0.228	470	316	154		Brown
Clear Lake	5252	08-Apr-97	920	CLT-5	Kringen	Grab		0.0	8.14	7.90	10	160	0	0.60	0.00677	1.7	1.90	1.30	3.60	0.403	0.360	305	12	293		Brown
Clear Lake	5252	14-May-97	945	CLT-5	Kringen	Grab		9.5	8.60	9.50	110	298	3	0.02	0.00133	0.1	0.67	0.65	0.77	0.050	0.038	534	3	531		Brown
Clear Lake	5252	02-Jul-97	845	CLT-5	Kringen	Grab		16.0	8.29	8.50	7200	119		0.02	0.00109	4.0	1.89	1.87	5.89	0.434	0.355	517	19	498		Brown
Clear Lake	5252	08-Jul-97	1040	CLT-5	Kringen	Grab		18.0	8.54	11.40	2300	261	0	0.02	0.00212	0.4	1.16	1.14	1.56	0.144	0.081	662	12	650		Brown
Clear Lake	5252	15-Jul-97	945	CLT-5	Kringen	Grab		22.0	8.38	6.30	3800	319	0	0.02	0.00198	0.1	0.99	0.97	1.09	0.133	0.089	715	11	704		Brown
Clear Lake	5252	21-Jul-97	930	CLT-5	Kringen	Grab		21.0	8.37	5.60	6700	213	0	0.02	0.00182	2.7	1.88	1.86	4.58	0.332	0.231	650	19	631		Brown
Clear Lake	5252	25-Jul-97	945	CLT-5	Kringen	Grab		21.0	8.33	6.00		112	0	0.02	0.00167	2.5	1.38	1.36	3.88	0.326	0.272	371	27	344		Brown
Clear Lake	5252	05-Aug-97	1115	CLT-5	Kringen	Grab		21.5	8.54	7.70	310	253	0	0.02	0.00266	0.2	0.85	0.83	1.05	0.335	0.280	485	26	459		Brown
Clear Lake	5252	09-Sep-97	930	CLT-5	Kringen	Grab		16.5	8.48	7.90	350	389	2.5	0.04	0.00339	0.3	1.01	0.97	1.31	0.218	0.164	686	13	653		Brown
Clear Lake	5252	15-Oct-97	1100	CLT-5	Kringen	Grab	17	8.0	8.41	10.40	1000	340	2	0.02	0.00079	0.7	1.18	1.16	1.88	0.228	0.208	729	10	719	4	Tan
Clear Lake	5313	26-Mar-98	1100	CLT-5	Kringen	Grab		1.5	8.27	11.00	30	124	0	0.14	0.00240	1.4	1.71	1.57	3.11	0.375	0.196	319	96	223	20	Brown
Clear Lake	5313	08-Apr-98	925	CLT-5	Kringen	Grab	4.4	3.5	8.37	11.10	< 10	231	0	0.02	0.00051	1.5	1.21	1.19	2.71	0.130	0.099	487	2	485	1	Tan
Clear Lake	5313	13-May-98	920	CLT-5	Kringen	Grab	17.2	13.5	8.49	9.60	340	373	0	0.02	0.00140	0.7	1.43	1.41	2.13	0.141	0.093	614	4	610	4	Tan
Clear Lake	5313	11-Jun-98	800	CLT-5	Kringen	Grab	21.1	13.0	8.36	8.00	7600	171	0	0.03	0.00153	1.5	1.30	1.27	2.80	0.272	0.159	553	318	235	136	Brown

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP (C)	W TEMP (C)	PH	DO (mg/L)	COLIFORM (per 100 ml)	ALKA-M (mg/L)	ALKA-P (mg/L)	AMMONIA (mg/L)	UN-AMM (mg/L)	NITRATE (mg/L)	TKN (mg/L)	ON (mg/L)	TN (mg/L)	TPO4 (mg/L)	TDPO4 (mg/L)	TSOL (mg/L)	TSSOL (mg/L)	TDSOL (mg/L)	VTSS (mg/L)	COLOR
Clear Lake	5252	14-Apr-97	1045	CLT-6	Kringen	Grab			8.04	7.10	< 10	174		0.05	0.00045	0.4	0.97	0.92	1.37	0.159	0.096	341	4	337		Brown
Clear Lake	5252	28-Jul-97	1245	CLT-6	Kringen	Grab		25.0	8.62	4.70	10	172	0	0.02	0.00383	0.1	1.15	1.13	1.25	0.043	0.029	428	4	424		Brown
Clear Lake	5252	20-Oct-97	1100	CLT-6	Kringen	Grab		9.0	8.66	11.00	10	296	7	0.02	0.00148	0.1	1.25	1.23	1.35	0.045	0.021	471	10	461	5	Tan
Clear Lake	5313	26-Mar-98	1140	CLT-6	Kringen	Grab		2.0	8.28	4.80	40	371	0	0.12	0.00219	0.1	1.69	1.57	1.79	0.170	0.108	637	9	628	7	Tan
Clear Lake	5313	17-Jun-98	845	CLT-6	Kringen	Grab	18.9	20.5	8.74	5.10	40	260	5	0.02	0.00389	0.1	1.57	1.55	1.67	0.067	0.048	453	4	449	4	Clear

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP (C)	W TEMP (C)	PH	DO (mg/L)	COLIFORM (per 100 ml)	ALKA-M (mg/L)	ALKA-P (mg/L)	AMMONIA (mg/L)	UN-AMM (mg/L)	NITRATE (mg/L)	TKN (mg/L)	ON (mg/L)	TN (mg/L)	TPO4 (mg/L)	TDPO4 (mg/L)	TSOL (mg/L)	TSSOL (mg/L)	TDSOL (mg/L)	VTSS (mg/L)	COLOR
Clear Lake	5252	30-Oct-96	810	CLT-7	Kringen	Grab	-6	1.0	7.94	9.80	45000									0.288	0.198	614	30	517		
Clear Lake	5252	01-Apr-97	1445	CLT-7	Kringen	Grab			8.21		40	92	0	0.23	0.00304	0.9	0.41	0.18	1.31	1.250	0.198	285	66	199		Brown
Clear Lake	5252	09-Apr-97	935	CLT-7	Kringen	Grab		0.0	8.09	10.40	< 10	141	0	0.11	0.00111	0.9	1.15	1.04	2.05	0.151	0.113	312	8	304		Brown
Clear Lake	5252	13-May-97	1015	CLT-7	Kringen	Grab	11	6.0	8.51	11.20	10	203	0	0.02	0.00084	0.2	0.56	0.54	0.76	0.059	0.031	451	8	443		Brown
Clear Lake	5252	17-Jun-97	950	CLT-7	Kringen	Grab		18.0	8.42	5.10	1800	242	0	0.10	0.00827	0.1	1.38	1.28	1.48	0.198	0.096	578	36	542		Brown
Clear Lake	5252	02-Jul-97	1045	CLT-7	Kringen	Grab		16.5	8.28	6.10	59000	95		0.02	0.00110	2.8	1.77	1.75	4.57	0.438	0.274	467	62	405		Brown
Clear Lake	5252	09-Jul-97	1015	CLT-7	Kringen	Grab		20.0	8.52	8.30	1300	196	0.3	0.02	0.00232	0.1	1.26	1.24	1.36	0.141	0.071	528	23	505		Brown
Clear Lake	5252	21-Jul-97	1150	CLT-7	Kringen	Grab		22.0	8.46	5.30	64000	228	0	0.24	0.02807	0.3	2.12	1.88	2.42	0.337	0.195	670	84	586		Brown
Clear Lake	5252	25-Jul-97	1145	CLT-7	Kringen	Grab		22.0	8.42	5.00		196	0	0.04	0.00431	0.3	1.19	1.15	1.49	0.331	0.181	622	146	476		Brown
Clear Lake	5252	04-Aug-97	1200	CLT-7	Kringen	Grab		24.0	8.59	6.40	7900	230	0	0.02	0.00342	0.1	0.85	0.83	0.95	0.278	0.184	506	39	467		Brown
Clear Lake	5252	28-Aug-97	1030	CLT-7	Kringen	Grab		22.0	8.41	5.90	42000	181	0	0.09	0.00950	0.3	1.63	1.54	1.93	0.305	0.228	501	31	470		Brown
Clear Lake	5252	08-Sep-97	1050	CLT-7	Kringen	Grab		20.5	8.47	7.20	1000	213	1	0.02	0.00217	0.2	1.17	1.15	1.37	0.177	0.112	490	21	469		Brown
Clear Lake	5252	06-Oct-97	1115	CLT-7	Kringen	Grab	14	14.5	8.43	9.40	3200	216	0	0.02	0.00133	0.3	1.07	1.05	1.37	0.144	0.091	511	10	501	3	Tan
Clear Lake	5252	16-Oct-97	1115	CLT-7	Kringen	Grab		8.5	8.38	9.40	720	240	0	0.02	0.00076	0.5	1.23	1.21	1.73	0.159	0.085	582	21	561	3	Tan
Clear Lake	5313	30-Mar-98	1110	CLT-7	Kringen	Grab	3.3	3.0	8.34	10.90	< 10	197	0	0.02	0.00045	0.6	1.21	1.19	1.81	0.125	0.065	437	10	427	6	Brown
Clear Lake	5313	07-Apr-98	1110	CLT-7	Kringen	Grab	4.4	6.5	8.35	9.60	30	212	0	0.02	0.00061	0.5	1.04	1.02	1.54	0.137	0.054	476	21	455	3	Brown
Clear Lake	5313	12-May-98	1050	CLT-7	Kringen	Grab	13.3	15.0	8.48	7.80	1000	252	0	0.02	0.00153	0.2	0.41	0.39	0.61	0.181	0.090	570	27	543	5	Brown
Clear Lake	5313	10-Jun-98	1005	CLT-7	Kringen	Grab	21.1	15.0	8.51	9.20	800	239	0	0.02	0.00163	0.2	1.04	1.02	1.24	0.132	0.072	578	29	549	4	Tan
Clear Lake	5313	11-Jun-98	1340	CLT-7	Kringen	Grab	24.4	19.0	8.50	9.00	4600	238	0	0.02	0.00209	0.3	1.17	1.15	1.47	0.150	0.094	620	19	601	6	Tan

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP	W TEMP	PH	DO	COLIFORM	ALKA-M	ALKA-P	AMMONIA	UN-AMM	NITRATE	TKN	ON	TN	TPO4	TDPO4	TSOL	TSSOL	TDSOL	VTSS	COLOR
							(C)	(C)		(mg/L)	(per 100 ml)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Clear Lake	5252	10-Jul-97	1015	CLO-8	Kringen	Grab		22.0	9.11	9.20	370	150	7	0.02	0.00744	0.1	1.09	1.07	1.19	0.120	0.069	438	12	426		Brown
Clear Lake	5252	15-Jul-97	1110	CLO-8	Kringen	Grab		22.5	8.66	7.60	1900	173	1	0.02	0.00357	0.1	1.37	1.35	1.47	0.241	0.114	524	49	475		Brown
Clear Lake	5252	22-Jul-97	1140	CLO-8	Kringen	Grab		24.0	8.83	8.30	580	170	0	0.02	0.00528	0.1	1.61	1.59	1.71	0.316	0.150	513	42	471		Brown
Clear Lake	5252	25-Jul-97	1250	CLO-8	Kringen	Grab		22.0	8.31	3.50		108	0	0.02	0.00171	1.8	0.90	0.88	2.70	0.342	0.283	417	13	404		Brown
Clear Lake	5252	06-Aug-97	950	CLO-8	Kringen	Grab		22.5	8.72	5.30	150	167	0	0.02	0.00400	0.1	0.79	0.77	0.89	0.220	0.140	424	21	403		Brown
Clear Lake	5252	28-Aug-97	1145	CLO-8	Kringen	Grab		24.5	8.91	6.80	720	159	7	0.02	0.00617	0.1	1.65	1.63	1.75	0.188	0.091	434	27	407		Brown
Clear Lake	5252	10-Sep-97	920	CLO-8	Kringen	Grab		18.0	8.65	7.70	190	195	0	0.02	0.00266	0.1	1.57	1.55	1.67	0.217	0.074	473	40	433		Brown
Clear Lake	5252	16-Oct-97	930	CLO-8	Kringen	Grab		8.0	8.47	8.90	210	228	0	0.24	0.01076	0.3	1.95	1.71	2.25	0.289	0.128	565	48	517	15	Brown
Clear Lake	5313	02-Apr-98	900	CLO-8	Kringen	Grab	0.6	2.5	8.32	9.20	< 10	201	0	0.21	0.00438	0.5	1.56	1.35	2.06	0.228	0.139	419	12	407	4	Brown
Clear Lake	5313	08-Apr-98	1145	CLO-8	Kringen	Grab	4.4	4.5	8.40	11.30	20	203	0	0.02	0.00059	0.6	1.28	1.26	1.88	0.127	0.067	448	7	441	5	Brown
Clear Lake	5313	13-May-98	950	CLO-8	Kringen	Grab	17.8	15.5	8.65	8.70	50	253	0	0.02	0.00225	0.1	1.58	1.56	1.68	0.172	0.058	591	31	560	5	Brown
Clear Lake	5313	11-Jun-98	845	CLO-8	Kringen	Grab	21.1	15.0	8.44	6.50	8200	182	0	0.02	0.00140	0.7	1.37	1.35	2.07	0.378	0.145	538	90	448	16	Brown

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP	W TEMP	PH	DO	COLIFORM	ALKA-M	ALKA-P	AMMONIA	UN-AMM	NITRATE	TKN	ON	TN	TPO4	TDPO4	TSOL	TSSOL	TDSOL	VTSS	COLOR
							(C)	(C)		(mg/L)	(per 100 ml)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Clear Lake	5252	14-May-97	1020	CLO-9	Kringen	Grab		9.0	8.92	11.20	< 10	187	0	0.02	0.00251	0.1	0.99	0.97	1.09	0.090	0.019	400	29	371		Brown
Clear Lake	5252	10-Jul-97	945	CLO-9	Kringen	Grab		21.5	9.24	8.50	30	137	8.5	0.02	0.00870	0.1	1.27	1.25	1.37	0.086	0.035	400	8	392		Clear
Clear Lake	5252	15-Jul-97	1020	CLO-9	Kringen	Grab		23.5	8.95	7.30	30	158	8	0.02	0.00626	0.1	1.23	1.21	1.33	0.152	0.092	436	10	426		Clear
Clear Lake	5252	22-Jul-97	1210	CLO-9	Kringen	Grab		24.5	9.04	7.10	470	159	0	0.02	0.00752	0.1	1.38	1.36	1.48	0.292	0.126	447	23	424		Brown
Clear Lake	5252	25-Jul-97	1330	CLO-9	Kringen	Grab		23.5	8.36	3.30		104	0	0.06	0.00629	1.4	1.02	0.96	2.42	0.438	0.373	406	17	389		Brown
Clear Lake	5252	06-Aug-97	910	CLO-9	Kringen	Grab		23.0	9.08	5.50	80	143	0.3	0.02	0.00745	0.1	0.97	0.95	1.07	0.179	0.097	391	13	378		Brown
Clear Lake	5252	28-Aug-97	1115	CLO-9	Kringen	Grab		24.5	9.21	8.50	40	141	10	0.02	0.00942	0.1	1.66	1.64	1.76	0.111	0.033	352	14	338		Tan
Clear Lake	5252	10-Sep-97	1000	CLO-9	Kringen	Grab		19.0	8.87	8.20	50	170	0	0.02	0.00430	0.1	1.98	1.96	2.08	0.165	0.040	411	24	387		
Clear Lake	5252	16-Oct-97	1015	CLO-9	Kringen	Grab		9.0	8.60	9.55	80	200	0	0.27	0.01733	0.1	2.09	1.82	2.19	0.248	0.084	486	44	442	16	Soapy
Clear Lake	5252	10-Dec-97	1045	CLO-9	Kringen	Grab		2.5	8.28	8.20	< 10	232	0	0.06	0.00114	0.2	1.55	1.49	1.75	0.121	0.066	530	7	523	2	Clear
Clear Lake	5313	10-Feb-98	950	CLO-9	Kringen	Grab	2.2	1.0	8.24	13.20	< 10	291	0	0.02	0.00031	0.1	1.74	1.72	1.84	0.153	0.064	656	8	648	8	Clear
Clear Lake	5313	02-Apr-98	940	CLO-9	Kringen	Grab	0.6	2.0	8.31	9.00	< 10	196	0	0.23	0.00450	0.5	1.64	1.41	2.14	0.220	0.149	405	10	395	9	Tan
Clear Lake	5313	08-Apr-98	1015	CLO-9	Kringen	Grab	4.4	4.0	8.39	11.20	10	197	0	0.02	0.00055	0.5	1.36	1.34	1.86	0.120	0.051	437	15	422	5	Brown
Clear Lake	5313	13-May-98	1025	CLO-9	Kringen	Grab	21.1	16.0	8.76	8.95	150	228	1	0.02	0.00290	0.1	1.29	1.27	1.39	0.127	0.021	535	34	501	12	Tan
Clear Lake	5313	11-Jun-98	925	CLO-9	Kringen	Grab	21.1	16.0	8.63	7.80	90	203	0	0.02	0.00224	0.1	1.77	1.75	1.87	0.212	0.029	584	62	522	26	Brown

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	TYPE	A TEMP	W TEMP	PH	DO	COLIFORM	ALKA-M	ALKA-P	AMMONIA	UN-AMM	NITRATE	TKN	ON	TN	TPO4	TDPO4	TSOL	TSSOL	TDSOL	VTSS	COLOR
							(C)	(C)		(mg/L)	(per 100 ml)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Clear Lake	5252	14-Apr-97	915	CLT-10	Kringen	Grab			8.06	8.70	30	160	0	0.32	0.00301	0.2	2.46	2.14	2.66	0.381	0.272	297	12	285		Brown
Clear Lake	5252	28-Jul-97	1320	CLT-10	Kringen	Grab		25.0	8.44	0.20	980	197	0	0.03	0.00406	0.1	1.20	1.17	1.30	0.381	0.345	338	3	335		Brown
Clear Lake	5313	26-Mar-98	1200	CLT-10	Kringen	Grab		2.0	8.28	8.20	1000	144	0	1.74	0.03181	0.3	6.42	4.68	6.72	0.658	0.524	329	8	321	4	Tan
Clear Lake	5313	17-Jun-98	910	CLT-10	Kringen	Grab	18.9	18.5	8.33	0.30	280	246	0	0.02	0.00141	0.1	1.53	1.51	1.63	0.180	0.171	398	5	391	4	Clear

Clear Lake, Deuel County															
Storm Sewer Samples															
319 Phase I (FY96)															
		(C)	(C)		(mg/L)	(per 100 ml)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
DATE	SITE	A TEMP	W TEMP	PH	DO	COLIFORM	ALKA-M	TKN	AMMONIA	NITRATE	TPO4	TDPO4	TSOL	TSSOL	TDSOL	VTSS
25-Mar-98	CLT-5 North		5.0	8.18	10.40	30	103	1.68	0.26	0.4	0.505	0.088	465	172	293	12
15-Jun-98	CLT-5 North	18	17.0	8.03	8.40	15000	44	1.39	0.26	0.6	0.290	0.073	161	72	89	16
25-Mar-98	CLT-5 South		5.0	8.11	10.60	20	84	1.55	0.22	0.4	0.390	0.095	399	136	263	16
15-Jun-98	CLT-5 South	18	17.0	8.05	8.40	31000	46	1.35	0.24	0.8	0.270	0.076	179	72	107	8
15-Jun-98	Elevator north	18	17.0	8.12	7.90	30000	90	0.97	0.19	1.8	0.602	0.428	262	76	186	10
06/01/1998	Elevator south	16		7.92		20000	91	7.15	0.83	1.4	1.8	0.84	586	348	238	60
06/15/1998	Elevator south	18	17	8.03	7.8	35000	95	0.98	0.13	1.3	0.92	0.128	522	340	182	48
06/01/1998	Park Tile	16		8.00		61000	117	9.95	4.85	1.6	9.13	7.28	513	260	253	32
06/15/1998	Park Tile	18	16	8.26	8	7800	180	1.82	0.07	0.9	0.36	0.319	373	23	350	4

APPENDIX C

Clear Lake, Deuel County
Inlake Quality Assurance/Quality Control Samples
319 Phase I (FY98)

Duplicate Samples

LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	A TEMP (C)	W TEMP (C)	WATER DEPTH (feet)	SECCHI (feet)	PH	DO (mg/l)	CONDUCT (umhos)	FECAL COLIFORM (per 100 ml)	ALKA-M (mg/l)	ALKA-P (mg/l)	AMMONIA (mg/l)	ION-AMMON (mg/L)	NITRATE (mg/l)	TKN (mg/l)	ON (mg/l)	TN (mg/l)	TPO4 (mg/l)	TDPO4 (mg/l)	TSOL (mg/l)	TSSOL (mg/l)	TDSOL (mg/L)
Clear Lake	5252	01/14/1997	1145	CL-2	Kringen	-10.0	0.0	5.0	2.5	7.54	1.60	10	10	293	0	0.45	0.00129	0.1	2.20	1.75	2.30	0.121	0.087	622	4	585
Clear Lake	5252.	01/14/1997	1145	CL-2D	Kringen	-10.0	0.0	5.0	2.5	7.54	1.60	10	10	296	0	0.46	0.00132	0.1	2.19	1.73	2.29	0.124	0.087	618	6	586
				Percent Difference		0%	0%	0%	0%	0%	0%	0%	0%	-1%	0%	-2%	-2%	0%	0%	1%	0%	-2%	0%	1%	-50%	0%
Clear Lake	5252	05/20/1997	1115	CL-1	Kringen	12.0	13.0	5.0	1.7	8.96	9.20	425	10	191	4	0.03	0.00530	0.1	1.14	1.11	1.24	0.079	0.024	421	17	404
Clear Lake	5252	05/20/1997	1115	CL-1D	Kringen	12.0	13.0	5.0	1.7	8.96	9.20	425	10	189	4	0.02	0.00353	0.1	1.20	1.18	1.30	0.082	0.018	422	15	407
				Percent Difference		0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	33%	33%	0%	-5%	-6%	-5%	-4%	25%	0%	12%	-1%
Clear Lake	5252	07/22/1997	1020	CL-1	Kringen		24.0	5.8	1.7	8.62	4.50	550	10	159	0	0.02	0.00362	0.1	1.31	1.29	1.41	0.254	0.151	474	16	458
Clear Lake	5252	07/22/1997	1020	CL-1D	Kringen		24.0	5.8	1.7	8.62	4.50	550	10	162	0	0.02	0.00362	0.1	1.41	1.39	1.51	0.261	0.153	447	18	429
				Percent Difference		0%	0%	0%	0%	0%	0%	0%	0%	-2%	0%	0%	0%	0%	-8%	-8%	-7%	-3%	-1%	6%	-13%	6%
Clear Lake	5252	09/22/1997	1050	CL-1	Kringen	17.0	15.0	5.5	0.9	8.90	7.90	440	10	199	2	0.02	0.00357	0.1	1.57	1.55	1.67	0.225	0.054	473	52	421
Clear Lake	5252	09/22/1997	1050	CL-1D	Kringen	17.0	15.0	5.5	0.9	8.90	7.90	440	20	200	0.8	0.02	0.00357	0.1	1.51	1.49	1.61	0.218	0.044	477	52	425
				Percent Difference		0%	0%	0%	0%	0%	0%	0%	-100%	-1%	60%	0%	0%	0%	4%	4%	4%	3%	19%	-1%	0%	-1%
Clear Lake	5252	10/14/1997	1020	CL-1	Kringen	5.6	8.5	5.5	0.5	8.45	9.50	380	30	206	2	0.24	0.01070	0.1	1.88	1.64	1.98	0.198	0.084	495	80	415
Clear Lake	5252	10/14/1997	1020	CL-1D	Kringen	5.6	8.5	5.5	0.5	8.45	9.50	380	10	190	0	0.23	0.01025	0.1	1.83	1.60	1.93	0.288	0.080	499	78	421
				Percent Difference		0%	0%	0%	0%	0%	0%	0%	67%	8%	100%	4%	4%	0%	3%	2%	3%	-45%	5%	-1%	3%	-1%
Clear Lake	5252	12/17/1997	1040	CL-1	Kringen	3.3	1.0	4.8	3.5	8.42	13.60	420	10	243	2	0.02	0.00046	0.3	1.45	1.43	1.75	0.085	0.039	556	3	553
Clear Lake	5252	12/17/1997	1040	CL-1D	Kringen	3.3	1.0	4.8	3.5	8.42	13.60	420	10	242	0	0.06	0.00139	0.3	1.43	1.37	1.73	0.085	0.042	555	6	549
				Percent Difference		0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	-200%	-200%	0%	1%	4%	1%	0%	-8%	0%	-100%	1%

lank Samples

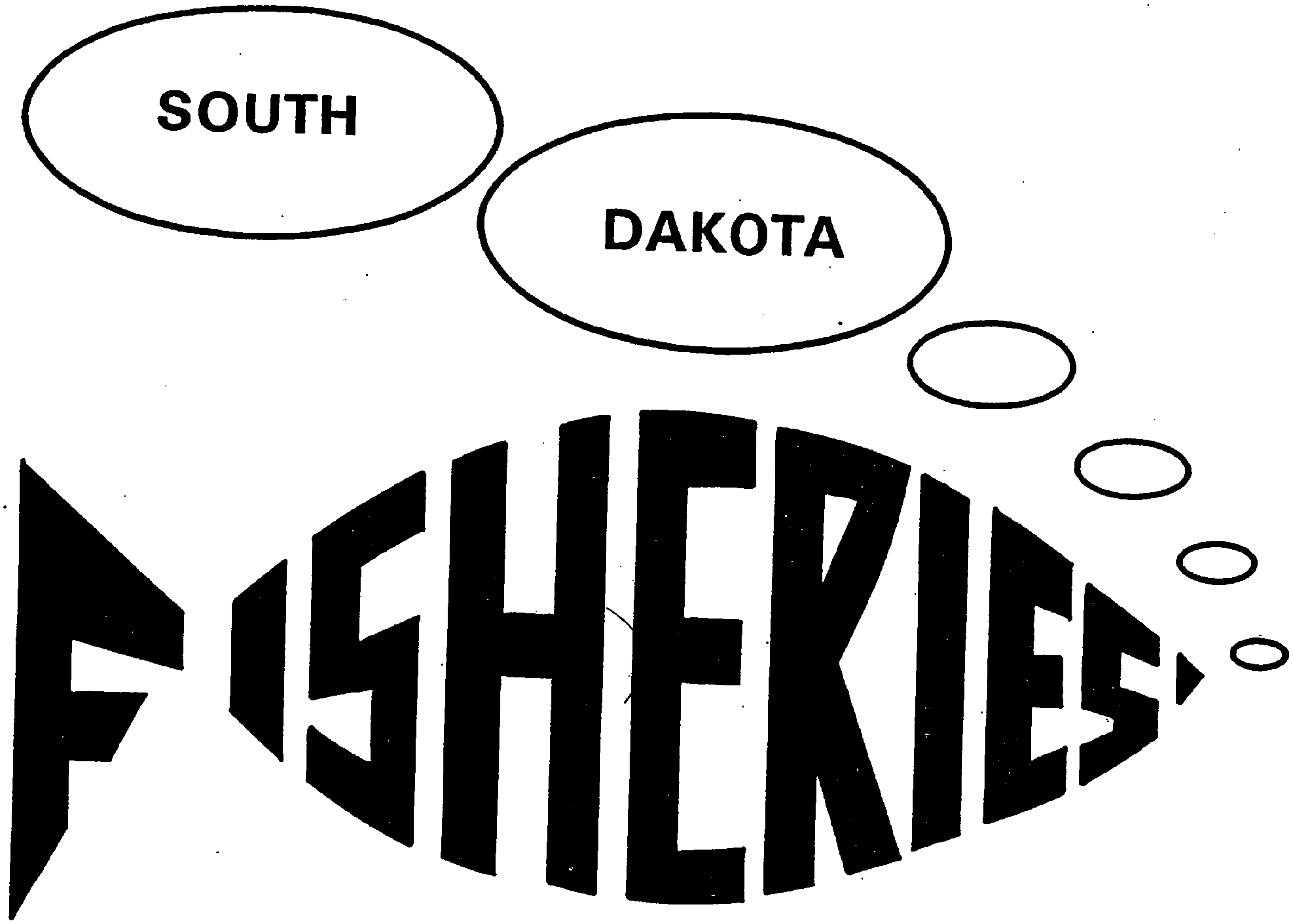
LAKE NAME	LAKE ID	DATE	TIME	SITE	SAMPLER	A TEMP (C)	W TEMP (C)	WATER DEPTH (feet)	SECCHI (feet)	PH	DO (mg/l)	CONDUCT (umhos)	FECAL COLIFORM (per 100 ml)	ALKA-M (mg/l)	ALKA-P (mg/l)	AMMONIA (mg/l)	ION-AMMON (mg/L)	NITRATE (mg/l)	TKN (mg/l)	ON (mg/l)	TN (mg/l)	TPO4 (mg/l)	TDPO4 (mg/l)	TSOL (mg/l)	TSSOL (mg/l)	TDSOL (mg/L)
Clear Lake	5252	05/20/1997	1115	CL-1B	Kringen								< 10	26	0	0.02	0.00000	0.1	0.11	0.09	0.21	0.002	< 0.002	53	< 1	52
Clear Lake	5252	07/22/1997	1020	CL-1B	Kringen								< 10	24	0	0.02	0.00000	0.1	0.25	0.23	0.35	0.003	0.005	42	< 1	41
Clear Lake	5252	09/22/1997		CL-1B	Kringen								< 10	2.8	0	0.02	0.00000	0.1	0.10	0.08	0.20	0.011	0.004	< 22.34	< 1	
Clear Lake	5252	10/14/1997		CL-1B	Kringen								< 10	< 31.42	0	0.02	0.00000	0.1	0.10	0.08	0.20	0.003	0.002	3	< 1	2
Clear Lake	5252	12/17/1997		CL-1B	Kringen								< 10	< 31.42	0	0.02	0.00000	0.1	0.10	0.08	0.20	< 0.002	< 0.002	< 22.34	< 1	
Clear Lake	5252	01/14/1997	1145	CL-2B	Kringen								< 10	7	0	0.02	0.00000	0.6	0.10	0.08	0.70	0.017	0.008	11	<1	14

APPENDIX D

Clear Lake, Deuel County								
Insantaneous Discharge Measurements								
319 Phase I (FY96)								
Site			Site			Site		
CLT-1		instant	CLT-2A		instant	CLT-3		instant
date	stage	discharge	date	stage	discharge	date	stage	discharge
31-Oct-96	2.35	2.27	04/14/1997	3.91	104.9	10/18/1996	2.16	8.85
02-Apr-97	4.14	140.55	04/23/1997	3.29	72.67	04/02/1997	5.43	614.28
04-Apr-97	3.83	60.24	05/12/1997	2.36	20.02	04/24/1997	2.84	113.57
16-Apr-97	2.6	6.59	05/21/1997	1.94	8.28	05/13/1997	1.95	30.81
12-May-97	2.04	1.59	05/30/1997	1.82	4.76	05/30/1997	1.61	11.13
30-May-97	1.95	0.54	06/09/1997	1.43	1.39	06/06/1997	1.49	2.36
01-Jul-97	2.84	22.06	06/16/1997	1.19	0.5	06/16/1997	1.34	0.51
03-Jul-97	2.17	1.99	07/10/1997	1.88	2.5	07/01/1997	1.56	16.7
21-Jul-97	2.27	2.21	07/18/1997	1.32	0.72	07/03/1997	1.88	33.02
24-Jul-97	1.93	0.64	07/21/1997	1.42	0.88	07/09/1997	1.59	6.31
25-Jul-97	3.7	24.22	07/24/1997	1.32	0.63	07/22/1997	1.59	4.88
30-Jul-97	2.05	1.52	07/30/1997	2.54	7.35	07/25/1997	2.86	76.97
04-Aug-97	2.87	10.27	08/04/1997	3.03	14.61	07/30/1997	1.77	19.9
08-Aug-97	2.3	2.05	08/28/1997	2.69	11.29	08/04/1997	2.21	38.64
08-Sep-97	2.11	1.28	09/08/1997	2.46	8.03	09/08/1997	2.37	14.1
07-Oct-97	1.9	0.25	10/07/1997	1.77	1.92	03/30/1998	3.09	104.03
16-Oct-97	2.01	1.06	10/20/1997	1.83	2.54	04/24/1998	2.4	45.22
30-Mar-98	2.49	8.3	03/30/1998	3.61	61.28	05/12/1998	1.8	12.8
09-Apr-98	2.67	13.31	04/09/1998	3.89	107.13	06/10/1998	1.45	3.72
10-Jun-98	1.73	0.7						
Site			Site			Site		
CLT-4		Instant	CLT-5		instant	CLT-6		Instant
Date	Stage	Discharge	date	stage	discharge	date	stage	discharge
09/26/1996	0.21	0.34	26-Sep-96	0.82	0.41			
10/17/1996	0.79	15.51	18-Oct-96	1.14	4.17	14-Apr-97	2.52	16.03
04/01/1997	1.4	149.91	31-Oct-96	1.53	5.18	18-Apr-97	2.13	9.50
04/03/1997	0.88	36.23	01-Apr-97	5.32	266.64	21-May-97	0.73	0.79
04/07/1997	0.82	34.6	03-Apr-97	1.86	33.01	29-May-97	0.78	0.65
04/25/1997	0.35	5.5	10-Apr-98	1.28	10.76	12-Jun-97	0.76	0.10
05/14/1997	0.22	1.8	15-Apr-97	1.27	18.69	11-Jul-97	0.92	0.21
05/29/1997	0.04	0.39	25-Apr-97	0.8	5.64	18-Jul-97	0.80	0.10
06/12/1997	0.03	0.03	14-May-97	0.89	2.16	24-Jul-97	1.09	0.53
06/19/1997	0.02	0.17	04-Jun-97	0.86	0.5	28-Jul-97	1.43	4.30
07/02/1997	0.56	7.83	01-Jul-97	1.42	2.15	07-Aug-97	1.37	2.01
07/08/1997	0.04	0.76	08-Jul-97	1.19	0.88	15-Aug-97	1.16	1.09
07/21/1997	0.22	1.85	15-Jul-97	0.93	0.14	25-Aug-97	0.85	0.28
07/25/1997	1.39	47.44	21-Jul-97	1.26	2.88	17-Sep-97	1.03	0.87
08/05/1997	0.36	4.86	25-Jul-97	2.63	59.02	20-Oct-97	0.99	0.86
09/09/1997	0.03	0.57	29-Jul-97	0.84	3.23	29-Dec-97	0.71	0.22
10/15/1997	0.13	1.28	05-Aug-97	1.16	5.27	26-Feb-98	1.54	5.98
03/26/1998	1.19	46.5	15-Aug-97	0.81	2.04	26-Mar-98	1.61	5.69
04/09/1998	0.75	12.11	09-Sep-97	1.23	0.91	17-Jun-98	1.20	2.06
05/13/1998	0.32	1.49	15-Oct-97	0.86	1.95			
			26-Mar-98	2.3	66.1			
			12-Jun-98	0.89	2.58			
			15-Jun-98	1.75	27.21			

Site			Site			Site		
CLT-7		Instant	CLO-8		instant	CLO-9A		instant
Date	Stage	Discharge	date	stage	discharge	date	stage	discharge
			17-Apr-97	6.19	314.91	02/06/1997	0.05	1.07
09/26/1996	0.37	0.88	19-May-97	3.78	25.57	04/18/1997	1.85	210.90
10/18/1996	0.82	16.87	28-May-97	3.63	11.28	04/25/1997	1.35	126.18
10/31/1996	1.16	29.02	06-Jun-97	3.28	6.27	05/15/1997	0.30	34.01
11/08/1996	0.62	8.5	03-Jul-97	2.86	8.34	05/28/1997	0.15	6.74
04/01/1997	4.9	667.2	07-Jul-97	2.99	9.73	07/10/1997	0.10	5.43
04/03/1997	5.24	785.33	10-Jul-97	2.97	6.86	07/25/1997	0.50	20.63
04/24/1997	2.44	98.3	15-Jul-97	2.56	0.87	07/29/1997	0.40	39.50
05/13/1997	1.35	32.94	22-Jul-97	3.04	9.5	08/01/1997	0.25	25.98
05/28/1997	0.82	11.72	25-Jul-97	5.03	74.87	08/06/1997	0.40	40.97
06/06/1997	0.64	3.69	29-Jul-97	3.98	44.55	08/15/1997	0.20	19.39
06/17/1997	0.31	0.66	06-Aug-97	4.01	47.01	08/28/1997	0.30	27.86
07/01/1997	0.26	0.46	15-Aug-97	3.65	23	12/10/1997	0.10	5.79
07/01/1997	0.95	19.01	25-Aug-97	3.19	12.49	01/02/1998	0.05	2.96
07/02/1997	1.51	35.45	28-Aug-97	3.91	35.81	02/10/1998	0.03	1.02
07/03/1997	1.18	26.79	10-Sep-97	3.24	14.96	02/18/1998	0.15	8.80
07/09/1997	0.77	8.14	17-Oct-97	2.98	10.31	02/23/1998	0.45	36.04
07/22/1997	0.71	7.02	26-Feb-98	4.54	94.26	02/27/1998	1.00	79.19
07/25/1997	2.18	83.21	20-Mar-98	3.43	28.58	03/13/1998	0.35	42.40
07/30/1997	0.95	19.55	02-Apr-98	4.71	117.42	03/20/1998	0.25	23.88
08/04/1997	1.47	41.22	10-Apr-98	5.45	216.43	04/02/1998	1.20	94.82
08/28/1997	1.11	27.89	13-May-98	3.13	20.84	04/10/1998	1.90	137.63
09/08/1997	0.96	21.04	12-Jun-98	2.47	12.97	04/17/1998	1.30	108.14
10/07/1997	0.72	6.14				04/24/1998	0.80	69.11
10/16/1997	0.84	11.19				05/13/1998	0.20	16.60
03/30/1998	2.5	102.27						
04/09/1998	3.27	162.09						
Site								
CLT-10		instant						
date	stage	discharge						
14-Apr-97	2.5	13.63						
22-Apr-97	1.72	7.35						
30-Apr-97	1.15	3						
19-May-97	1.1	0.7						
29-May-97	1.04	0.38						
24-Jul-97	0.67	0.06						
28-Jul-97	1.06	0.89						
07-Aug-97	0.94	0.47						
18-Aug-97	0.72	0.11						
05-Sep-97	0.86	0.21						
26-Feb-98	1.4	1.33						
26-Mar-98	1.51	2.48						
15-Apr-98	1.96	4.35						
19-May-98	0.99	0.29						
17-Jun-98	0.91	0.43						

APPENDIX E



STATEWIDE FISHERIES SURVEYS, 1997
MANAGEMENT PLAN

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

Annual Report
No. 98-9

FIVE YEAR FISHERIES MANAGEMENT PLAN

Water Clear County Deuel

Present Plan F-21-R- 30 Date 1998 to 2002
Previous Plan F-21-R- 25

INVENTORY

A. Water No. (23-3) Yr. last sur. 1979 Mgt.Class M Prority 6.3
Size 608 ac.; Depth: Max. 6 Ave. 4 Littorial 608 ac
Type N Shape 0
Veg. density: Submerg. 400 acres Emerg. 24 acres.
Outlet structure type: CS Barriers none Subimp. none
No. 0 ac.; Rear.Pond (s) none No. 0 acres.
No access areas 1 No. Boat Ramps/type 1 Docks 1
Toilets 1

B. Species managed, reproduction & population potential, condition & tren

	Primary Game Fish	Repro. Poten.	Pop. Poten.	Pop. Cond.	Population Trend
1.	Northern Pike	good	fair	good	Ave. and stable since 1992
2.	Yellow Perch	good	good	poor	Below ave since 1992
3.					
4.					
5.					
	Secondary Game Fish				
1.					
2.					
3.					
4.					
5.					
	Other Species				
1.	White Sucker	good	good	fair	Ave. and stable since 1992
2.	Carp	good	good	fair	Ave. and stable since 1992
3.	Buffalo	fair	fair	fair	Ave. and stable since 1992
4.	Bl. Bullhead	good	good	good	Ave. and stable since 1992
5.					

I. PROBLEMS

A. Biological (fish pop., forage, growth reproduction, harvest, etc. rank 1,2,3 in priority)

1. Winterkills frequently
2.
3.

I. PROBLEMS: (cont.)

B. Environmental (water qual. or quan. enrich., veg., etc., rank 1,2,3 in priority)

1. Sediment in flows provide excessive nutrient resulting in ex-
2. cessive algal growth.
3. Excessive submergent vegetation.

C. Physical (Depth, size, shape, structure, outlets, etc., rank 1,2,3 in priority)

1. Overall lack of depth
2. Lack of diversity of habitat
3.

D. Access & others (areas, ramps, roads, signs, facilities, etc. rank in priority)

1. Access to Clear Lake is very good via county road on north and
2. east side and state highway 22 along the south side. A public
3. road also runs from Clear Lake to the west shoreline. A city park is on the east side.

II. MANAGEMENT NEEDS AND ACTIONS:

A. Analysis and evaluations:

1. Uses, values & importance: Clear Lake has a priority rating of 6.3. It is a fairly important fishery locally for northern pike and yellow perch. Excessive submergent vegetation hampers fishing and other recreation by mid-summer.

2. Fisheries assessment schedule (Surveys/studies needed):

Year	Type(s)	Duration	Costs
1999	General Lake Survey	2 days	$300.00

II. MANAGEMENT NEEDS AND ACTIONS: (cont.)

B. Management action schedule (five year minimum)

a. Removal (commercial or Department Crews)

Year	Species	Type	Quantities	Est. Cost
1998	Bl. Bullhead	contract	100 lb./ac/yr	$100.00/yr

b. Chemical removal:

Year	Species	Type	Chemical/Amount	Est. Cost
	N/A			

c. Water level manipulations:

Year	Species	Type	Amount/Duration	Est. Cost
	N/A			

d. Stocking: (group by years)

Year	Species/Strain	Size	Number	Type	Est. Cost
	If winkill				
	occurs				
	Yellow Perch	Adt	1200	W	$300.00
	Northern Pkke	fry	300,000	W	$1050.00

2. Habitat Improvement Schedule:

Year	Type	Number	Location	Est. Cost
1998	Best management practices in the watershed and possible			
2000	dredging			

3. Access Development Schedule:

Year	Type	Number	Location	Est. Cost
1998	N/A			

4. Access Maintenance Schedule:

Year	Type	Number	Location	Est. Cost
	N/A city			
	owned			

5. Public Information Program:

Year	Type	Number	Location	Est. Cost
1998	media releases	2		50.00 each
to				
2002				

C. Other Management Activities or Developments:

Presently a two year study is being conducted by DENR looking at the watershed and potential solutions to water quality. Dredging of portions of the lake are being considered.

SUBMITTED BY: ________ Title________ Date________

APPROVED BY:

Region________ Title Asst Reg Supv Date 3-23-98

Division________ Title________ Date________

SD Department of Environment & Natural Resources
Water Resources Assistance Program
Total Maximum Daily Load

Clear Lake Watershed,
Deuel County, South Dakota
May, 2000

A TMDL for total phosphorus has been developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by the US Environmental Protection Agency and is supported below.

TMDL Summary Table:

Waterbody Name	**Clear Lake**
Hydrologic Unit Code (HUC)	7020003
TMDL Pollutant	**Total phosphorus**
Water Quality Target	Inlake chlorophyll *a* TSI $\leq$ 61 (chlorophyll *a* inlake concentration reduction of 30%)
TMDL Goal	Reduce tributary phosphorous loadings by 20%
303(d) Status	Priority 1, page 20
Impaired Beneficial Uses	Warmwater marginal fish life propagation; immersion recreation; limited contact recreation
Reference Document	Phase I Watershed Assessment Final Report Clear Lake Deuel County South Dakota (SDDENR, 1999)

I. Executive Summary:

- *Waterbody Description and Impairments*

Clear Lake is a 532 acre (215.3 hectare) natural lake located in central Deuel County in the Prairie Coteau region of northeastern South Dakota (Fig. 1). The lake was derived from glacial activity and has a contributing watershed of approximately 27,360 acres (11,072.6 ha). The maximum depth of Clear Lake is 6 feet (1.8 meters) with a mean depth of 4.5-ft (1.4 m) and has an estimated volume of 2,400 acre-feet (2.761×10^6 cubic meters).

The major surface water connection with the lake is an unnamed tributary draining into the lake from the northwest. The importance of this tributary increased substantially during the early 1900s when a diversion channel was created that allowed a direct surface connection to the lake. Without this diversion, the tributary would have entered the lake only during times of heavy flooding by passing through a natural wetland complex.

The natural outlet of Clear Lake is located in the southwest corner of the lake and delivers water into Hidewood Creek which eventually enters the Big Sioux River. In 1996, a new concrete spillway was constructed to replace the old one, which had been broken out and replaced with rocks. The new spillway was built at an elevation of 6 inches (1773.5 msl) below the ordinary high water mark of 1774.0 msl.

Clear Lake has been used for general recreation and immersion recreation purposes such as swimming, boating, and fishing. However, since the initial diversion channel was created allowing a direct surface connection, Clear Lake has experienced loss of depth, declining water quality and other related problems due to activities that are usually associated with agricultural watersheds.

- ***Stakeholder Description***

  The Deuel Conservation District was the local sponsor of the Clear Lake Watershed Assessment project. As local sponsor, the District hired the local coordinator and administered project funds. Funds for the project were from Section 319 Nonpoint Source funds administered by the Environmental Protection Agency (EPA). EPA granted the money to the state of South Dakota for the water quality assessment. The 40% local match needed for the project was provided by the Clear Lake Restoration Association.

Table 1. Stakeholders

Deuel Conservation District Clear Lake Restoration Association City of Clear Lake Deuel County Natural Resource Conservation Service US Environmental Protection Agency – Section 319 Nonpoint Source Program	SD Department of Game Fish & Parks SD Department of Environment & Natural Resources – Water Rights SD Department of Environment & Natural Resources – Environmental Services SD Department of Environment & Natural Resources – Watershed Protection

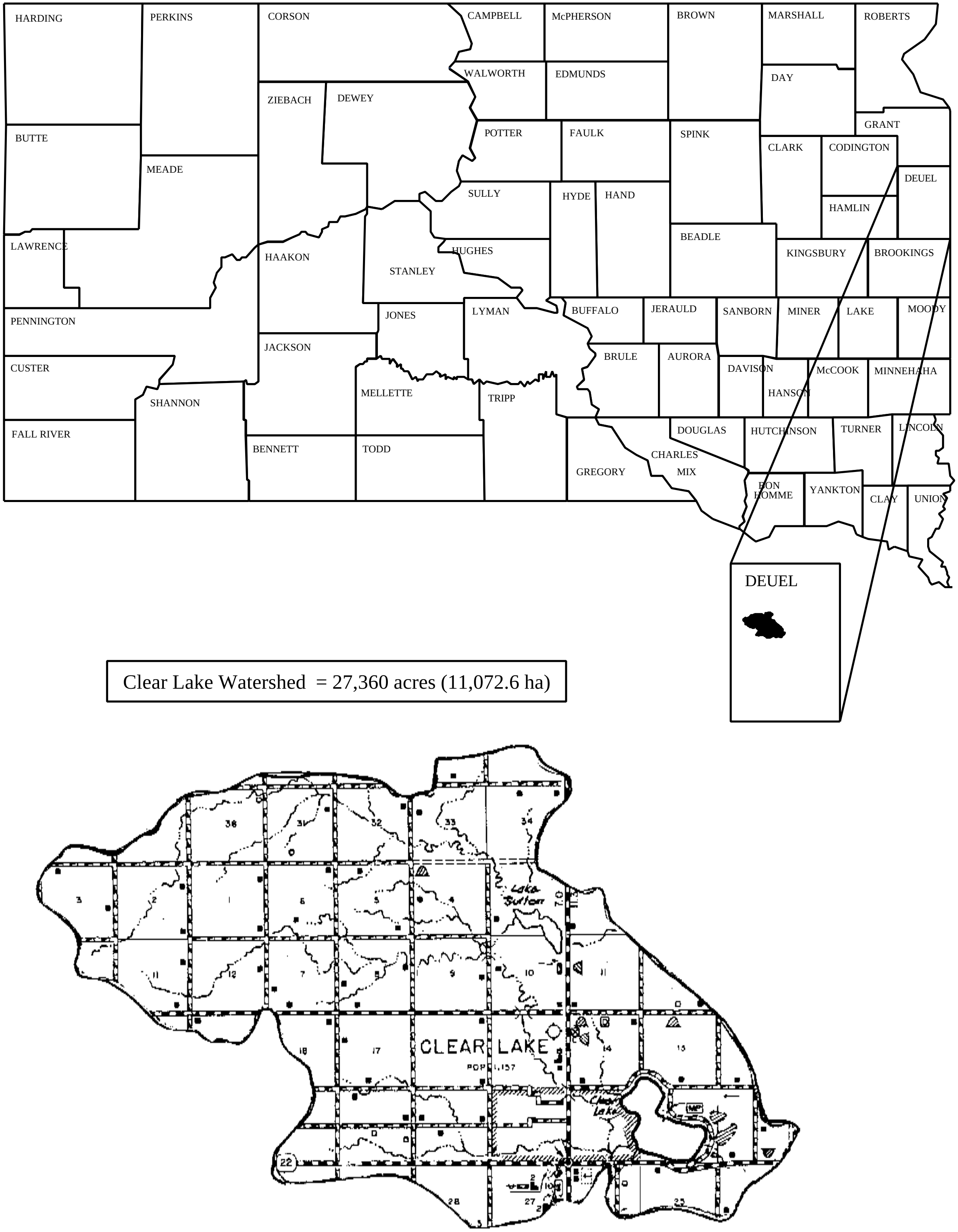
- ***Intent to Submit as a Clean Water Act Section 303(d) TMDL***

  In accordance with Section 303(d) of the Clean Water Act, the South Dakota Department of Environment and Natural Resources submits for EPA, Region VIII review and approval, the phosphorus total maximum daily load (TMDL) for Clear Lake as provided in this summary and attached document. This TMDL has been established at a level necessary to meet the applicable water quality standards with consideration of seasonal variation and a margin of safety. The following designated use classifications will be protected through implementation of this TMDL: warmwater marginal fish life propagation, immersion recreation, and limited contact recreation.

II. Problem Characterization:

- ***Waterbody description/Maps***

Figure 1 Clear Lake Watershed



Clear Lake Watershed = 27,360 acres (11,072.6 ha)

- ***Waters Covered by TMDL***

  Clear Lake is the benefactor of this TMDL.

- ***Pollutant(s) of Concern***

  Total Phosphorus

- ***Rationale for Geographic Coverage***

  Nine tributary locations were chosen for collecting hydrologic and nutrient information from the Clear Lake watershed. These monitoring locations were placed at specific areas within the watershed that would best show DENR which sub-watersheds were contributing the largest nutrient and sediment loads. Inlake water quality samples were collected once monthly at two inlake monitoring sites except during periods of unsafe ice conditions.

- ***Use Impairments or Threats***

  The beneficial use classifications established for Clear Lake are not to be construed as limiting the actual use of the lake. The classifications designate the minimum quality at which the surface waters of Clear Lake are to be maintained and protected. Clear Lake has been assigned the following water quality beneficial uses:

  (6) Warmwater marginal fish life propagation
  (7) Immersion recreation
  (8) Limited contact recreation
  (9) Wildlife propagation and stock watering

  Clear Lake is an extremely shallow lake (mean depth = 4.8 ft) with excessive amounts of nutrient enriched sediment. Moreover, the tremendous amount of organic matter (algae blooms) that accumulates over the growing season needs to undergo biodegradation which reduces dissolved oxygen levels. In recent decades, Clear Lake has undergone considerable siltation and nutrient enrichment. The former has reduced average lake depth to less than five feet while the latter process has resulted in greatly diminished water clarity produced mainly by the growth and decay of large standing crops of algae which has dramatically resulted in non-use for swimming and boating and has limited fishing to early season use only .

- ***Probable Sources***

  The most likely source of nutrients is from animal feeding operations located near stream channels and runoff from fertilized cropland.

  When a detailed subwatershed analysis was performed, four of the ten subwatersheds analyzed appeared to have high nutrient deliverability rates. On an annual basis, 77 tons of nitrogen and 18.8 tons of phosphorus are delivered to the lake while only 76 tons of nitrogen and 16.1 tons of phosphorus leave Clear Lake. This correlates to a trapping efficiency of 1.3 % for nitrogen and 14.4% for phosphorus entering Clear Lake. The model indicates that these high loads may be related to 10 animal feeding areas located near the subwatershed outlets and close to channelized flows. It is recommended that these ten animal feeding areas be evaluated for potential operational or structural modifications in order to minimize future nutrient releases.

The model results also indicate that runoff from fertilized cropland was a significant source of water soluble nutrients to Clear Lake. Four subwatersheds contribute 51.6% (39.7 tons) of the total nitrogen and 56.4% (10.6 tons)of the total phosphorus load to Clear Lake and only make up 38.3%of the watershed area.

III. TMDL Endpoint:

- ***Description***

  Since blue-green algae are only able to assimilate dissolved phosphorus but can assimilate several kinds of nitrogen, a total nitrogen to total phosphorus ratio was used to determine the limiting nutrient. When the total nitrogen to total phosphorus ratio increases to 10:1, blue green algae appear to be phosphorus limited. The average total nitrogen to total phosphorus ratio for Clear Lake was 15.8. Turbidity was a limiting factor in Clear Lake where shallow depth allows resuspension of solids, reducing the amount of available light. The mean total phosphorus trophic status (TSI) was 77 for Clear Lake. The hypereutrophic range of Carlson's Trophic Index begins at 65 indicating that Clear Lake is in the hypereutrophic range.

- ***Endpoint Link to Surface Water Quality Standards***

  A model estimated the effect on Clear Lake of reducing tributary phosphorus in the lake watershed for both Clear Lake. A 20% reduction of tributary loadings to Clear Lake would result in a chlorophyll *a* concentration reduction of 30%. If the reduction could be reached, the TSI ranking of <61 for chlorophyll *a* would be reduced to well below the hypereutrophic level for Clear Lake.

IV. TMDL Analysis and Development:

- ***Data Sources***

  Ten tributary sites were monitored during the course of the investigation to locate potentially high phosphorus, nitrates, and sediment loadings. A total of 11 parameters were analyzed and used to determine the state of the water quality at each of these monitoring stations during 1996-1998.

Monitoring was conducted from March through November of 1997. Monitoring began late 1996 after the monitoring stations were installed in October with one sample collected from sites that were currently running water. Water quality and discharge monitoring continued through the spring of 1998. At that time it was decided to continue to monitor the hydrologic loadings until June of 1998 when all the monitoring and gauging equipment were finally removed. Continuous base flow data were collected from each tributary monitoring site. Data that were collected included average daily stage, instantaneous discharge, and water quality samples. When possible peak flow event data were also collected in order to determine the loadings delivered during these events.

- ***Analysis Techniques or Models***

  The following analysis techniques and models were used in this project:

  - Reduction/Response Model, Vollenweider and Kerekes (1980)
  - Aquatic Plant Survey
  - Clear Lake Sediment Survey
  - Agricultural Nonpoint Source Model
  - Feeding Area Evaluation

- ***Seasonality***

  Different seasons of the year can yield different water quality in a tributary due to changes in precipitation and agricultural practices. Tributary samples were separated into spring (March 15 to May 31, 1997), summer (June 1 to August 31, 1997), and fall (September 1 to October 30, 1997). According to the water quality samples collected in 1997, the largest nutrient and sediment concentrations and loadings typically occurred during the spring (Table 3).

  The heavy snows that occurred during the 1996-97 winter explain this. The excessive amount of snow that melted during spring transported the bulk of the nutrients and sediment during the 1997 sampling year. This was also evident from the data collected from the outlet of Clear Lake. Although Clear Lake retained some nutrients and sediment, the period in which the greatest amount of nutrients/sediment was transported out of the lake also occurred during the spring runoff period.

  The concentrations of phosphorus, nitrogen, and suspended solids are higher in the spring than at any other time of year with the exception of dissolved phosphorus (see Figure 2 as an example). Applied fertilizer, and the presence of animal waste, which are indicated by the increased fecal coliform concentrations during the summer, are probably the cause of the higher concentrations of bioavailable phosphorus during the summer season. The other increases in nutrients and sediment during the spring are the result of the heavy spring flows and the decaying vegetation from the previous year's growing season. Nitrate is water-soluble; meaning it can easily dissolve in water. In the spring the soil may be either frozen or water-saturated so most of the flow is overland into surface waters. During summer, with the presence of livestock in summer pastures, increases in bioavailable phosphorus during this season are not unreasonable.

Many of the water quality parameters increased in concentration during the spring runoff. During the spring runoff (March – May), when greater than 80% of the runoff occurred for some of the tributary sites, the concentrations for nutrients and suspended solids concentrations increased. These higher concentrations can be attributed to the much higher flows that occurred during this sampling period. Typically, each tributary's sample concentrations exhibited a variety of seasonal trends. Site CLT-1 (northwestern tributary) exhibited the maximum concentrations during the spring and, as the sampling year continued, the samples decreased in concentration. However, this was highly dependent upon the individual parameter. Nutrients were typically higher in the spring with periodic spikes occurring during the year, which may have been due to fertilizer and animal waste runoff. The higher concentrations also may have been due to overland flow across frozen ground. Dissolved nutrients are able to adsorb to any soil particle and there is very little nutrient demand by the vegetation due to the early time of the year.

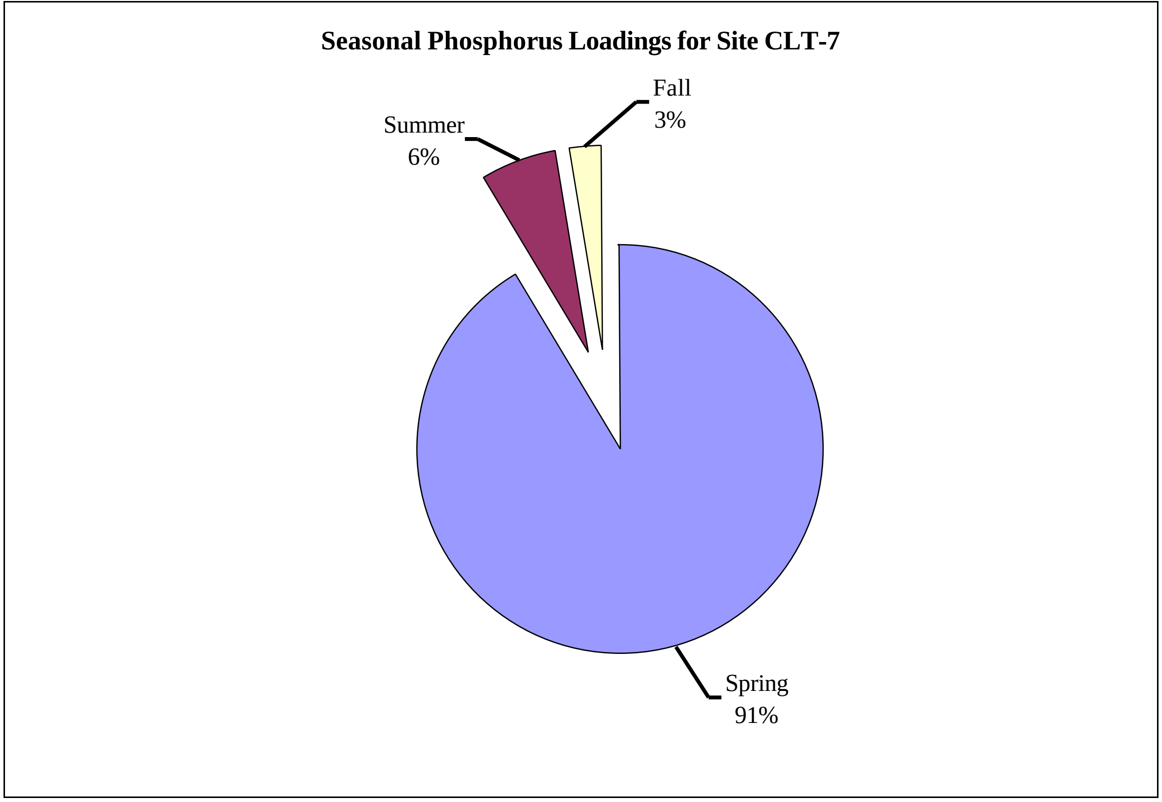


Figure 2 Example of seasonal phosphorous loadings on tributary site

- ***Margin of Safety***

  The 20% phosphorous reduction goal does not take into consideration any additional reductions due to BMP implementation for lawn fertilization, storm sewers and inlake dredging.

  A final option and an opportunity for further inlake phosphorus reductions for Clear Lake is dredging. The contribution of internal phosphorus loading to the nutrient budget of Clear Lake was not calculated. Clear Lake continually receives phosphorus from the northwestern tributary which settles to the bottom, depending upon if it is in the particulate form. The shallow nature of Clear Lake allows this phosphorus to be reused through the resuspension of sediment and uptake by aquatic macrophytes and algae which can be a severe problem in Clear Lake. All of these inlake problems (aquatic macrophytes, blue-green algae blooms, internal loading, and lack of depth) can be solved through dredging. However, this restoration alternative is extremely expensive. The sediment survey indicated that there is 2.48 million cubic yards of sediment contained in the Clear Lake basin. This represents an average sediment depth of 2.9 feet over the entire 532 surface acres of the lake.

  The north bay near where the northwestern tributary enters the lake contains the deepest and largest area of sediment. To remove all 2.48 million cubic yards is not economically feasible. Partial lake dredging will provide an affordable option that will still provide benefits to the lake and its users. The removal of 750,000 cubic yards of sediment would increase the depth of the lake by four feet over 116 surface area acres. Although this will increase average depth, aquatic plants can still develop in a depth of eight feet or more due to the anticipated improvement in water clarity. In addition, through the use of dredging, certain patterns can be created in the sediment to increase the fisheries habitat within the lake.

  With the nutrient reductions from the watershed and dredging, over time there may be a reduction in the aquatic macrophyte problem. As less and less nutrients become available the growth of aquatic plants and blue-green algae blooms will begin to be limited. However, this would be the optimum situation and, more than likely the aquatic macrophytes will continue to be a problem. To reduce the impact of the aquatic macrophytes the users of the lake may choose to explore the possibility of an aquatic plant harvesting program. The removal of the plants will also help in the reduction of inlake phosphorus concentrations.

V. Allocation of TMDL Loads or Responsibilities:

- ***Wasteload Allocation***

There are no known point sources of pollutants that are of concern in this watershed, therefore the "wasteload allocation" component of the TMDL is considered a zero value. The TMDL is considered wholly included in the "load allocation" component of the TMDL.

- ***Load Allocation***

The AGNPS computer modeling conducted on the Clear Lake watershed indicated high sediment and nutrient yield results from the same subwatersheds where water quality data indicated high export coefficients for these same parameters.

AGNPS identified these critical subwatersheds as CLT-1, CLT-4, CLT-5, and CLT-10 which appeared to be contributing very high amounts of nutrients especially in the form of water soluble (dissolved) nutrients. The AGNPS model indicated that the high nutrients may be due to animal feeding areas and runoff from fertilized cropland. The water quality data indicated that these same subwatersheds (CLT-1, CLT-4, CLT-5, and CLT-10) were major contributors to the nutrient loading of Clear Lake, with one exception. The water quality data indicated that Site CLT-10 had very low nutrient export coefficients. However, the water quality coefficients were based on insufficient data (two samples) and the outlet site for CLT-10 was also located on a wetland.

Possible sources in these areas of high nutrients and sediment were identified as high slopes and bank erosion due to lack of riparian vegetation, reduced residue management, as well as crop and lawn fertilization. Other sources which were identified as significant were confined and pastured livestock feeding areas.

Another subwatershed of concern was Site CLT-2a which drains 9,000 acres above Lake Sutton. Presently, most or a large percentage of sediments and nutrients that enter Lake Sutton and are trapped. However, once Lake Sutton becomes “silted-in” its capacity for holding nutrients and sediments will be reduced to the point where it will become a major contributor (point source) to Clear Lake.

Site CLT-7 contributed over 93% to the overall phosphorus budget for Clear Lake. Clear Lake accumulated 24,822 lbs (12.4 tons) of phosphorus during 1997. Ninety-one percent of the phosphorus discharged into the lake was received during the spring season when 85% of the hydrologic load occurred.

Storm sewer samples were collected from three sites within the city of Clear Lake. Each of these samples exhibited extremely high concentrations of nutrients (phosphorus and nitrogen), fecal coliform bacteria, and sediment (total suspended solids).

- ***Allocation of Responsibility***

Because of the soluble nature of nitrogen it is very difficult to remove it from a lake and watershed system. Phosphorus will not pass through groundwater as readily as nitrogen, as it adsorbs on to soil and other substrates. Phosphorus is also considered the limiting nutrient when blue-green algae bloom. For these reasons the sponsors should concentrate on the removal of phosphorus from sources entering Clear Lake.

There are a variety of sources of phosphorus that were identified within the Clear Lake watershed. Various treatments and best management practices will need to be implemented in order to attain a 20% reduction in phosphorus loadings (Table 2). According to the relationship between total phosphorus and chlorophyll *a*, this should result in a 30% reduction of lake Chlorophyll concentrations (Figure 1).

			Percent Reduction in nutrients if:		
			AGNPS Cells with Erosion > 9.0 tons/acre,10 lbs of Nitrogen/acre, 5lbs of phosphorus/acre are treated	10 feeding areas rated > 60 undergo BMP installation	Total Reduction
	Nutrient	Total AGNPS Loadings			
Clear Lake	Nitrogen (tons)	77.0	10.9%	10.7%	21.6%
	Phosphorus (tons)	18.8	10.6%	9.6%	20.2%

Table 2 Agricultural Nonpoint Source Computer Model Reduction Response Results

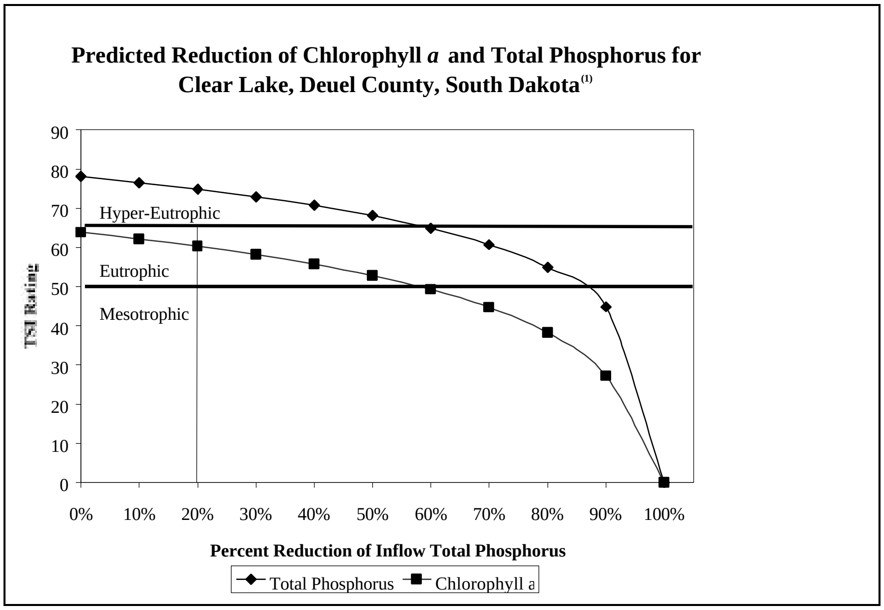


Figure 1 Predicted reduction of Chlorophyll *a* and Total Phosphorous

In order to achieve a chlorophyll *a* reduction a variety of best management practices (BMPs) need to be implemented in the subwatersheds identified in the AGNPS report in Appendix A. According to the AGNPS program, there are 56, 40-acre cells that need to be treated for a combination of sediment and nutrient problems. Twenty-six cells (1040 acres) need to implement a no-tillage practice and 30 cells (1200 acres) need to be converted over to minimum tillage. These cells either have rates of erosion greater than 9.0 tons per acre, or they contribute 10 lbs of sediment-based nitrogen per acre and 5 lbs of sediment-based phosphorus per acre to the overall loadings from the watershed. BMP installation (minimum tillage, no till, and animal waste management systems) on these areas identified in the AGNPS report in Appendix A will create the largest possible reduction in phosphorus loadings to Clear Lake (Table 15).

VI. Schedule of Implementation:

The Clear Lake Watershed Implementation Project is a four-year watershed improvement and sediment removal project sponsored by the Deuel County Conservation District with a start date of January, 2000. Several Best Management Practices (BMPs) are planned and funded. The watershed project is far-reaching and will go beyond the TMDL goal and target to improve inlake water quality. Some of the major BMPs include the following:

- Construction of 10 Animal Waste Management Systems
- Dredge removal of 300,000 cubic yards of sediment to increase lake depth and remove dissolved phosphorous contributions from the sediment
- 3,000 acres in crop rotation / residue management
- 200 acres in grassed waterways
- 2500 acres in grazing management
- 600 acres in wetland / riparian / upland restoration
- 721 feet in riparian / bank / shoreline stabilization
- Extensive information and education program that include urban components such as lawn fertilization BMPs, etc.

VII. Post-Implementation Monitoring:

Once the implementation project is completed, post-implementation monitoring will be required to assure that the TMDL has been reached and improvements to the beneficial uses occur.

VIII. Public Participation:

- ***Summary of Public Review***

The Clear Lake watershed is composed of a very small population. Efforts were made to inform and educate all urban, rural and producer groups. The Clear

Lake Restoration Association held monthly meetings throughout the life of the project and published several informational articles in the local newspaper. A letter explaining the project and the need for and use of data was also sent out to each feeding area operator and adjacent landowners.

- ***Project Information and Education Efforts***

Table 2.

Public Meetings/ Personal Contact	***Articles/ Fact Sheets***	***Document Distribution***
• 24 monthly meetings between 1996 - 1998 • 31 letters sent to feeding area operators and adjacent landowners	• 4 semi-annual project status updates published in the local newspaper	Deuel Conservation District Natural Resource Conservation Service Clear Lake Restoration Association City of Clear Lake Deuel County SD Department of Game Fish & Parks SD Department of Environment & Natural Resources – Water Rights SD Department of Environment & Natural Resources – Environmental Services SD Department of Environment & Natural Resources – Watershed Protection US Environmental Protection Agency – Section 319 Nonpoint Source Program
Electronic media	***Mailings***	***Public Comments Received***
May 2000 TMDL Summary advertised on department website	**Interested parties** May 5, 2000 **Stakeholders** May 5, 2000 **Daily Newspapers** May 5, 2000	Comments received during project meetings and review of the draft report and findings were considered.

IX. Supporting Development Document(s) (attached):

Wittmuss, Alan and McIntire, Mark. June 1999. PHASE I WATERSHED ASSESSMENT FINAL REPORT CLEAR LAKE DEUEL COUNTY SOUTH DAKOTA. South Dakota Watershed Protection Program, Division of Financial and Technical Assistance, South Dakota Department of Environment and Natural Resources, Pierre, South Dakota.

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

February 7, 2001

Ref: 8EPR-EP

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

Re: TMDL Approvals
Blue Dog Lake
Clear Lake
Freeman Lake
Punished Woman Lake
Upper Lake Sharpe

Dear Mr. Pirner:

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

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

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

In the course of developing TMDLs for impaired waters, EPA has recognized that not all impairments are linked to water chemistry alone. Rather, EPA recognizes that *"Section 303(d) requires the States to identify all impaired waters regardless of whether the impairment is due to toxic pollutants, other chemical, heat, habitat, or other problems."* (see 57 Fed. Reg. 33040 for July 24, 1992). Further, EPA states that "*...in some situations water quality standards – particulary designated uses and biocriteria – can only be attained if nonchemical factors such as* *hydrology, channel morphology, and habitat are also addressed. EPA recognizes that it is appropriate to use the TMDL process to establish control measures for quantifiable non-chemical parameters that are preventing the attainment of water quality standards.*" (see Guidance for Water Quality-based Decisions: The TMDL Process; USEPA; EPA 440/4-91-001, April 1991; pg. 4). We feel the State has developed TMDLs that are consistent with this guidance, taking a comprehensive view of the sources and causes of water quality impairment within each of the watersheds. For example, in several of the TMDLs, the State considered nonchemical factors such as lake depth and its relationship to the impaired uses. Further, we feel it is reasonable to use factors such as lake depth as surrogates to express the final endpoint of the TMDL.

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

Sincerely,

Jerry Anderson for

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

Enclosure

Enclosure

APPROVED TMDLs

Waterbody Name*	TMDL Parameter/ Pollutant	Water Quality Goal/Endpoint	TMDL	Section 303(d)1 or 303(d)3 TMDL	Supporting Documentation (not an exhaustive list of supporting documents)
Blue Dog Lake*	phosphorus	TSI ≤ 65	30% reduction in phosphorus loads	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report, Blue Dog Lake, Day County, South Dakota (SD DENR, Sept. 1999) ■ Report on the Activities and Expenditures of the Blue Dog / Enemy Swim Lake Watershed Assessment Study (Day Conservation District, January 1999)
Clear Lake*	phosphorus	TSI ≤ 61	20% reduction in average annual tributary phosphorus loads	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report, Clear Lake, Deuel County, South Dakota (SD DENR, June 1999)
	sediment	Increase average lake depth by 4 feet over 116 surface area acres	Remove 750,000 cubic yards of lake sediment	Section 303(d)(1)	
Freeman Lake*	nitrate	nitrate - 50 mg/L as a 30 day average nitrate - 88 mg/L as a daily maximum	reduce nitrate delivery to the lake by 33,000 Kg/year	Section 303(d)(1)	■ Water Quality Sample Results (SD DENR, 1979-1999) ■ Freeman Lake Watershed AGNPS Study Results ■ Saline-Seep Diagnosis, Control and Reclamation (USDA, Conservation Research Report No. 30, May, 1983)
	selenium	selenium - 5 µg/L as a 30 day average selenium - 20 µg/L as a daily maximum	reduce selenium delivery to the lake by 152.6 Kg/year	Section 303(d)(1)	

Waterbody Name*	TMDL Parameter/ Pollutant	Water Quality Goal/Endpoint	TMDL	Section 303(d)1 or 303(d)3 TMDL	Supporting Documentation (not an exhaustive list of supporting documents)
Punished Woman Lake*	sediment	Increase average lake depth in mid-lake area to 12 - 15 feet	■ 50% reduction of in-lake sediment ■ Remove 421,000 cubic yards of lake sediment	Section 303(d)(1)	■ 1993 South Dakota Lakes Assessment Final Report (SD DENR, March 1994) ■ Punished Woman's Lake Diagnostic / Reasibility Study Report (SD DWNR, April 1991) ■ South Dakota Lakes Classification and Inventory Final Report (SD DWNR, 1981) ■ Classification, Preservation, Resoration of lakes in Northeastern South Dakota (State Lakes Preservation Committee, 1977)
	nutrients	50% reduction of pondweed, cattail, and bulrush 15% reduction of in-lake sediment	Remove 421,000 cubic yards of lake sediment	Section 303(d)(1)	
Upper Lake Sharpe*	sediment	re-vegetate 45% of stream channel types F and G (Rosgen's Stream Channel Classification)	30% reduction of annual sediment delivery to Lake Sharpe by the year 2010	Section 303(d)(1)	■ Lower Bad River Basin Study Final Report (USDA, NRCS, revised June 1994) ■ Upper Bad River Basin Study (USDA, NRCS, October 1998) ■ Bad River Phase II Water Quality Project Final Report (Stanley County Conservation District, 1996) ■ Report on Factors Affecting Sediment Yield in the Pacific Southwest Area and Selection and Evaluation of Measures for Reduction of Erosion and Sediment Yield (Pacific Southwest Inter-Agency Committee, October 1968)

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

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Blue Dog Lake, Day County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 12, 2000 Date Review completed: January 10, 2001 VEB

Review Criteria (All criteria must be met for approval)	Approved (check if yes)	Comments
■ TMDLs result in maintaining and attaining water quality standards	X	The waterbody classification uses which are addressed by this TMDL are warmwater marginal fish life propagation, immersion recreation, and limited contact recreation.
■ Water Quality Standards Target	X	Water quality targets were established based on trophic status. This is a reasonable approach because the trophic status of the waterbody relates to the uses of concern.
■ TMDL	X	The TMDL is expressed in terms of annual phosphorus load reduction. This is a reasonable way to express the TMDL for this lake because it provides an effective surrogate that reflects both aquatic life and recreational needs, and reflects the long response time of lakes of this type to pollutant controls within the watershed.
■ Significant Sources Identified	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified.
■ Technical Analysis	X	Monitoring, empirical relationships, AGNPS modeling, and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ Margin of Safety and Seasonality	X	An appropriate margin of safety is included by performing ongoing monitoring to assure water quality goals are achieved and by application of additional nonpoint source BMPs for croplands within the watershed. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by tailoring the BMPs to seasonal needs.
■ Allocation	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to such sources as animal feeding areas and croplands.
■ Public Review	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ EPA approved Water Quality Standards	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Clear Lake, Deuel County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 12, 2000 Date Review completed: January 10, 2001 VEB

Review Criteria (All criteria must be met for approval)	Approved (check if yes)	Comments
■ **TMDLs result in maintaining and attaining water quality standards**	X	The waterbody classification uses which are addressed by this TMDL are warmwater marginal fish life propagation, immersion recreation, and limited contact recreation.
■ **Water Quality Standards Target**	X	Water quality targets were established based on trophic status and lake depth. This is a reasonable approach since it relates to the trophic status of the waterbody as well as the physical nature of the lake, which in turn, relate to the uses of concern.
■ **TMDL**	X	The TMDL is expressed in terms of annual phosphorus load reduction and removal of lake sediment. This is a reasonable way to express the TMDL for this lake because it provides an effective surrogate that reflects both aquatic life and recreational needs.
■ **Significant Sources Identified**	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified (including the removal of lake bottom sediments, if needed).
■ **Technical Analysis**	X	Monitoring, empirical relationships, AGNPS modeling, and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ **Margin of Safety and Seasonality**	X	An appropriate margin of safety is included by augmenting the watershed land use controls with in-lake dredging, and urban BMPs for lawn fertilization. The in-lake dredging will further reduce the amount of available nutrients into the lake because of increased depth and provide further aquatic life habitat. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by tailoring the BMPs to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to such sources as animal feeding areas and croplands.
■ **Public Review**	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ **EPA approved Water Quality Standards**	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Freeman Lake, Jackson County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: January 16, 2001 Date Review completed: January 30, 2001 VEB

Review Criteria (All criteria must be met for approval)	**Approved** (check if yes)	**Comments**
■ **TMDLs result in maintaining and attaining water quality standards**	X	The waterbody classification uses which are addressed by this TMDL are warmwater permanent fish life propagation, immersion recreation, limited contact recreation, and criteria for fish and wildlife propagation, recreation and stock watering.
■ **Water Quality Standards Target**	X	The 30-day average and daily maximum numeric standards for nitrate and selenium were used as quantified endpoints.
■ **TMDL**	X	The TMDLs are expressed in terms of annual nitrate load reduction, and annual selenium load reduction. These are reasonable ways to express the TMDLs for this lake because they provide effective surrogates that reflect both aquatic life and recreational needs, and reflect the long response time of lakes of this type to pollutant controls within the watershed.
■ **Significant Sources Identified**	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified.
■ **Technical Analysis**	X	Monitoring, empirical relationships, AGNPS modeling, and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ **Margin of Safety and Seasonality**	X	An appropriate margin of safety is included by performing ongoing monitoring to assure water quality goals are achieved and possibly by application of additional nonpoint source BMPs. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by tailoring the BMPs to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to saline seeps which are compounded by factors such as fallow croplands and poor surface drainage.
■ **Public Review**	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ **EPA approved Water Quality Standards**	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Punished Woman Lake, Codington County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 12, 2000 Date Review completed: January 10, 2001 VEB

Review Criteria (All criteria must be met for approval)	**Approved** (check if yes)	**Comments**
■ **TMDLs result in maintaining and attaining water quality standards**	X	The waterbody classification uses which are addressed by this TMDL are warmwater semi-permanent fish life propagation, immersion recreation, and limited contact recreation.
■ **Water Quality Standards Target**	X	Water quality targets were established based on lake depth and reduction of in-lake aquatic vegetation and sediment. These are reasonable targets because they relate to the impaired uses of concern.
■ **TMDL**	X	The TMDL is expressed in terms sediment load reduction and removal of lake sediment. Lake depth is a particularly important factor related to both the recreational use and fisheries use of the lake.
■ **Significant Sources Identified**	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified.
■ **Technical Analysis**	X	Monitoring, empirical relationships, AGNPS modeling, and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ **Margin of Safety and Seasonality**	X	An appropriate margin of safety is included by performing ongoing monitoring to assure water quality goals are achieved and possibly by application of additional nonpoint source BMPs. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by tailoring the BMPs to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to such sources as shoreline erosion and bank sloughing.
■ **Public Review**	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ **EPA approved Water Quality Standards**	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Upper Lake Sharpe, Jones & Stanley Counties
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 12, 2000 Date Review completed: January 10, 2001 VEB

Review Criteria (All criteria must be met for approval)	**Approved** (check if yes)	**Comments**
■ TMDLs result in maintaining and attaining water quality standards	X	The waterbody classification uses which are addressed by this TMDL are coldwater permanent fish life propagation, immersion recreation, and limited contact recreation.
■ Water Quality Standards Target	X	Water quality targets were established based on re-vegetation of Bad River channels (i.e., F & G types according to Rosgen's Stream Channel Classification) flowing into the lake. This is a reasonable approach because the majority of sediment delivered to the lake originates in the Bad River watershed. This target relates to the uses of concern in the lake.
■ TMDL	X	The TMDL is expressed in terms of annual sediment load reduction. This is a reasonable way to express the TMDL for this lake because the measure reflects both aquatic life and recreational needs and reflects the long response time of lakes of this type to pollutant controls within the watershed.
■ Significant Sources Identified	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified.
■ Technical Analysis	X	Monitoring, empirical relationships, modeling (e.g., PSIAC, USLE, EGEM), and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ Margin of Safety and Seasonality	X	An appropriate margin of safety is included by performing ongoing monitoring to assure water quality goals are achieved and by application of additional nonpoint source BMPs (e.g., improved grazing management) within the Bad River and Antelope Creek watersheds. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by tailoring the BMPs to seasonal needs.
■ Allocation	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to such sources as gully and channel erosion from poor landuse management practices (e.g., grazing).
■ Public Review	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ EPA approved Water Quality Standards	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.