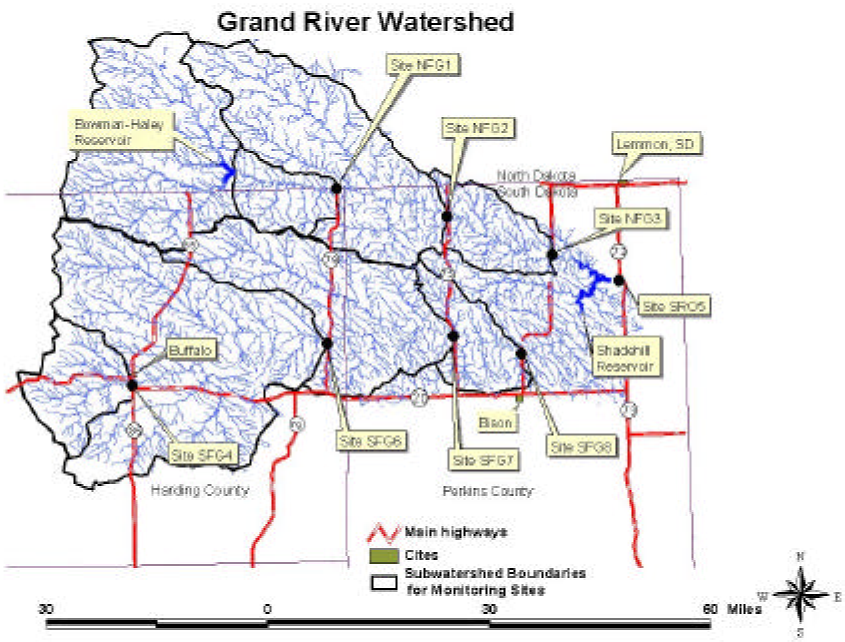
Executive Summary

PROECT TITLE Grand River Watershed and TMDL Assessment

PROJECT START DATE April 1, 1999 PROJECT COMPLETION DATE May 1, 2001

FUNDING: TOTAL BUDGET



The 1998 303(d) impaired waterbody list for the State of South Dakota included two segments of the Grand River that were included in this watershed and total maximum daily load (TMDL) assessment. The South Fork of the Grand River was listed in the in the 303(d) list as impaired for total suspended solids (TSS) and the 18 mile segment below Shadehill Reservoir to the Corson County line was impaired for temperature. These two segments of the Grand River were included in the watershed assessment.

Sampling and data collection began in early 1999 and continued through the spring of 2000. Physical, chemical, and biological data were collected to determine areas of greatest impairment and the causes of these impairments. During the summer of 1999 field work for the Pacific Southwest Interagency Committee (PSIAC) landuse assessment model sediment evaluation method was used to determine total sediment loads and the sediment contributions form each of the different agricultural land uses.

After data collection and analysis was complete the North Fork of the Grand River exhibited few exceedances of any of the daily maximum concentrations for the beneficial uses and associated water quality criteria designated for this waterbody. For the 18-mile segment of the Grand River below Shadehill Reservoir to the Corson County a total of 13 temperature samples were collected. There was one exceedance of the temperature standard, which corresponds to 7.7% rate of exceedance. The South Fork of the Grand River did not exhibit any temperature exceedances.

The South Fork did exhibit a significant number of exceedances from a variety of other parameters. The pH standard of 9.0 su for all of the four monitoring sites located on this segment of the Grand River was exceeded 17 times out 82 samples collected resulting in a 21% rate of exceedance. According to the water quality data set the variables that were causing at least 66% of the variability in the pH observations were flow, water temperature, and dissolved solids.

Average concentrations of nitrogen were extremely low. However, there were high levels of phosphorus periodically detected throughout the South Fork watershed. These high concentrations were directly linked to total suspended solids concentrations collected from the stream. Phosphorus data collected from the North Fork and below Shadehill exhibited extremely low concentrations.

Total suspended solids (TSS) concentrations were not significant in the North Fork of the Grand River or for the 18-mile segment below Shadehill Reservoir. The South Fork of the Grand River exhibited extremely high levels of suspended solids. The concentrations were significantly higher in the upper watershed which is located in the Sagebrush Steppe ecoregion (level IV-43e). As the South Fork left this ecoregion and entered the Missouri Plateau ecoregion (level IV-43a) the TSS concentration dropped significantly. A mean concentrations of 1,017 mg/L was observed in the upper watershed (Site SFG4) whereas 262 mg/L was observed from the last downstream site on the South Fork (Site SFG8).

Fecal coliform concentrations exceeded the daily maximum standard of 2,000 colonies per 100 ml from several locations on the North and South Forks of the Grand River. However, there were no constant observations and, in most instances, the concentration of 2,000 colonies per 100 ml was only slightly exceeded. Most of the higher observations of fecal bacteria were observed in the upper watershed where the higher concentrations of TSS were also observed. However, no relationship was detected between fecal coliform and TSS concentrations.

Sodium is another parameter in which high concentrations were observed throughout the watershed. The concentrations are reflective of the soil conditions that exist within the Grand River Basin. According to the State of South Dakota water quality standards, the sodium adsorption ratio or SAR associated with the irrigation beneficial use should not exceed 10 units. However, the SAR data collected for the year 2000 305(b) report to congress and for the 106 ambient monitoring program indicated that this standard is consistently exceeded due to the “sodium affected” soils in Grand River Watershed.

In addition to water chemistry, physical habitat and benthic macroinvertebrate data were collected. The physical habitat data was collected using the 1999 EPA Rapid Bioassessment Protocols (RBP). The RBP data indicated few differences between monitoring sites. The habitat parameter which showed the least difference between sites, was little to no channel alteration in the stream. Although the three sites from the North Fork scored slightly higher than the four sites on the South Fork there was little difference exhibited between each of the seven monitoring sites. The average score for the North Fork was 138 versus the 122 for the South Fork.

Benthic macroinvertebrates were collected from each site using rockbaskets. Metrics were calculated for each site and then compared to determine which metrics exhibited the greatest difference between sites. Five metrics were chosen and these were then incorporated into one index or IBI ranked on a scale of 0 to 100 for each site. The North Fork IBI scores ranked significantly higher than the South Fork. The IBI scores in the South Fork indicated greater impairment in the upper most watersheds. An IBI score of 51 was observed upstream whereas downstream the IBI score exceeded 65. When the IBI scores were regressed with average TSS concentration a significant relationship was exhibited (R^2=0.84). This relationship suggests that the change in the benthic macroinvertebrate population is a function of water chemistry as opposed to habitat differences.

Sediment and nutrient loadings were calculated using the FLUX program. Data from these calculation methods indicated that: 1) nutrient loadings were very low throughout the watershed, and 2) extremely high sediment export coefficients (lbs/acre) were observed from the upper watershed areas of the South Fork. This was also confirmed by the PSIAC modeling process conducted by the Natural Resources Conservation Service (NRCS). The Clark Forks Creek Subwatershed and the Pine Springs Subwatershed, which are located in the upper watershed of the South Fork of the Grand River, are delivering significantly higher sediment loads when compared to the rest of the Grand River watershed. These areas are dominated by extremely friable soils that are easily eroded.

To determine what level of reduction in sediment loadings could occur through the implementation of conservation measures, three different levels of resource management practice application were assessed.

The first level (low) considered was the continuation of present conditions with no additional special projects or funding for sediment and erosion control conservation practices. Two other levels of consideration (moderate and high) were based on an increase in the total number of acres with improved rangeland grazing management for erosion and sediment control. The moderate and high levels of participation were selected to represent a reasonable expectation of change if there were assistance for a special project. A comparison between the different levels of participation provides a guide to the expected decrease in sediment versus the number of acres that would need to be treated to achieve any goals set for sediment reduction.

The moderate level of participation is an estimate of sediment reduction that can be expected if 20 percent of the rangeland in the watershed is managed to improve these acres one-condition class. Typical range management practices would include grazing distribution, proper grazing use, and prescribed grazing systems. This would achieve an overall reduction of only five-percent in sediment loadings with the remaining load derived from natural or background sources.

To bring the South Fork of the Grand River into compliance with current water quality standards a 90% reduction in sediment loadings would be required. The PSIAC model estimated that a five percent reduction in loadings could be expected with a moderate level participation. The remaining 85% of the loadings can be attributed to natural or background causes originating from the Pine Springs and Clark Forks Jump Off areas located in the upper watershed of the South Fork of the Grand River.

Waterbody Type:	River
Pollutant:	Suspended Sediment, pH, and Temperature
Designated Uses:	Recreation, Fish Life Propagation, Irrigation, Stock Watering
Size of Waterbody and Hydrologic Unit Code:	North Fork – 65 total stream miles (SD). HUC = 10130301 South Fork – 134 total stream miles. HUC = 10130302
Size of Watershed:	1.9 million acres
Water Quality Standards:	Numeric (Suspended Solids Concentrations)
Indicators:	Sediment Load and Volume Weighted Mean TSS Concentration, Benthic Macroinvertebrates
Analytical Approach:	Effect of suspended solids concentrations on IBI

1.0 INTRODUCTION

This project was initiated by the Perkins County Conservation District (PCCD). In 1998, portions of the Grand River were placed on the 303(d) Impaired Waterbody list for suspended solids and pH. The Grand River is a natural stream that drains portions of Perkins and Harding counties in South Dakota (Figure 1). The north and south forks of the Grand River drain a watershed of approximately 768,930 ha (1.9 million acres) and are impounded at their confluence by Shadehill Reservoir. Shadehill is a recreational lake of approximately 1,899 ha (4,693 acres) that has been impacted by excessive sedimentation resulting in a loss of reservoir volume and a reduction of recreational value. The upper Grand River has a predominantly agricultural land use with grazing and wheat farming composing the major uses.

This project is intended to be the initial phase of a watershed-wide restoration project. Through water quality monitoring, stream gauging, stream channel analysis and land use analysis, the sources of impairment to the river, reservoir, and the watershed were documented. Feasible alternatives for restoration are presented in this final report.

Land use in the watershed is primarily agricultural. Approximately 25 percent of the land use is cropland and 75 percent grass or pasture. Wheat and alfalfa are the main crops. Only a few animal feeding operations are located in the watershed. Grazing is the largest land use in the watershed. Livestock and livestock products are the main source of income, but income from cash crops is also important.

Major soil associations found in the watershed include Vebar-Reeder-Cohagen, Cabba-Lantry-Amor, Banks-Trembles-Shambo, Shambo-Farmuf-Stady, Regent-Reeder-Amor, Savage-Regent, and Morton-Landry.

The average annual precipitation in the watershed is 16 inches of which 76 percent usually falls in April through September. Thunderstorms occur on about 29 days each year, and most occur in summer.

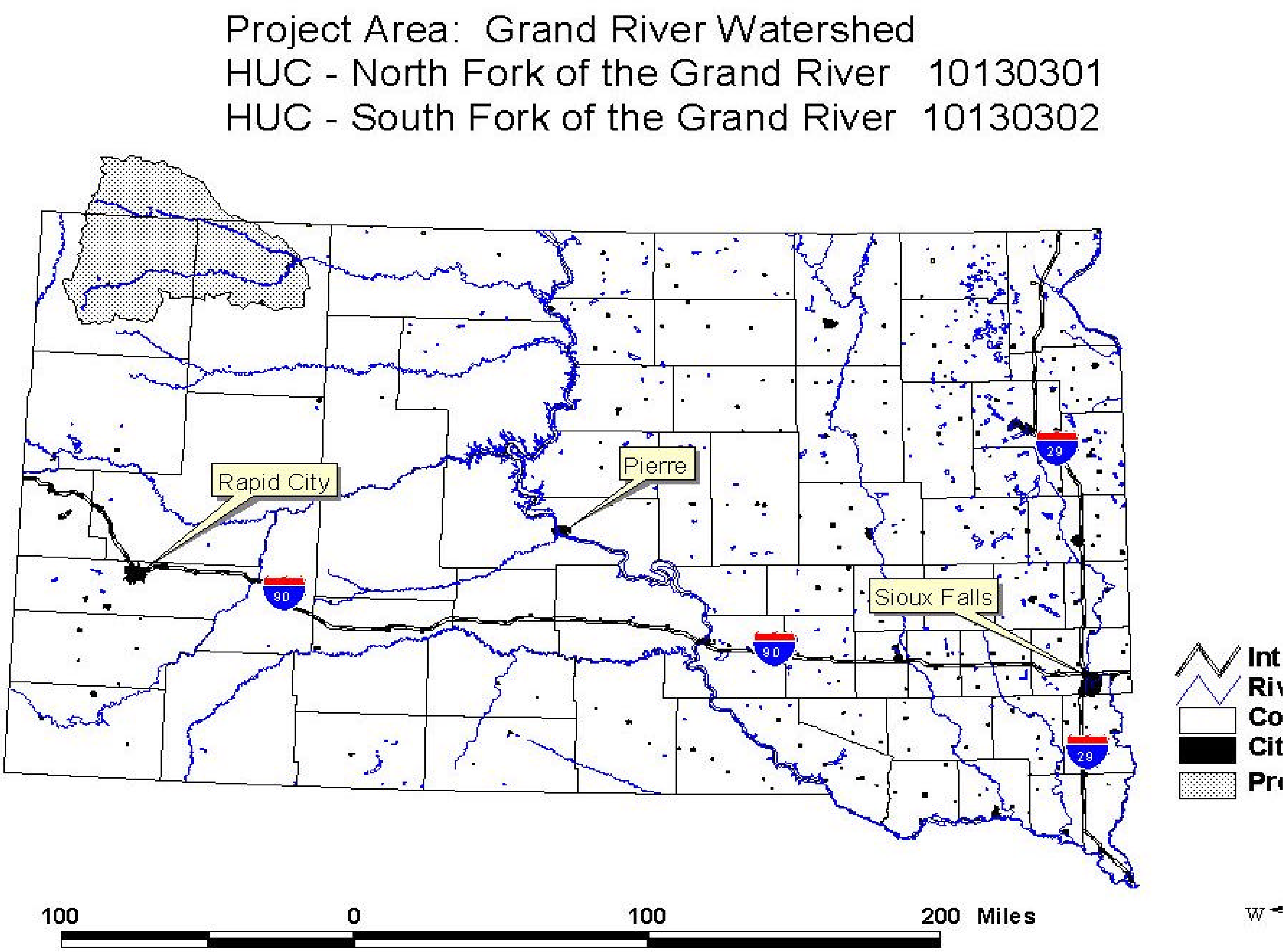


Figure 1. Project Area

Tornadoes and severe thunderstorms strike occasionally. These storms are local and of short duration and occasionally produce heavy rainfall events. The average annual snowfall is 30 inches.

The landscape in the watershed is characterized by an upland plain that is moderately dissected by streams and entrenched drainageways. Land elevation ranges from about 3,800 feet msl in the west and north parts of the watershed to about 2,600 msl in the eastern part.

The Grand River in South Dakota was listed in the South Dakota 1998 303(d) Waterbody List as nonsupporting resulting from exceedances of the total suspended solids water quality standard (SDDENR, 1998). In addition, the Grand River from the Shadehill Reservoir to 18 miles downstream was nonsupporting of its coldwater marginal fishery designation due to elevated stream temperature (>75^{o}F) (moderate impairment) and high pH (>8.8 su). Shadehill Reservoir itself was listed for accumulated sediment, nutrients, and sodium as part of an existing Section 319 Implementation project.

In the most current 305(b) report to the U.S. Congress, the North Fork of the Grand River was reported as being fully supporting for the present (2000) and previous (1998) assessment, whereas only minor improvement in TSS levels is evident so far in South Fork samples. The South Fork drainage contains erosive soils which contribute sediment and suspended solids that often produce high TSS levels in the South Fork Grand River. These problems are aggravated by agricultural and grazing practices. Past observations indicated agricultural practices such as streamside grazing and cropping are continuing in the South Fork drainage. The years 1993 to 1995 were generally periods of above average waterflows in the Grand River basin. Similar to past 305(b) reporting periods, the South Fork drainage did not support its beneficial uses last assessment due to excessive TSS. Moderate impairments noted in previous assessments were from high conductivity, elevated dissolved solids, low dissolved oxygen, and elevated pH. This assessment the South Fork was non-supporting again due to elevated TSS. There were no other impairments observed ($SDDENR_{(a)}$, 2000).

Figure 1 illustrates the size and location of the Grand River watershed in northwestern South Dakota.

The Grand River watershed above Shadehill Reservoir splits into two main drainages: 1) North Fork and 2) South Fork. Each subwatershed or fork has unique soil types and environmental conditions, which makes it different than its counterpart. The North Fork drains from the northwestern part of the watershed located in North Dakota and is approximately 320,569 ha (792,114 acres) in size. This subwatershed is completely contained within the Missouri Plateau (43a) Level IV ecoregion (43-Northwestern Great Plains). The South Fork is approximately 389,504 ha (962,451 acres) in size. The South Fork drains through two Level IV ecoregions. This first is the Sagebrush Steppe (43e) and the second is the Missouri Plateau (43a). Both of these Level IV ecoregions are located within in the Level III ecoregion: Northwestern Great Plains (43) (Bryce, et al., 1997).

In the 1998 South Dakota Unified Watershed Assessment, the North and South Forks of the Grand River were categorized with 37 other 8-digit Hydrologic Units (HU) in the State of South Dakota as watersheds in need of restoration. Although both waterbodies ranked relatively low in comparison to the other HUs, rankings were weighted based on the density of Total Maximum Daily Loads (TMDL) acres within HUs. There were other factors involved in the ranking, i.e. landuse, treatment needs, point source density; but the Grand River ranked relatively low for all of these factors. The final ranking for the North Fork and South Fork was 27 and 31, respectively, out of a total 39 HU watersheds assessed in this manner (SDDENR, 1998).

The 1999 South Dakota Nonpoint Source Management Plan schedule is based on the 1998 Section 305(b) report and the related 1998 Section 303(d) list of impaired waters needing TMDLs. As previously mentioned, the South Fork of the Grand is listed in the 303(d) 1998 Waterbody list.

2.0 PROJECT GOALS, OBJECTIVES AND ACTIVITIES

The goal of this assessment project is to determine and identify sources of impairments of the North and South forks of the Grand River watershed.

Objective 1

Estimate the sediment and nutrient loadings along segments of the North and South Forks of the Grand River and the individual tributaries in the watershed through hydrologic and chemical monitoring. The information will be used to locate critical areas in the watershed for implementation. Figure 2 identifies the locations of the monitoring stations that were installed in the spring of 1999.

In order to complete Objective 1 the following tasks were implemented:

Task 1: Water level recorders were installed on eight river monitoring sites listed in the table below and continuous stage records were maintained for the project period with the exception of winter months after freeze-up (Figure 2).

Site	Location		Site	Location	
NFG1	Latitude	45.943444	SFG4	Latitude	45.576169
	Longitude	102.920065		Longitude	103.545730
NFG2	Latitude	45.882591	SFG6	Latitude	45.641692
	Longitude	102.652640		Longitude	102.997649
NFG3	Latitude	45.802376	SFG7	Latitude	45.648409
	Longitude	102.361929		Longitude	102.643218
SRO5	Latitude	45.760402	SFG8	Latitude	45.614062
	Longitude	102.176402		Longitude	102.457160

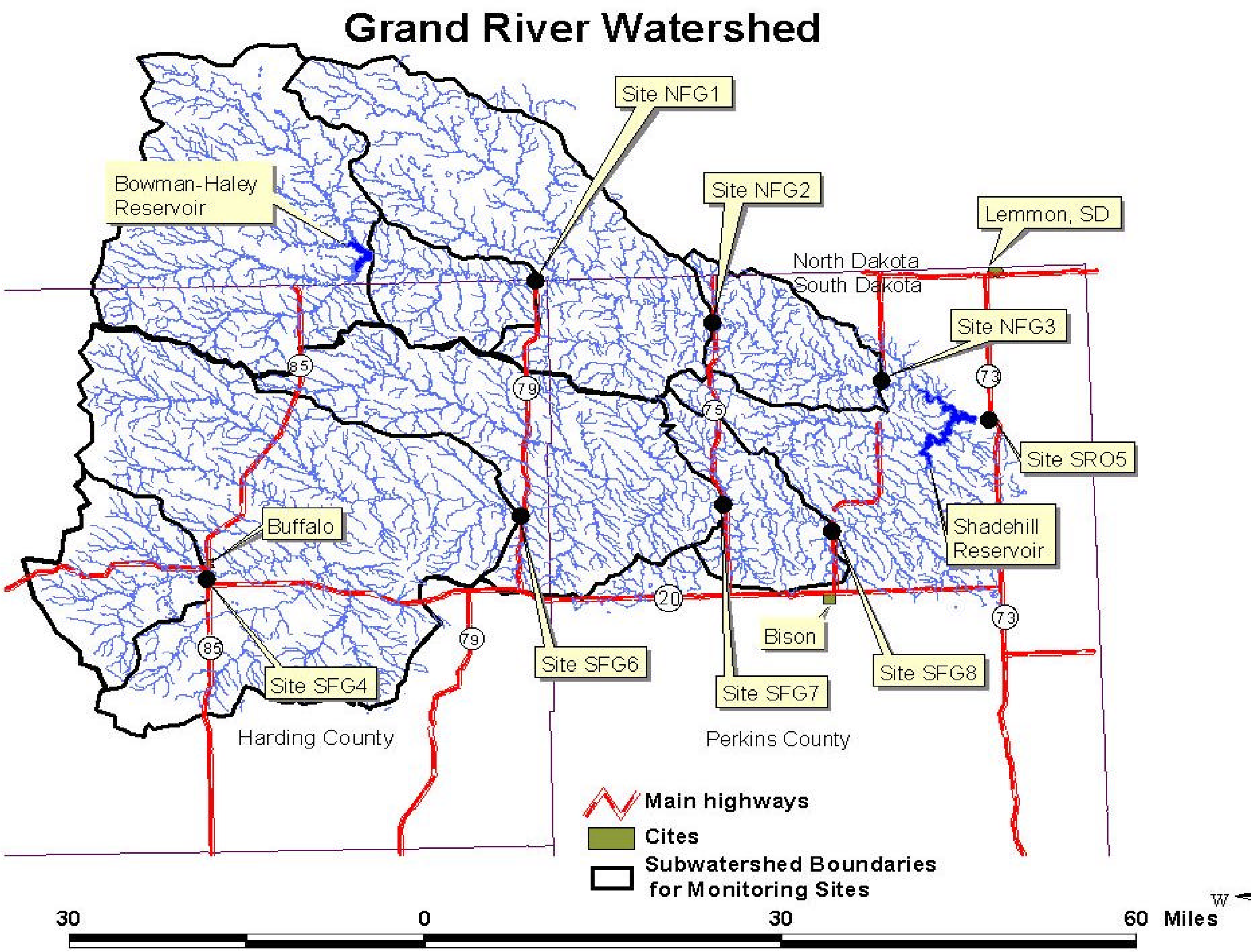


Figure 2. Location of Monitoring Sites within the Grand River Basin.

Task 2: Discrete discharge measurements were taken on a regular schedule and during storm surges. Discharge measurements were taken with a hand held current velocity meter.

Task 3: Discharge measurements and water level data were used to calculate a hydrologic budget for the river system. This information was used with concentrations of sediment and nutrients to calculate loadings from the watershed.

Task 4: Water samples were collected from eight tributary monitoring sites (Figure 2). Samples were collected during spring runoff (2000), storm events (1999), and monthly base flows (1999).

Task 5: Benthic macroinvertebrates were collected from seven of the monitoring sites in the watershed for baseline data.

Objective 2

Ensure that all water quality sample analyses are accurate and defendable through the use of approved Quality Assurance/Quality Control (QA/QC) procedures. To complete this objective the following tasks were implemented:

Task 1: The collection of all water quality data were accomplished in accordance with the *Standard Operating Procedures for Field Samplers, South Dakota Water Resources Assistance Program*.

Task 2: A minimum of 10 percent of all the water quality samples collected during the project were QA/QC samples. QA/QC samples consisted of field blanks and field duplicate samples.

Task 3: All QA/QC activities were conducted in accordance with the Nonpoint Source Program Quality Assurance Project Plan.

Task 4: The activities involved with QA/QC procedures and the results of QA/QC monitoring were compiled and are reported in a separate section of this final report.

Objective 3

Evaluation of agricultural impacts on the water quality of the watershed through the use of the Pacific Southwest Inter-Agency Committee (PSIAC) model. The following tasks were completed to accomplish this objective.

Task 1: The watershed of the North and South Forks of the Grand River will be modeled using the PSIAC model. PSIAC is a comprehensive land use model which estimates soil loss and delivery and evaluates the impact of livestock grazing areas. The watershed was divided into small subwatersheds. Each sub-watershed was analyzed by a multi-disciplinary team consisting of range specialists, soil scientists, district conservationists and others. Random areas of cropland were selected and analyzed by the Revised Universal Soil Loss Equation (R.U.S.L.E.) with additional information collected for animal feeding operations.

Task 2: The above model was used to identify critical sub-watersheds for nonpoint source pollution to the surface waters in the watershed.

Objective 4

Public participation and involvement will be provided for and encouraged. The following tasks were completed to attain this objective.

Task 1: Informational meetings were held for the general public and involved parties were informed on the progress of the study. These meetings provided an avenue for input to the residents of the area.

Task 2: News releases were prepared and related to local news media on a quarterly basis.

Objective 5

Development of watershed restoration alternatives.

Task 1: Once the field data were collected, an extensive review of the historical and project data was conducted.

Task 2: Loading calculations using the FLUX program were completed using the project data. A hydrologic, sediment, and nutrient budget for the watershed was developed.

Task 3: The results of the PSIAC and RUSLE modeling of the watershed were used in conjunction with the water quality and hydrologic budget to determine critical areas in the watershed.

Task 4: The feasible management practices were compiled into a list of alternatives for the development of an implementation project and included in the final project report.

Objective 6

Produce and publish a final report containing water quality results and restoration alternatives. The following assigned tasks have been completed and the results are contained within this final report.

Task 1: Produce loading calculations based on water quality sampling and hydrologic measurements.

Task 2: Summarize the results of the PSIAC and RUSLE models for the watershed and report locations of critical areas.

Task 3: Write a summary of historical water quality and land use information and compare with project data to determine any possible trends.

Task 4: Based on data, evaluate the hydrology of the North and South Forks of the Grand River and the chemical, biological, and physical condition of the river.

Task 5: Produce a summary report of all QA/QC activities conducted during the project and include in the final project report.

Task 6: Write a description of feasible restoration alternatives for use in planning watershed nonpoint source implementation.

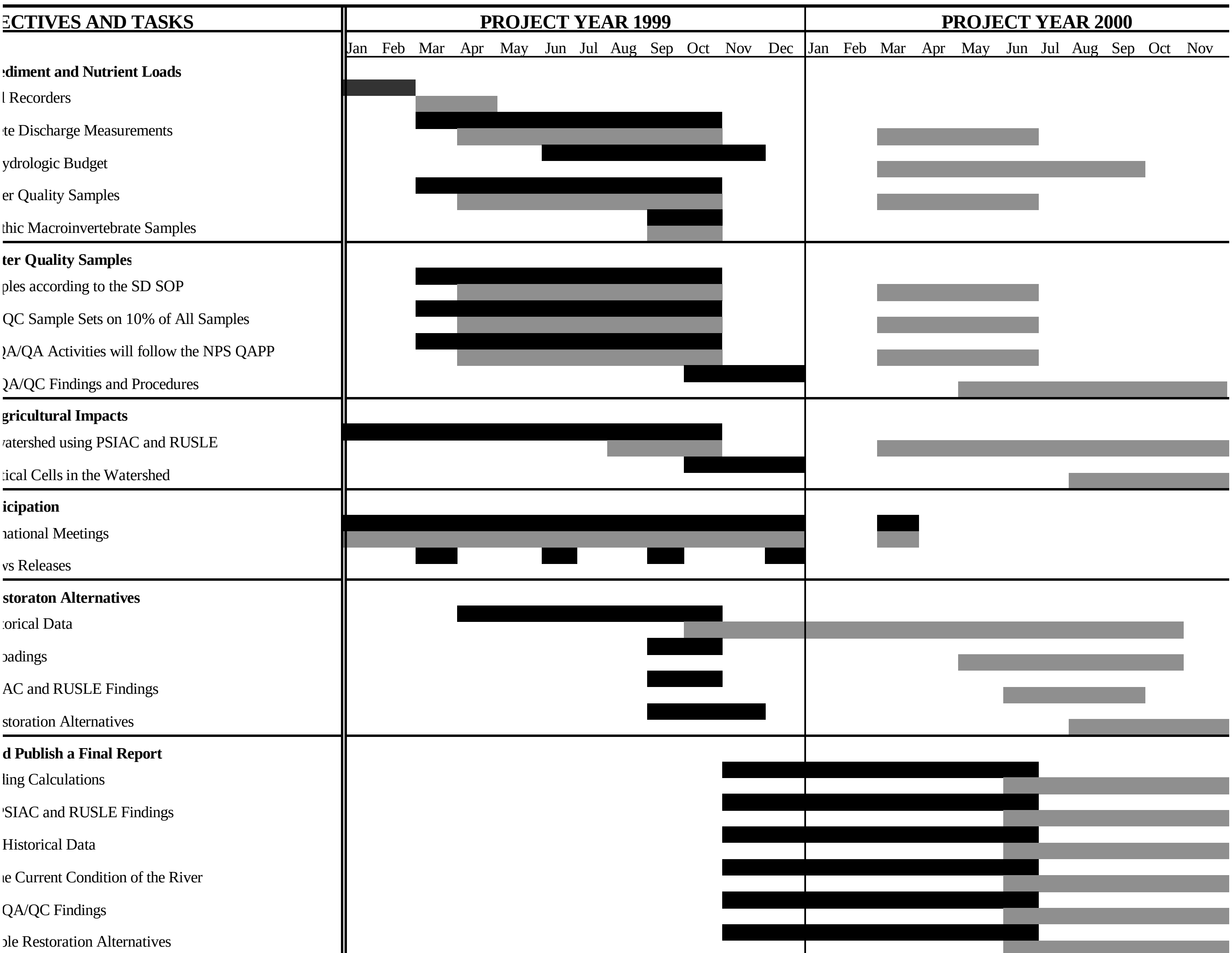
2.1 PLANNED AND ACTUAL MILESTONES, PRODUCTS, AND COMPLETION DATES

The milestones for the tasks associated with each of the six objectives listed above are located in Table 1 on the following page. Most of the tasks did not begin on the estimated time, primarily because the Section 319 Grant dollars were not available until May of 1999. Equipment was then ordered which did not arrive until the end of May 1999. Monitoring was conducted from late April through October of 1999. Because the 1999 spring snowmelt runoff was missed, monitoring was conducted during the spring of 2000. After the entire monitoring process was completed the current and historical data were compiled. The tasks associated with Objective 5 (watershed restoration alternatives) and Objective 6 (final report) were not completed until the second half of 2000 as a direct result of these events.

2.2 EVALUATION OF GOAL ACHIEVEMENT AND RELATIONSHIP TO THE STATE NPS MANAGEMENT PLAN

This watershed and TMDL assessment was designed to identify segments of the Grand River which are impaired and to document the causes of impairment. Critical areas within each subwatershed were identified to determine where BMPs could be applied to provide the greatest impact in improving the water quality within those impaired segments. One of the nine key elements of the State of South Dakota NPS program is to identify waters and their watersheds that are impaired by nonpoint source pollution. This project is just one of a myriad of similar projects specifically designed to document the sources of water quality impairment through a detailed watershed assessment. Implementation plans will be developed to abate nonpoint source pollution from sources identified and documented in this report.

Table 1. Planned Milestone Schedule and Actual Milestone Schedule for all Tasks for the Grand Rive Assessment.*



*** Planned Milestones Schedule =**

Actual Milestone Schedule =

Segments of the Grand River have been classified as impaired and have been placed on the 303(d) Impaired Waterbody list and were also identified in the 1998 and 2000 305(b) Report to Congress. The assessment project is the first phase in the necessary abatement procedures that will be required to reduce the sediment, pH, and temperature-related impairments that have been identified in this report. Those three parameters are closely interwoven in the documentation of water quality impairments. The Grand River Assessment is an example of the necessary Section 319 programmatic steps that are required to bring about the improvement of those segments of the Grand River identified in these publications.

The Grand River Watershed Assessment used a watershed-wide approach to determine the causes of the water quality impairments that resulted in the river being listed on the 303(d) Impaired Waterbody list.

2.3 SUPPLEMENTAL INFORMATION

The PSIAC model has suggested that the necessary BMPs that need to be instituted in the Grand River watershed are related to local grazing practices. Establishment of BMPs in areas that have high sediment export coefficients has been identified as having the greatest effect on reducing the overall loadings from those subwatersheds. There are numerous combinations of conservation practices that can be used to reduce sediment. The measures that are used for erosion and sediment control in South Dakota may be classified by purpose into several groups: 1.) To intercept and/or conserve moisture; 2.) To increase infiltration capacity; 3.) To reduce or eliminate stress on existing cover; 4.) To preserve existing cover regarded as adequate or in the process of becoming adequate with time; 5.) To increase the protection of the soil by a change in the type as well as density of vegetation.

Additional conservation practices used in conjunction with rangeland management would greatly enhance the overall reduction of sediment from the study area. An example would be the use of fencing riparian areas for dormant season grazing in conjunction with proper grazing use. It was beyond the scope of this assessment to evaluate individual, site-specific conservation practices.

3.0 MONITORING RESULTS

In order to collect the necessary data to complete the objectives identified in Section 2.0 the methods identified in the *Standard Operating Procedures for Field Samplers*, developed by the South Dakota Water Resources Assistance Program (SDWRAP SOP) were used. Table 2 shows the physical, chemical, and biological parameters that were collected during the course of the project.

Table 2. PARAMETERS MEASURED FOR TRIBUTARY SAMPLES

PHYSICAL	CHEMICAL	BIOLOGICAL
Air temperature	Total solids	Fecal coliform bacteria
Water temperature	Field pH	Benthic macroinvertebrates
Discharge	Dissolved oxygen	

Depth	Ammonia
Visual observations	Un-ionized ammonia
Water level	Nitrate-nitrite
	TKN
	Total phosphorus
	Total dissolved phosphorus
	Sodium
	Total suspended solids
	Total volatile susp. solids

The appropriate methodologies for collection and analysis of those parameters can be found in the SD WRAP SOP ($SDDENR_{(b)}$, 2000).

Tributary Water Quality Methods

The primary collection devices for water samples for this project were the ISCO automatic sampler Model GLS with an attached Model 4230 flow meter and bubbler used as gauging equipment. This equipment was installed near or on highway bridges during the latter part of May 1999. The samplers were programmed to collect a composite sample during the course of a rainfall event. Base flow monitoring also took place after the snowmelt runoff had ceased and between rainfall events. All collected samples were removed from the sampler, bottled, iced, and shipped to the U.S. Bureau of Reclamation (BOR) laboratory in Bismarck, ND, for analysis. The South Dakota Water Resources Assistance Program typically uses the SD Health Laboratory, but for this project, BOR contributed funding to the project in the way of analysis costs. The BOR laboratory followed the WRAP SOP for standard analysis methods for water samples.

Because the spring flush of 1999 was missed monitoring continued into the spring of 2000. Samples collected during Spring 2000 were iced and shipped to the SD Health Laboratory in Pierre. The automatic samplers were removed in November of 1999 and were not reinstalled the following spring. All tributary samples collected during the Spring 2000 runoff were collected with a model DH-47 suspended sediment sampler. The proper technique for using this device is described in the SOP. In addition to the eight main channel monitoring stations, nine smaller sub-tributary sites off the mainstem (upstream of Shadehill Reservoir) were included in the sample collection. With the larger number of monitoring locations it was felt that monitoring these areas would give a better resolution for determining critical areas within the seven subwatersheds (Figure 2).

During the spring of 2000, all tributary location were sampled once a week during the first week of snowmelt runoff and once a week thereafter until the spring runoff ceased. If the spring runoff had stopped at some or all of the smaller tributaries, no sample was collected there until another rainfall event had occurred. Due to the considerable distance between sampling locations it was only possible to collect samples once a week, at most, from these extremely remote locations.

Hydrologic Data Collection Methods

Seven tributary monitoring sites were installed with automatic samplers with gauging equipment to record the stage data. Instantaneous discharge measurements were collected for each station during the time each sample was collected. An Aquacalc 5000 (meter sensing instrument) manufactured by Rickly, Inc., connected to a Pygmy type or Price type (AA) meter was used to collect the discharge measurements. The stage and flow data from each monitoring site were used to develop a stage/discharge table that was used to calculate average daily loadings for each site. The discharge data from Shadehill Reservoir (Site SRO5) is recorded daily by BOR and this information was used to calculate loadings for this site. The methods used to calculate the hydrologic loadings can be found in the WRAP SOP manual. The individual discharge equations and data for each monitoring site can be found in Appendix #.

Modeling Methods

Loading Calculations

To develop nutrient and sediment loadings for the Grand River the FLUX program was used. The US Army Corps of Engineers developed the FLUX program for eutrophication (nutrient enrichment) assessment and prediction for reservoirs (Walker, 1996). The FLUX program uses six different calculation techniques for calculating nutrient and sediment loadings. The sample and flow data for this program can be stratified (adjusted) until the coefficient of variation (standard error of the mean loading divided by the mean loading = CV) for all six methods converge or are all similar. The uncertainty in the estimated loading is reflected by the CV value. The lower the CV value the greater certainty (less error) there is in the loading estimate. To decrease the CV value the data is usually stratified by flow or by season. This can give greater accuracy to the estimate. The nutrient and sediment loadings were calculated for all eight monitoring sites using these methods. A description of the model can be found in Appendix #.

After the loadings for all of the sites were completed, export coefficients were developed for each of the parameters. Export coefficients are calculated by taking the total nutrient or sediment loading (kilograms) and dividing by the total area of the subwatershed. This calculation derives kilogram of sediment delivered per acre of that subwatershed (kg/acre).

Landuse Modeling

The Pacific Southwest Interagency Committee (PSIAC) sediment evaluation method was developed as the result of an interagency cooperative effort to assess the average annual sediment yield from watersheds larger than ten square miles (6,400 acres). Those evaluations quantify and characterize the watershed sediment yield at a downstream delivery point based on nine physical features within the watershed. It is a method intended for use as an aid to develop and support broad-based resource planning strategies. No other method is currently available to use as a rapid assessment tool for evaluating sediment yield at the watershed level. Sediment surveys and monitoring studies require more intensive, long-term, and costly investigation procedures.

The Natural Resources Conservation Service (NRCS) Midwest National Technical Center sedimentation geologist approved the use of the PSIAC method of sediment yield evaluation in South Dakota (1993). The PSIAC evaluation correlates well with measured results from historic sediment surveys and United States Geological Survey (USGS) gage station data previously collected by various agencies in South Dakota. The NRCS has used PSIAC to evaluate sediment yield from agricultural sources for the purpose of broad-based resource planning in river basin studies, watershed plans, and resource assessment reports.

A full description of the PSIAC model can be found in Appendix #.

3.1 SURFACE WATER CHEMISTRY

3.1.1. Beneficial Uses

The Grand River within the State of South Dakota is divided into three sections based upon assigned beneficial uses. The beneficial uses that are assigned to various areas and waterbodies within the Grand River Watershed are shown in Table 3.

Table 3. **Excerpt from the State ARD Chp. 74:51:03:19 containing beneficial uses for the Grand River and its tributaries.**

Water Body	From	To	Beneficial Uses*	County
Grand River	West Corson County Line	Shadehill Reservoir	3,8,9,10	Perkins
South Fork Grand River	Shadehill Reservoir	S13, T18N, R3E of the Black Hills meridian	5,8,9,10	Harding
North Fork Grand River	Shadehill Reservoir	North Dakota border	6,8,9,10	Perkins
Big Nasty Creek	South Fork Grand River	S6, T21N, R8E	6,8,9,10	Harding
Bull Creek	South Fork Grand River	S15, T21N, R5E	6,8,9,10	Harding
Crooked Creek	North Dakota border	S34, T23N, R5E	6,8,9,10	Harding
Flat Creek	Grand River	North Dakota border	6,8,9,10	Perkins
Jones Creek	South Fork Grand River	S18, T20N, R5E	6,8,9,10	Harding
Lodgepole Creek	Shadehill Reservoir	S28, T21N, R13E	6,8,9,10	Perkins
Clarks Fork Creek	South Fork Grand River	S17, T17N, R5E	6,8,9,10	Harding
Buffalo Creek	Clarks Fork Creek	S35, T18N, R4E	6,8,9,10	Harding
Skull Creek	South Fork Grand River	S32, T21N, R8E	6,8,9,10	Harding
Shadehill Reservoir			4,9,10	Perkins

*The beneficial use classifications are as follows:
(1) Domestic water supply waters;
(2) Coldwater permanent fish life propagation waters;
(3) Coldwater marginal fish life propagation waters;
(4) Warmwater permanent fish life propagation waters;
(5) Warmwater semipermanent fish life propagation waters;
(6) Warmwater marginal fish life propagation waters;
(7) Immersion recreation waters;
(8) Limited-contact recreation waters;
(9) Fish and wildlife propagation, recreation, and stock watering waters;

(10) Irrigation waters; and
(11) Commerce and industry waters.

The water quality standards associated with each of these beneficial uses and for the daily maximums are shown in Table 4. Water quality criteria and standards have been defined in South Dakota state statute in support of these uses (South Dakota Administrative Rules, Article 74:51;Table 2). These standards provide physical and chemical benchmarks against which management decisions can be developed.

In addition to physical and chemical standards, South Dakota has developed narrative criteria for the protection of aquatic life uses. *All waters of the state must be free from substances, whether attributable to human-induced point sources discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities*.

Table 4. Water quality standards by segment for the Grand River, Harding and Perkins Counties, South Dakota.

Water Body	Beneficial Uses	Parameter	Standard Value
Grand River (to 18 miles below Shadehill Reservoir only).	3,8,9,10	Un-ionized ammonia nitrogen as N	< 0.035 mg/L
		Dissolved oxygen	> 5.0 mg/L
		Undisassociated hydrogen sulfide*	< 0.002 mg/L
		pH	> 6.5 - < 8.8 su
Remaining portions of Grand River below Shadehill Reservoir	4,8,9,10	Total Suspended Solids	< 158 mg/L
		Temperature	< 75°F
		Fecal coliform	< 2,000 colonies/100mL
		Total alkalinity as calcium carbonate	< 1313 mg/L
		Total dissolved solids	< 4,375 mg/L
		Conductivity at 25° C	< 4,375µmhos/cm
		Nitrates as N	< 88 mg/L
		Total petroleum hydrocarbon*	< 10 mg/L
		Oil and grease*	< 10 mg/L
		Sodium adsorption ratio*	< 10 mg/L
South Fork Grand River	5,8,9,10	Un-ionized ammonia nitrogen as N	< 0.07 mg/L
		Dissolved oxygen	> 5.0 mg/L
		Undisassociated hydrogen sulfide*	< 0.002 mg/L
		pH	> 6.5 - < 9.0
		Total Suspended Solids	< 263 mg/L
		Temperature	< 90°F
		Fecal coliform	< 2,000 colonies/100mL
		Total alkalinity as calcium carbonate	< 1313 mg/L
		Total dissolved solids	< 4,375 mg/L
		Conductivity at 25° C	< 4,375µmhos/cm
		Nitrates as N	< 88 mg/L
		Total petroleum hydrocarbon*	< 10 mg/L
		Oil and grease*	< 10 mg/L
		Sodium adsorption ratio*	< 10 mg/L

North Fork Grand River Big Nasty Creek Bull Creek Crooked Creek Flat Creek Jones Creek Lodgepole Creek Clarks Fork Creek Buffalo Creek Skull Creek	6,8,9,10	Un-ionized ammonia nitrogen as N Dissolved oxygen Undisassociated hydrogen sulfide* pH Total Suspended Solids Temperature Fecal coliform Total alkalinity as calcium carbonate Total dissolved solids Conductivity at 25° C Nitrates as N Total petroleum hydrocarbon* Oil and grease* Sodium adsorption ratio*	< 0.0875 mg/L > 4.0 mg/L < 0.002 mg/L > 6.5 - < 9.0 < 158 mg/L < 90°F < 2,000 colonies/100mL < 1313 mg/L < 4,375 mg/L < 4,375µmhos/cm < 88 mg/L < 10 mg/L < 10 mg/L < 10 mg/L
Shadehill Reservoir	4,9,10	Un-ionized ammonia nitrogen as N Dissolved oxygen Undisassociated hydrogen sulfide* pH Total Suspended Solids Temperature Total alkalinity as calcium carbonate Total dissolved solids Conductivity at 25° C Nitrates as N Total petroleum hydrocarbon* Oil and grease* Sodium adsorption ratio*	< 0.07 mg/L > 5.0 mg/L < 0.002 mg/L > 6.5 - < 9.0 < 158 mg/L < 80°F < 1313 mg/L < 4,375 mg/L < 4,375µmhos/cm < 88 mg/L < 10 mg/L < 10 mg/L < 10 mg/L

*Parameters not measured during this project.

3.1.2. Water Temperature

Surface water temperatures in the Grand River (above Shadehill) should be maintained below 32.2°C (90°F) to support *warmwater marginal fish propagation*. Statistical comparisons were completed between the seven monitoring sites and the North and South Fork of the Grand River. Significant differences were not identified between any of the sites (df=7, n=121, p>0.05) (Figure 3). There are two separate water temperature standards associated with the different sections of the Grand River. The North Fork and South Fork above Shadehill have a temperature standard of 32.2°C (90°F) whereas below Shadehill Reservoir to the Corson County line the temperature standard is 23.9°C (75°F) (Table 3).

Above Shadehill there were no exceedances of the 32.2°C surface water temperature standard (Figure 3). However, there was one observation that exceeded the 23.9°C standard in the reach below Shadehill Reservoir to the Corson County line (Site SRO5) that has been designated for *coldwater marginal fish life propagation* (Table 4) (Figure 3). This value of 25°C was observed in mid-August when temperatures are the most extreme for this area.

A total of 13 samples were collected from Site SRO5 which corresponds to a 7.7% rate of exceedance (one sample exceeding the standard out of 13 total samples). In the last 305(b) reporting period the temperature standard for this segment of the Grand River was exceeded four times out of 18 total samples (22% exceedance rate). This reach was classified as partially supporting or moderately impaired for that reporting period ($SDDENR_{(a)}$, 2000). The naturally open prairie conditions resulting in a lack of canopy coverage outside of the riparian grasses, do

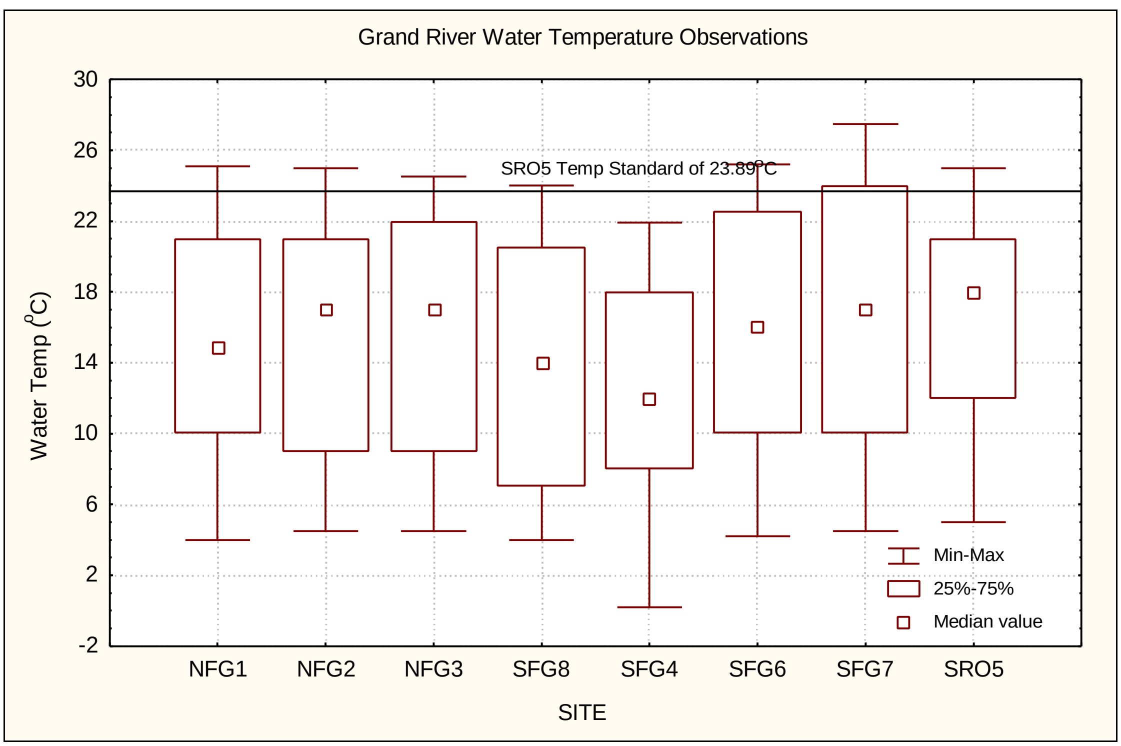


Figure 3. Grand River Water Temperature Observations.

not reduce the amount of surface area of the stream that is exposed to the sunlight. The natural conditions for this area should be incorporated into the standards for this site if this segment continues to be designated as *coldwater marginal fish life propagation waters.* It should allow for certain variations above the standard to occur during the summer months. Prior to the construction of Shadehill Reservoir in 1951, *salmonid spp*. were not found within the Grand River. After construction occurred, because of the design of the withdrawal/discharge system from Shadehill Reservoir, the temperature was low enough in the relatively short (18 miles) river segment below reservoir tailwaters to allow a marginal population of stocked trout to exist. However, periodic exceedances of the temperature standard (23.9°C) still occur especially during extremely hot summers with reduced rates of precipitation and withdrawal from the reservoir.

In the North and South Forks the temperature ranged from a minimum of 0.2°C in the month of November to a maximum of 27.5°C recorded from the South Fork during the month of August. The mean, maximum, and minimum values for each monitoring site are shown in Table 8, on pg.31.

3.1.3. pH

To support the beneficial use *coldwater marginal fish propagation* the pH standard below Shadehill Reservoir has been set at 8.80 su (Table 4). During the course of the study there were three observations out of 13 total measurements (23%) which exceeded the pH standard for this 18-mile segment of the main river. The South Fork exhibited 17 exceedances out of 82 observations (21%) of the 9.0 su standard for *warmwater permanent fish propagation* beneficial use. No pH observations exceeded this same standard (9.0 su) for the North Fork of the Grand River. Table 5 shows each exceedance and the percentage of exceedance per site. The locations of these sites can be found in Figure 2, pg 6.

There was no seasonality associated with the pH exceedances for the South Fork of the Grand River. There were seven exceedances observed during the spring period (3/1-5/31), nine exceedances during the summer (6/1-8/31), and one exceedance during the fall period (9/1-11/15). All of the pH values listed in Table 5 for the South Fork were evenly distributed throughout all four monitoring sites. Figure 4 shows all of the pH values for the South Fork plotted against time. Figure 5 shows a boxplot (minimum, maximum, and mean) of the pH values for all eight monitoring sites.

Table 5. pH exceedances from four monitoring sites located on the Grand River.

Date	SFG4	Date	SFG6	Date	SFG7	Date	SFG8	Date	SRO5
06/16/99	9.18	07/09/99	9.21	07/06/99	9.20	08/10/99	9.02	06/30/99	8.84
07/09/99	9.09	08/04/99	9.03	08/03/99	9.04	11/01/99	9.24	03/29/00	8.87
04/10/00	9.00	08/09/99	9.00	04/11/00	9.05	04/12/00	9.08	06/07/00	8.89
04/24/00	9.65	04/11/00	9.12			03/29/00	9.86		
05/08/00	9.10					06/07/00	9.05		
Total #	**5**		**4**		**3**		**5**		**3**
Exceedance Rate	**24%**		**20%**		**15%**		**22%**		**23%**

Table 6. Regression statistics for Site SRO5 which includes data collected only for the 305(b) report (1994-99). Dependent variable = pH, Independent Variables = Sodium, Calcium, and Conductivity.

Multiple R	0.9366	Adjusted R Square	0.8158			
R Square	**0.8772**	Standard Error	0.1152	Observations = 10		
ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*	
Regression	3	0.5683	0.1894	14.2848	0.0039	
Residual	6	0.0796	0.0133			
Total	9	0.6479				
Variable	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	6.9096	0.4320	15.9945	0.0000	5.8526	7.9667
SODIUM	0.0119	0.0023	5.2928	0.0018	0.0064	0.0175
CALCIUM	0.0430	0.0103	4.1854	0.0058	0.0179	0.0681
CONDUCTIVITY	-0.0021	0.0007	-3.2157	0.0182	-0.0038	-0.0005

Shadehill Reservoir to Corson County Line

The data collected during this Section 319 project and for the year 2000 305(b) report have indicated that the 18-mile segment of the Grand River below Shadehill is nonsupporting for the pH standard. A stepwise regression analysis was conducted between pH and other water chemistry variables collected each time a water quality sample was taken. The analysis indicated that 88% of the variability in pH values could be attributed to sodium, calcium, and conductivity (Table 6). Of these three water quality parameters, sodium had the most impact constituting over 50% of the variability in the pH values.

Although sodium may have had a significant impact on the pH values for this segment of Grand River below Shadehill Reservoir, the mean concentration of sodium below Shadehill Reservoir was the lowest observed for all of the eight monitoring sites. A complete discussion of sodium concentrations is presented later in this report on page 40.

South Fork of the Grand River (above Shadehill Reservoir)

Although the South Fork of the Grand River has been listed in the year 2000 305(b) report as fully supporting for pH, the data collected during this project seem to indicate that this segment does exhibit periodic exceedances of the pH standard.

The soils within the watershed of the South Fork are highly erosive in nature and have higher pH levels in comparison to the North Fork. Multiple regression analysis was used to determine which physical or chemical factors explained most of the variability in the pH measurements for the South Fork of the Grand River. Results from this analysis indicated that 66% of the variability in the pH values can be attributed to changes in flow and the concentration of dissolved solids (Table 7).

The regression model for pH in the South Fork of the Grand River is as follows:

$$pH = -0.0049FLOW + 0.010336WT + 0.000218TDS + 8.386$$

Table 7. Regression statistics for the South Fork of the Grand River. Dependent variable = pH, Independent variables = Flow, Water Temperature, and TDS (dissolved solids).

Multiple R	0.81	Adjusted R Square	0.64			
R Square	**0.66**	Standard Error	0.12	Observations = 59		
ANOVA	*Df*	*SS*	*MS*	*F*	*Significance F*	
Regression	3	1.52	0.51	35.69	0.000000	
Residual	55	0.78	0.01			
Total	58	2.31				
Variable	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
y-Intercept	8.385992	0.112511	74.53471	6.23E-57	8.160515	8.61147
FLOW	-0.0049	0.000546	-8.97007	2.36E-12	-0.00599	-0.0038
WT	0.010336	0.002405	4.297422	7.1E-05	0.005516	0.015156
TDS	0.000218	7.29E-05	2.987318	0.004198	7.16E-05	0.000364

It appears that increases in dissolved solids and water temperature have a positive effect on the pH (increasing) whereas increases in flow negatively impact the pH (dilution of the dissolved solids decreases the pH).

Dissolved solids, in general, are consistently lower in the South Fork but have a much stronger correlation with pH then that exhibited in the North Fork. A complex relationship exists between pH, flow, water temperature, dissolved solids, and suspended solids concentrations. The pH levels were lower in the North Fork compared to the South Fork. This can be partially attributed to the lower suspended solids concentrations in the North Fork. In comparison, the pH (>8.8) is higher in the South Fork which may be causing precipitation of some of the dissolved solids. The precipitation out of solution of the dissolved solids due to the high pH increases the suspended solids concentrations in the South Fork (Smith, 2000).

This is a very simplistic description of the complex chemical reactions that are involved with pH and the other water quality variables for both segments of the Grand River. Although the pH data did not indicate strong relationships between suspended solids, sodium, calcium, total alkalinity and others, all of these variables have some impact on pH levels and are interrelated. Sodium, calcium, and magnesium are all exchangeable cations that can influence pH readings. The composition of the exchangeable cations, the nature of the cation-exchange materials, the composition and concentration of soluble salts, and the presence or absence of gypsum and alkaline-earth carbonates effect the pH of the soil and water in the Grand River basin (USDA, 1954).

The river is impacted by sodium, calcium, and conductivity although more heavily in the South Fork and below Shadehill Reservoir. The complexity of the relationships between soil and water and their impact on pH is evidenced here. The natural background soil conditions and groundwater contributions to the stream are causing periodic exceedances of the pH standard both above Shadehill Reservoir in the South Fork and below Shadehill Reservoir to the Corson County line. The water quality standards for pH must allow for these natural periodic exceedances that occur during the course of the year due to sodium affected soils.

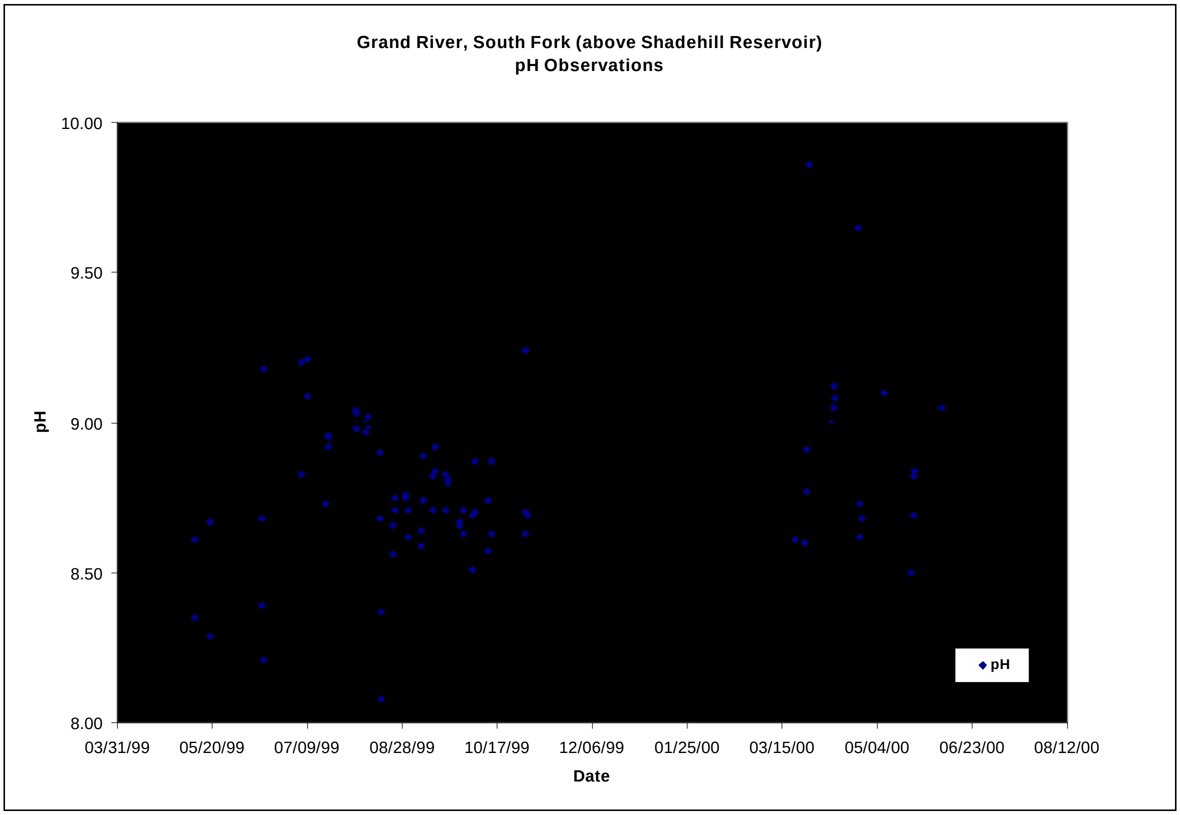


Figure 4 Grand River pH Observations for the South Fork of the Grand River.

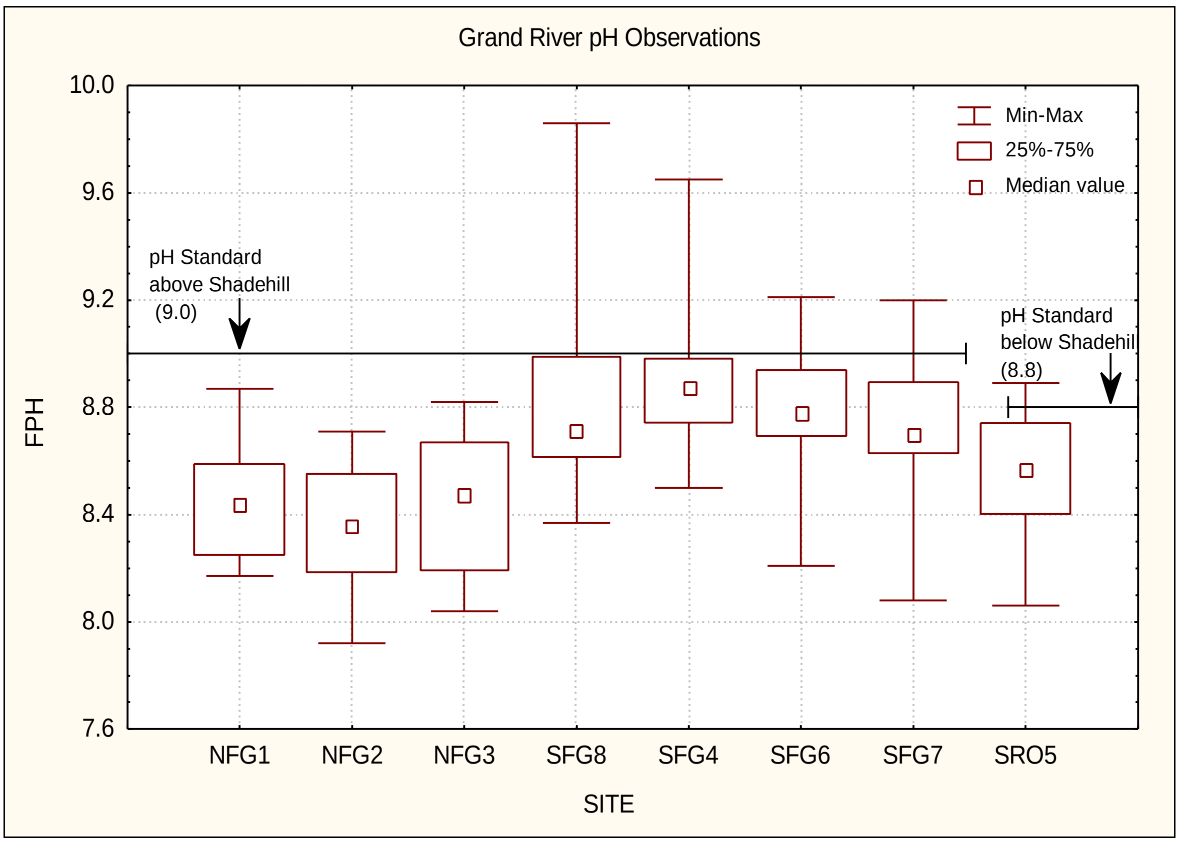


Figure 5. Box and Whisker Plots for pH observations collected from the Grand River.

3.1.4. Dissolved Oxygen

The dissolved oxygen concentrations ranged from a minimum of 6.00 mg/L (Site NFG2 to a maximum of 15.50 mg/L recorded from Site SFG6 (Figure 6). The dissolved oxygen standard for each of the three segments of the Grand River was not exceeded at any time during the project period.

Statistical analysis indicated no differences between any of the sites including the comparison between the North Fork and South Fork (df=1,n=160,p>0.05). This can be seen on the box and whisker plot in Figure 6. The dissolved concentrations did not exhibit any seasonal trends.

3.1.5. Nitrate+Nitrite (NO_{3+2})

Nitrate+Nitrite is a nutrient that can be converted into ammonia and various other forms of nitrogen through the nitrogen cycle in streams, rivers, and lakes (Stumm et al., 1996). High concentrations of nutrients within the Grand River system were not observed. Typically, the soils within the Grand River basin in Perkins and Harding Counties are generally "unsuited to cultivated crops and to tame pasture and hay because of extremely poor tilth. Conserving moisture, improving fertility and controlling wind erosion are the main management concerns" (USDA, 1988). These soil conditions (highly alkaline soils and a general lack of nutrients) are the cause for the agricultural economy in this area to be dominated by livestock grazing rather than cultivated crops.

The nitrate+nitrite water quality standard for all segments of the Grand River is 88 mg/L. This standard was never exceeded (Figure 7). The minimum concentration of 0.01 mg/L was

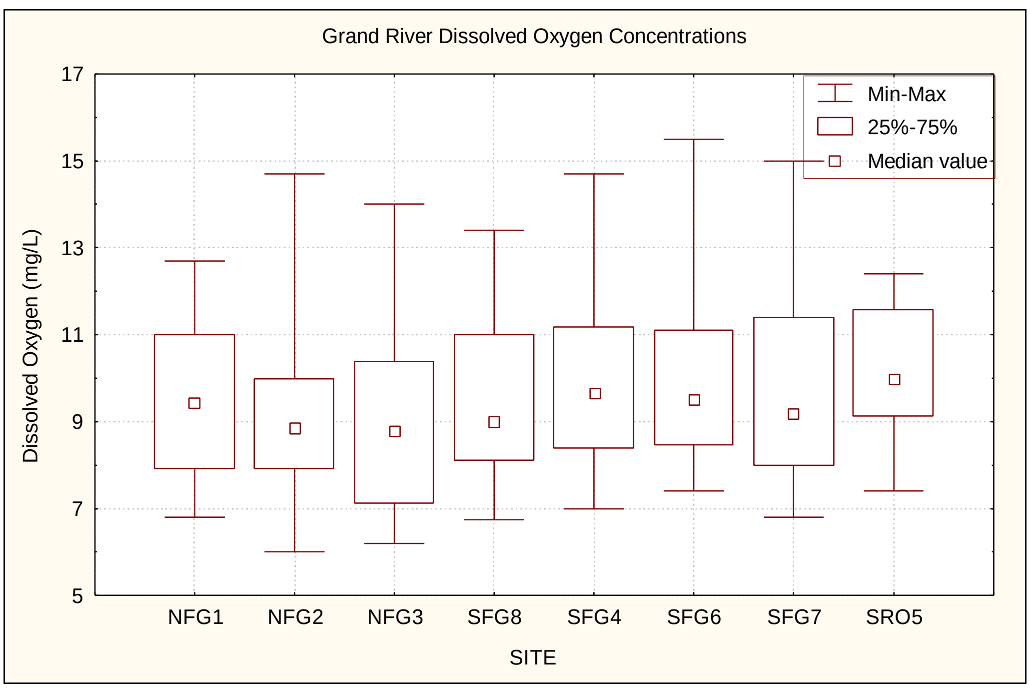


Figure 6. Grand River Dissolved Oxygen Concentrations.

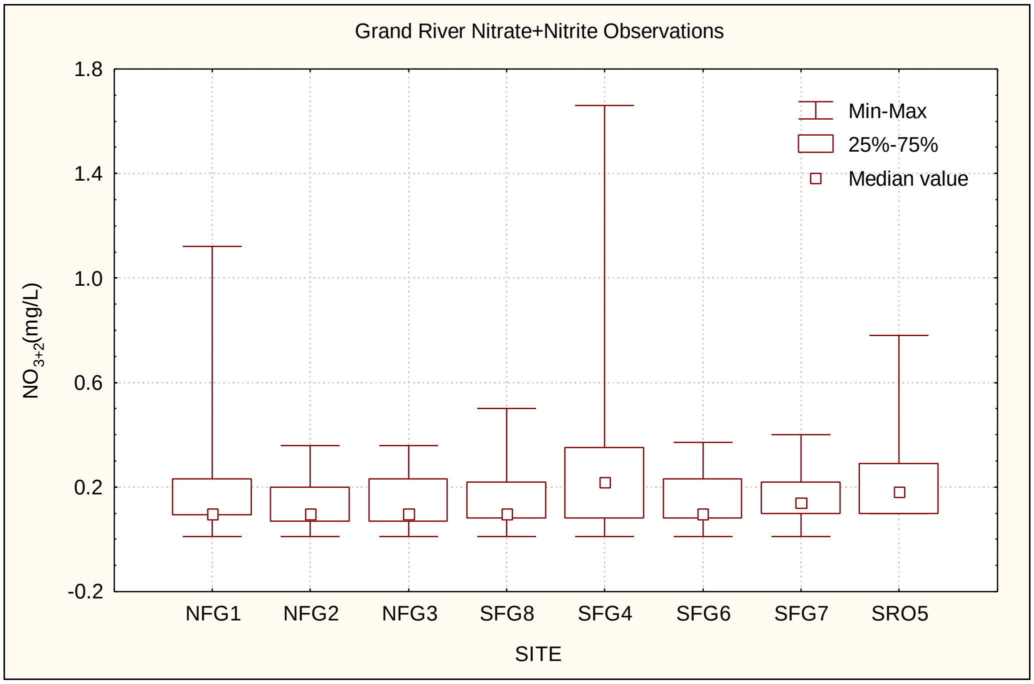


Figure 7. Grand River Nitrate+Nitrite Concentrations.

observed at several sites. The maximum concentration was 1.66 mg/L and was observed at Site SFG4 on August 30, 1999. There were no significant differences between any of the sites (df=7,n=121, p=0.61) (Figure 7).

Higher concentrations of nitrate and nitrite were observed during the summer sampling period from June through August 1999. Biological production and decomposition is at its maximum during the summer period when the nitrogen cycle is at its peak. Figure 8 shows the higher concentrations during the summer period for all of the monitoring sites pooled together.

3.1.6. Ammonia (NH_3)

Ammonia is another form of nitrogen that can be used as an indicator of organic pollution. Ammonia does not have a water quality standard whereas the unionized form does and will be discussed in subsequent paragraphs. Ammonia concentrations did not exhibit any significant differences between sites (df=7,n=121,P>0.05). The minimum concentrations found during the project were below the detection limit which were collected from several sites.

The maximum concentration of 0.38 mg/L was observed at Site NFG1. Comparatively speaking, although there were no observed significant differences between sites, the North Fork exhibited a slightly higher concentration of ammonia when compared to the South Fork (0.09 mg/L vs 0.06 mg/L). This may be due to discharges from Bowman-Haley Reservoir in North Dakota, located on the North Fork of the Grand River. Bowman-Haley stores water allowing higher rates of biological production and decomposition to take place. One of the by-products of decomposition is ammonia.

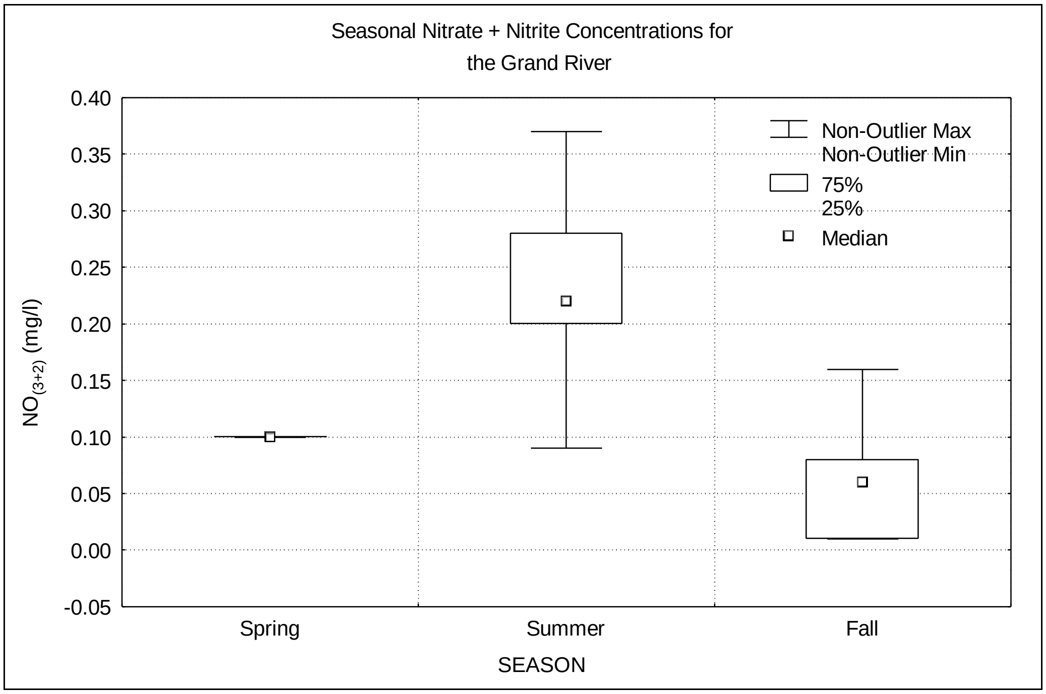


Figure 8. Seasonal Nitrate+Nitrite Concentrations for the Grand River.

3.1.7. Unionized Ammonia (NH_4^+)

Unionized ammonia is the form of ammonia subject to State's water quality standards (Table 2). Corrected from pH and temperature, unionized ammonia ranged from 0.18 µg/L (NFG1) to a maximum of 69.42 µg/L (SFG4). The water quality standard (daily maximum) for unionized ammonia is 0.07 µg/L for the South Fork and 0.0875 for the North Fork. Below Shadehill Reservoir the standard drops to 0.035 µg/L. According to these standards there were no exceedances. The maximum concentrations for each reach were the following: for the reach below Shadehill Reservoir - 26.71 µg/L, the South Fork - 69.42 µg/L (Site SFG4), and the North Fork was 41.60 µg/L (Site NFG3) (Table 8).

All of these maximum values occurred during the summer period of the project when higher temperatures and higher concentrations of nitrogen were observed as is indicated on Figure 8. Although there were no significant differences exhibited between the North Fork or the South Fork (df=2,n=167,p>0.05) or between sites (df=7,n=167,p>0.05), the mean concentration for unionized ammonia was slightly higher in the South Fork of the Grand River (Table 9).

3.1.8. Total Kjeldahl Nitrogen (TKN)

The Kjeldahl method of analysis measures the amount of ammonia nitrogen and organic nitrogen in a particular sample (Standard Methods AWWA, 1993). It can be used as another indicator of excessive amounts of organic pollution and is primarily used to determine the amount of organic nitrogen in a sample. Significant concentrations or trends are discussed in the organic nitrogen section. However, the trends for the forms of nitrogen indicate an increase during spring and

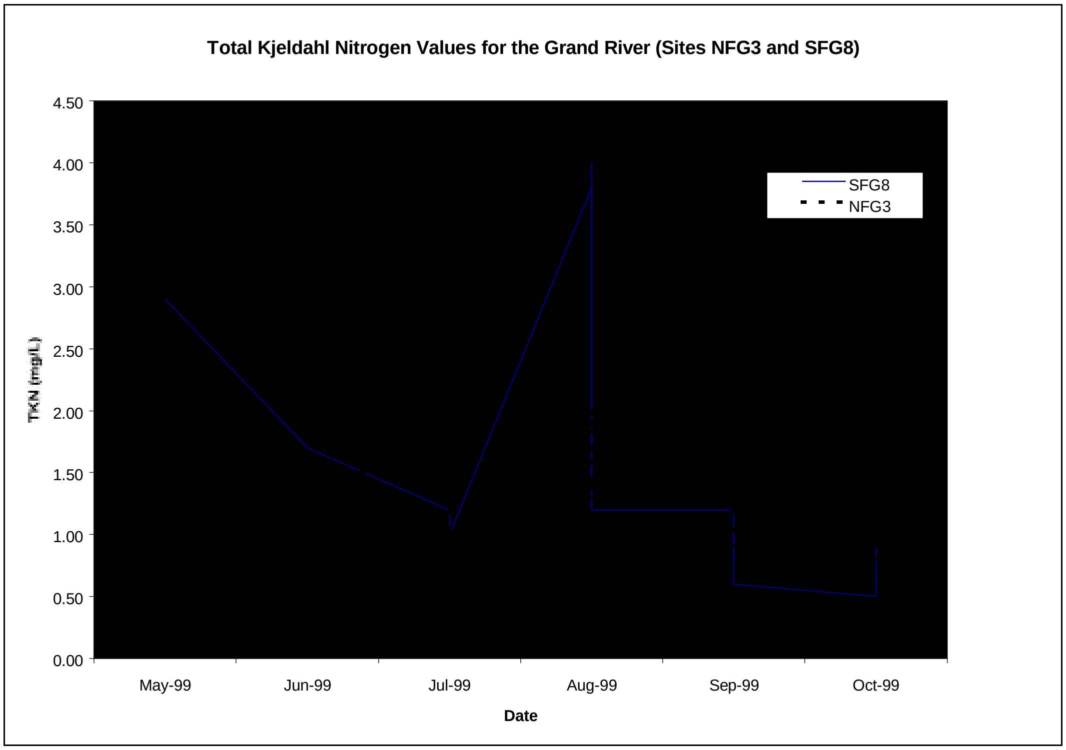


Figure 9. TKN Concentrations for the Grand River.

summer and gradual reductions in the concentrations as fall begins (Figure 9). There were significant differences between each fork and the sites exhibited differences ($p<0.05$). However, discussions about the differences will be limited to the other forms of nitrogen (organic and total nitrogen forms).

3.1.9. Organic Nitrogen (ON)

Organic nitrogen is a general form of nitrogen that can be used as a measurement of organic pollution and, to a certain extent, biological production, and decomposition. Organic nitrogen consists of those forms of nitrogen locked up in the biomass of organic material. The sites located on the South Fork exhibited slightly higher concentrations of organic nitrogen than North Fork sites ranging from of 0.26 mg/L to 7.36 mg/L. Site SFG4 exhibited the maximum concentration, which was collected on May 8, 2000. The flow was too high to enter the stream and collect flow information. There were no significant differences between sites on both forks but there were significant differences between the three main segments of the Grand River when sites were pooled for each fork ($df=2, n=167, p<0.05$). As was indicated with the total Kjeldahl nitrogen and the other nutrient concentrations there was a gradual increase from the spring to the summer concentrations and then a decrease to the annual lows exhibited during late fall. This trend can be attributed to the decline in biological production or low flows that occur during the course of the year. Figure 10 shows the seasonal changes for organic nitrogen. This trend was exhibited for all of the forms of nitrogen.

3.1.10. Total Nitrogen (TN)

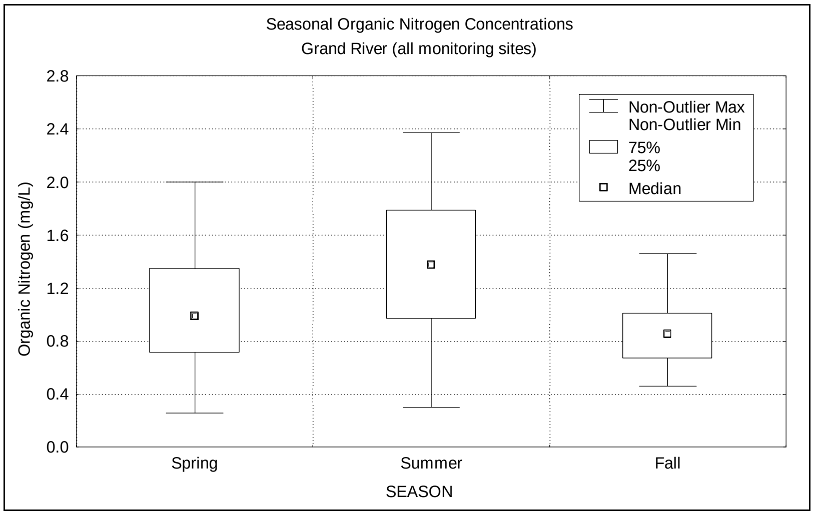


Figure 10. Seasonal Organic Nitrogen Concentrations for the Grand River.

Total nitrogen is the sum of all the forms of nitrogen that have been discussed. Most of the nitrogen is contained in the organic form. From data collected on the South Fork, total nitrogen ranged from 0.43 mg/L to 8.09 mg/L compared to the North Fork where the concentrations ranged from 0.59 mg/L to a maximum of 2.28 mg/L (Table 8). The mean concentrations were not very different, 1.43 mg/L in the North Fork compared to 1.57 mg/L in the South Fork. Again, the concentrations gradually decreased as the year progressed. The 8.09-mg/L maximum concentration observed in the South Fork can be attributed to the high concentration of TKN observed on May 8, 2000. The gradual decline in concentration levels over the course of the year was observed throughout the other forms of nitrogen as well. With the smaller drainage above Site SFG4 the runoff events effect this smaller stream more frequently and significantly. Table 8 and Table 9 show the descriptive statistics for all of the measured forms of nitrogen.

3.1.11. Total Phosphorus (TP)

Total phosphorus is a measure of the particulate and dissolved forms of phosphorus. There is no water quality standard affiliated with total phosphorus or dissolved phosphorus concentrations. Most of the land use within the Grand River basin is limited to grazing with a few areas that are dominated by cultivated crops. Although the mean concentration for the South Fork was 0.251 mg/L, most of the phosphorus is attached to the sediment particles of which there is abundance in the South Fork. Dissolved phosphorus concentrations are lower in these areas primarily due to lack of fertility of the soil and the lack of cultivation and application of fertilizers. The mean TP concentrations between the South Fork (0.251 mg/L) and the North Fork (0.082 mg/L) were significantly different (df=2,n=167,$p<0.05$) (Table 9). This difference can be attributed to the higher concentrations of sediment (suspended solids) that were observed in the South Fork. A significant relationship exists between total phosphorus and suspended solids concentrations in the South Fork of the Grand River (df=1,85,n=87,R^2=0.71) whereas no relationship exists between these same two variables within the North Fork (df=1,65,n=67,R^2=0.01).

Compared to the gradual decrease of nitrogen over the course of the sampling year, no seasonal trends were observed with the concentrations of total phosphorus. These concentrations were more dependent upon flow (Figure 11).

As will be seen in the discussion of suspended solids concentrations, the mean total phosphorus concentration for the South Fork gradually decreased when progressing downstream. Figure 12 is a box and whisker plot showing the minimum, maximum, and median concentrations of the sites from both forks of the Grand River. There is no trend indicated for the North Fork. However, the concentrations gradually decrease downstream for the South Fork, which indicates that the upper watersheds are contributing the bulk of the material and it is slowly depositing as it is transported downstream. The higher-energy flows in the smaller upstream subwatersheds, i.e. Site SFG4 and SFG6, and the highly erosive soils in these watersheds, resulted in a higher concentration of sediment which in turn carries more of the particulate forms of phosphorus. Although there were extreme phosphorus values observed from Site SFG4, these did not cause any significant differences to occur between the sites in the South Fork (df=7,n=167,P>0.05) (Figure 12).

Figure 12 also shows the phosphorus concentrations observed from some of the smaller tributaries sampled during the 2000 spring runoff. Clarks Fork Creek, Bull Creek, and Horse Creek all drain above monitoring Site SFG6 in the South Fork. These three smaller tributaries exhibited the same trends and levels of phosphorus concentration as those found in the mainstem monitoring sites SFG4 and SFG6.

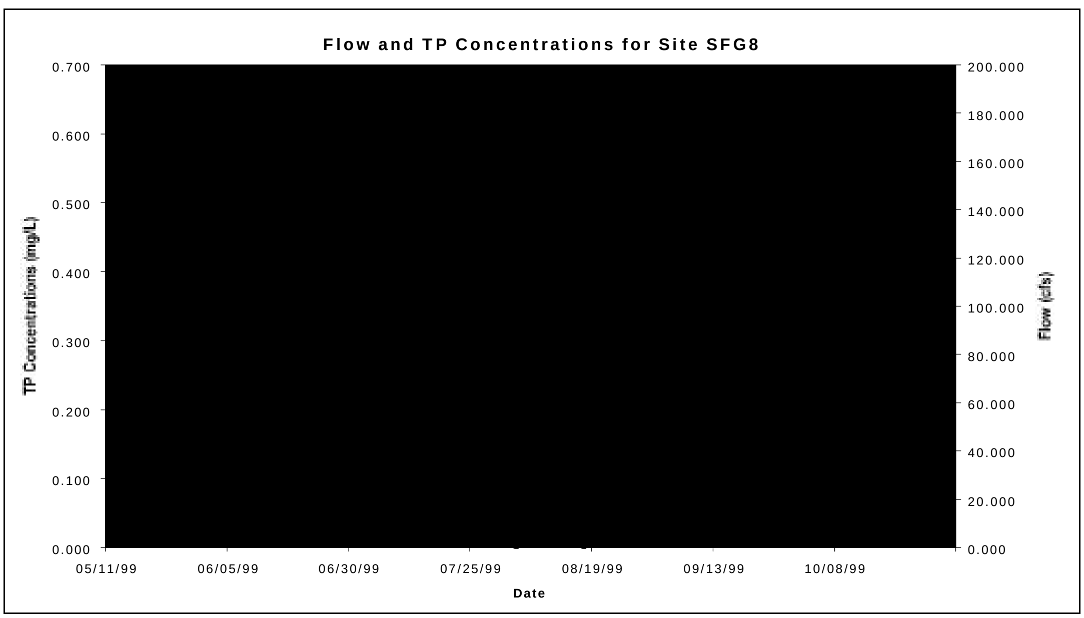


Figure 11. Flow vs. Total Phosphorus Concentrations for Site SFG8, 1999.

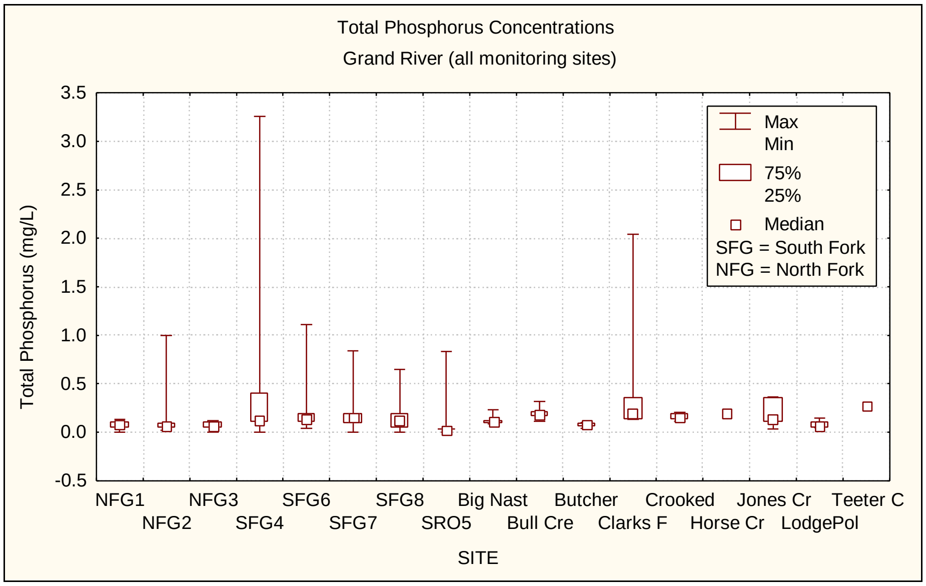


Figure 12. Box and Whisker Plots for total phosphorus concentrations collected from the Grand River, 1999.

Table 8. Mean, maximum, and minimum values for all parameters collected from all main stem monit and South Forks of the Grand River. <u>All data categorized by site location</u>.

Site	Stat	DO	PH	WT	FECAL	NH3	UNA	NO32	ON	TN	TKN	TP	TDP	TALK
NFG1	Mean	9.48	8.44	14.76	407	0.11	0.0074	0.22	1.17	1.50	1.28	0.073	0.032	440
	Max	12.70	8.87	25.10	7500	0.38	0.0351	1.12	1.90	2.72	2.00	0.130	0.120	511
	Min	6.80	8.17	4.00	10	0.00	0.0000	0.01	0.85	0.93	0.90	0.000	0.010	395
NFG2	Mean	9.08	8.36	15.66	148	0.09	0.0055	0.14	1.17	1.39	1.25	0.104	0.027	453
	Max	14.70	8.71	25.00	1200	0.25	0.0258	0.36	2.00	2.30	2.00	1.000	0.080	505
	Min	6.00	7.92	4.50	10	0.00	0.0000	0.01	0.66	0.83	0.80	0.020	0.010	418
NFG3	Mean	8.88	8.45	15.70	1110	0.09	0.0072	0.14	1.18	1.41	1.27	0.068	0.023	438
	Max	14.00	8.82	24.50	17000	0.34	0.0416	0.36	1.96	2.21	2.00	0.120	0.070	486
	Min	6.20	8.04	4.50	10	0.00	0.0000	0.01	0.66	0.84	0.77	0.000	0.010	385
SFG4	Mean	9.90	8.88	12.31	1020	0.07	0.0122	0.31	1.51	1.89	1.58	0.442	0.065	550
	Max	14.70	9.65	21.90	5400	0.23	0.0694	1.66	7.36	8.09	7.39	3.260	0.292	737
	Min	7.00	8.50	0.20	10	0.00	0.0000	0.01	0.26	0.43	0.30	0.000	0.010	297
SFG6	Mean	10.04	8.79	15.88	1010	0.05	0.0085	0.15	1.23	1.44	1.28	0.227	0.043	662
	Max	15.50	9.21	25.20	5900	0.23	0.0359	0.37	3.55	3.88	3.60	1.110	0.160	700
	Min	7.40	8.21	4.20	10	0.00	0.0000	0.01	0.39	0.51	0.41	0.040	0.010	601
SFG7	Mean	9.90	8.72	16.93	669	0.06	0.0092	0.16	1.26	1.48	1.32	0.201	0.055	619
	Max	15.00	9.20	27.50	6500	0.23	0.0511	0.40	3.97	4.42	4.10	0.840	0.170	665
	Min	6.80	8.08	4.50	30	0.00	0.0000	0.01	0.37	0.49	0.39	0.000	0.010	554
SFG8	Mean	9.52	8.80	13.65	544	0.06	0.0076	0.15	1.28	1.49	1.33	0.135	0.034	583
	Max	13.40	9.86	24.00	5900	0.23	0.0379	0.50	3.87	4.29	4.00	0.650	0.100	641
	Min	6.75	8.37	4.00	10	0.00	0.0000	0.01	0.46	0.54	0.50	0.000	0.010	454
SRO5	Mean	10.16	8.55	17.04	107	0.06	0.0052	0.23	0.73	1.02	0.79	0.085	0.026	361
	Max	12.40	8.89	25.00	740	0.25	0.0267	0.78	1.50	2.28	1.50	0.830	0.080	364
	Min	7.40	8.06	5.00	10	0.00	0.0000	0.10	0.30	0.59	0.30	0.000	0.010	359

Table 9. Mean, maximum, and minimum values for all parameters collected from all main stem-monit the North and South Forks of the Grand River. <u>All data categorized by fork (Below = Monitoring Site is located immediately below Shadehill Reservoir).</u>

Fork	Stat	FECAL	WT	FPH	DO	NO32	NH3	UNA	TKN	ON	TN	TP	TDP	TALK	TS	T
Below	Mean	107	17.04	8.55	10.16	0.23	0.06	0.0052	0.79	0.73	1.02	0.085	0.026	361	1343	1
Below	Max	740	25.00	8.89	12.40	0.78	0.25	0.0267	1.50	1.50	2.28	0.830	0.080	364	1460	1
Below	Min	10	5.00	8.06	7.40	0.10	0.00	0.0000	0.30	0.30	0.59	0.000	0.010	359	1241	1
North	Mean	541	15.38	8.42	9.14	0.17	0.09	0.0067	1.27	1.17	1.43	0.082	0.027	443	2086	2
North	Max	17000	25.10	8.87	14.70	1.12	0.38	0.0416	2.00	2.00	2.72	1.000	0.120	511	2822	2
North	Min	10	4.00	7.92	6.00	0.01	0.00	0.0000	0.77	0.66	0.83	0.000	0.010	385	1513	1
South	Mean	813	14.64	8.80	9.83	0.19	0.06	0.0094	1.38	1.32	1.57	0.251	0.049	599	2045	1
South	Max	6500	27.50	9.86	15.50	1.66	0.23	0.0694	7.39	7.36	8.09	3.260	0.292	737	11635	5
South	Min	10	0.20	8.08	6.75	0.01	0.00	0.0000	0.30	0.26	0.43	0.000	0.010	297	1144	

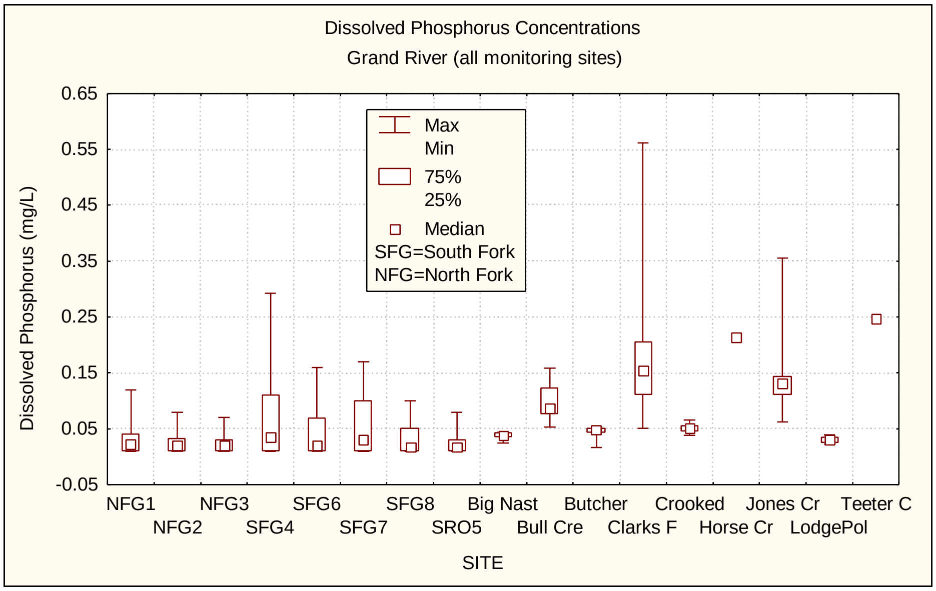


Figure 13. Box and Whisker Plots for Dissolved Phosphorus Concentrations collected from the Grand River, 1999,2000.

3.1.12. Total Dissolved Phosphorus (TDP)

Total dissolved phosphorus consists of the most reactive forms of phosphorus, i.e. soluble reactive phosphorus. These forms of phosphorus can be termed as the non-particulate forms or that which is unattached to any type of soil particle. It is also the most available to plants and algae for immediate uptake. There were no significant differences exhibited between the forks of the Grand River or between any of the eight mainstem monitoring sites ($p>0.05$) (Table 8 and Figure 13). The mean concentrations were slightly higher in the South Fork. The highest mean concentration was observed from Site SFG4 which equaled 0.065 mg/L (Table 8). The lowest mean concentration observed from all eight monitoring sites was from Site NFG3 which equaled 0.023 mg/L (Table 8). These concentrations are low and significant seasonal trends were not identified during the course of the sampling year (Figure 13 and 14).

Although dissolved phosphorus concentrations in excess of 0.02 mg/L were observed from both forks, the maximum concentration was collected from Site SFG4 (0.292 mg/L). The mean concentrations for dissolved phosphorus were slightly higher in the South Fork (Figure 13) there were no statistical differences detected between the all eight mainstem monitoring sites or between the forks ($P>0.05$). The median concentrations as indicated on Figure 13 are slightly higher in the South Fork. The TDP concentrations at the monitoring sites located downstream were also slightly reduced compared to the upstream sites for both forks of the Grand River. The number of samples that exceeded 0.02 mg/L were similar between sites as well. Approximately 50% of the samples from the South Fork sites exceeded 0.02 mg/L with the exception of SFG7 where 67% of the samples exceeded 0.02 mg/L. There is no water quality standard for dissolved phosphorus but it has been reported that an average concentration of 0.02 mg/L of dissolved phosphorus can cause nuisance blue-green algal blooms in lakes (Wetzel, 1983).

The smaller tributaries draining to the South Fork located in subwatershed SFG6 exhibited some

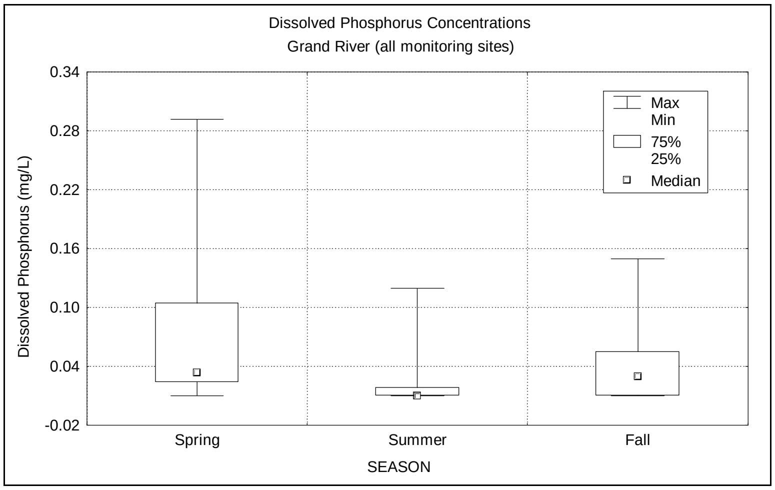


Figure 14. Seasonal Dissolved Phosphorus Concentrations for the Grand River.

relatively high concentrations. Dissolved phosphorus concentrations exceeding 0.15 mg/L were observed from Clarks Fork Creek, Bull Creek, and Jones Creek (Figure 13).

3.1.13. Total Alkalinity (TALK)

Total alkalinity is a measure of the buffering capacity of the water. This is different than the pH which is a measure of the activity of the hydrogen ion within the water. "It is important to distinguish between high basicity, manifested by a high pH, and high alkalinity, a high proton-accepting capability. Whereas pH is an intensity factor, alkalinity is a capacity factor" (Manahan, 1990). Alkalinity was only measured during the spring of 2000. All of the segments of the Grand River (below Shadehill Reservoir, Shadehill Reservoir, and the North and South Forks) have the same water quality standard. Total alkalinity as calcium carbonate shall not exceed 1313 mg/L (Table 2). There was one observation which exceeded the standard. This sample was collected from Teeter Creek which drains into the North Fork of the Grand River right along the border of North Dakota.

Most waters within the State of South Dakota have total alkalinity concentrations that usually range between 150 to 250 mg/L. The minimum and maximum concentrations were both observed from Site SFG4 (297 mg/L and 737 mg/L). This can be attributed mainly to the high variability of flows at this site. A statistically strong relationship between flow and alkalinity was observed at Site SFG4 (df=3,n=4,R^2=0.88). However, an increased sample size may have produced a less significant relationship between these two variables at Site SFG4 as there was only one sample collected during extremely high flows. The remaining sites on the both forks of the Grand River exhibited essentially no relationship between flow and total alkalinity concentrations due to the small sample size.

The small sample size collected during the spring of 2000 also resulted in no statistical differences between the sites upstream of Shadehill Reservoir (NFG1 through SFG8). However, the three lower sites on the South Fork (SFG6, 7,and 8) differed from the single monitoring site

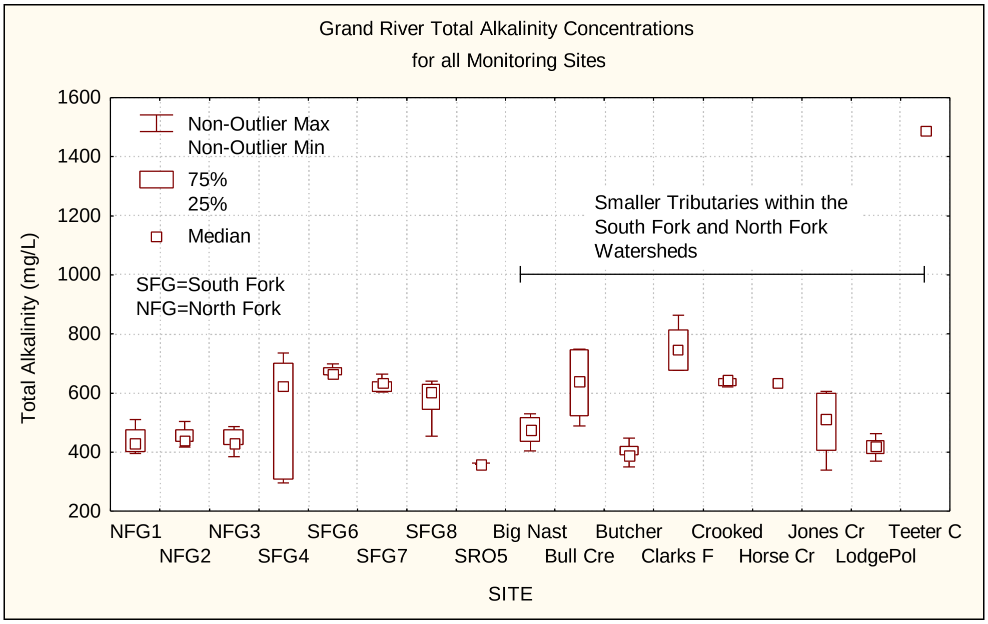


Figure 15. Grand River Total Alkalinity Observations, 2000.

located downstream of Shadehill Reservoir (Site SRO5) (df=7,n=46,p=0.0003). When the sites were pooled together for each fork (north, south and below Shadehill) (mainstem monitoring sites only), the mean concentration of the North Fork did not differ from that below Shadehill. The South Fork was significantly higher from the North Fork and below Shadehill (df=2,n=46,p=0.0000). The mean concentration for the South Fork was 599 mg/L whereas the North Fork was 443 mg/L and below Shadehill it was 361 mg/L. The maximum concentrations for all of the South Fork sites exceeded 600 mg/L. There was no defining trend progressing upstream or downstream for the concentration levels (Figure 15).

Although the monitoring sites did not exhibit any significant differences the South Fork was much more variable in its concentration levels (Figure 15). The smaller tributaries of the South Fork, sampled during the spring of 2000, probably influence this variability. The impoundment upstream of the North Dakota-South Dakota border (Bowman-Haley Reservoir) retains a large amount of sediment and regulates the flows as compared to the South Fork which is more variable due to the rates of change that occur in the watershed during runoff events.

3.1.14. Total Solids (TS)

Total solids consist of two forms: dissolved and suspended solids. There is no water quality standard associated with total solids. Total solids at the seven monitoring sites above Shadehill (NFG1-SFG8) ranged from a maximum concentration of 11,635 mg/L to a minimum concentration of 1,144 mg/L. Both of these concentrations were observed at Site SFG4. The high variability in the total solids concentrations can be attributed to the erosive nature of the soils which greatly influence the suspended solids and dissolved solids concentrations in the SFG4 subwatershed.

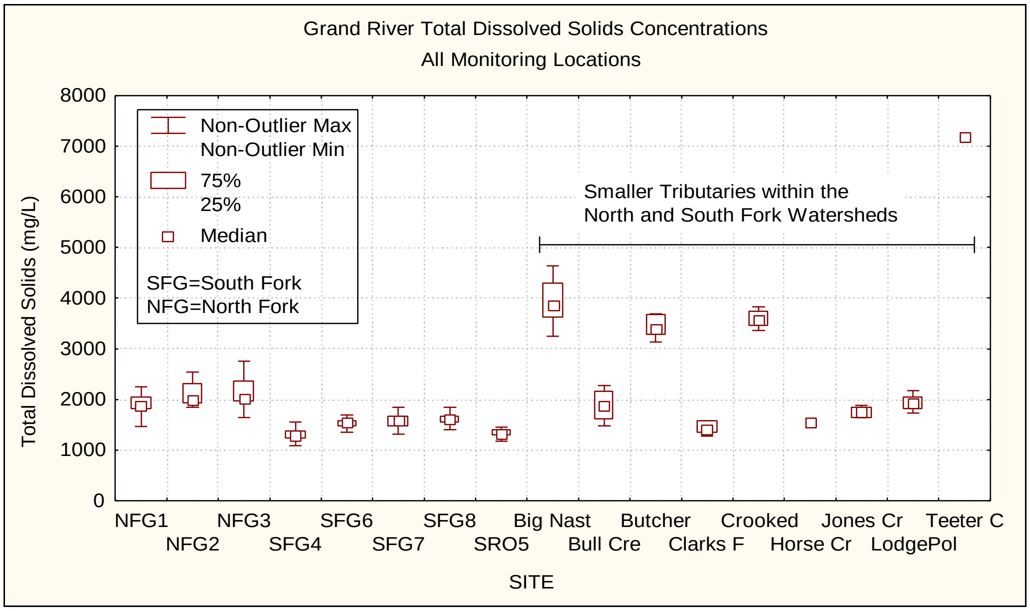


Figure 16. Grand River Total Dissolved Solids Concentrations, 1999-2000.

3.1.15. Total Dissolved Solids (TDS)

As indicated on Figure 16, the TDS concentrations in the North Fork were higher and more variable when compared to the South Fork concentrations. All segments of the Grand River fall under the standard of dissolved solids not exceeding 4,375 mg/L for a 30-day average. There were two observations which exceeded this standard and both can be attributed to natural (geologic) background conditions for this area. Big Nasty Creek, which drains directly into South Fork, exhibited a concentration of 4,636 mg/L and Teeter Creek draining to the North Fork along the North Dakota border exhibited a concentration of 7,189 mg/L.

Significant differences were detected when the mainstem sites (NFG1-SFG8) were compared (df=7,n=167,p=0.000). The North Fork concentrations were significantly higher than the South Fork Concentrations (Table 9). This difference in mean concentrations can be attributed to the substantially higher concentrations of suspended solids. The pH and suspended solids were significantly higher in the South Fork. Although the dissolved solids and suspended solids concentrations were not normally distributed, even after data transformations were conducted, a slight relationship existed between the dissolved solids and pH and suspended solids where the tds=613.38(pH)+0.26(TSS)-3963.43 (df=2,93,n=96,r^2=0.42). This slight relationship indicated that the dissolved solids increased whenever there was a corresponding increase in the suspended solids and pH of the water in the South Fork. This relationship was not evident in the North Fork due to the significantly lower suspended solids concentrations. The total watershed area above Site NFG3 is approximately 792,114 acres and Bowman-Haley Reservoir is trapping sediment from 323,955 acres of this area (41%). This may be impacting the pH, and the suspended and dissolved solids relationship in the North Fork of the Grand River.

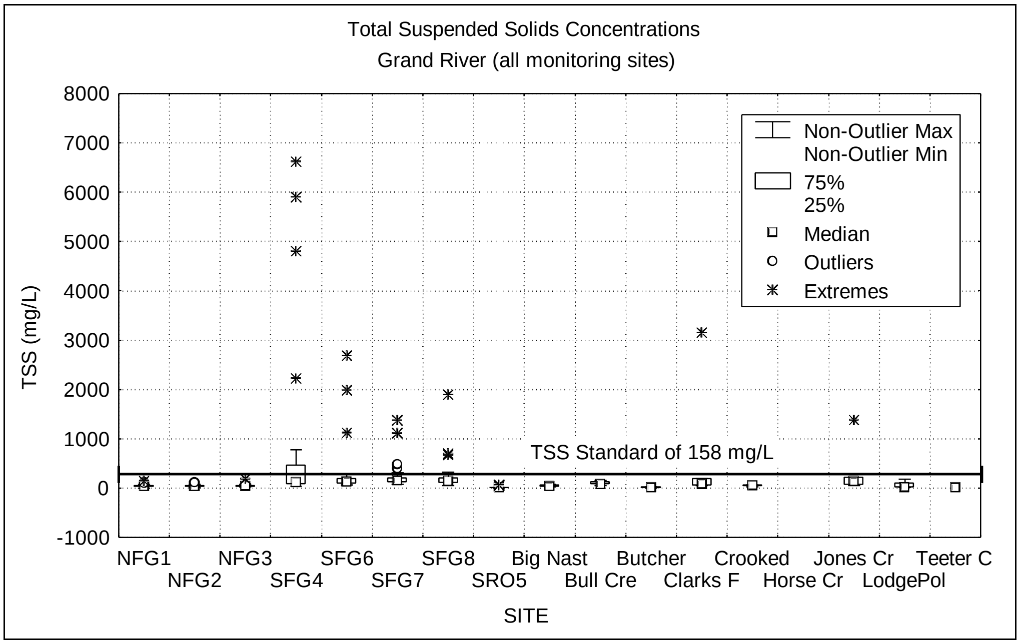


Figure 17. Grand River Total Suspended Solids Concentrations, 1999-2000.

3.1.16. Total Suspended Solids (TSS)

Total suspended solids concentrations are measurements of the amount of suspended sediment particles in the stream. This includes volatile (organic) and non-volatile (geologic) material. The water quality standard for two segments of the Grand River is 158 mg/L (daily maximum). This includes the South Fork and below Shadehill Reservoir to the Corson County line. In the North Fork the TSS standard is 263 mg/L (daily maximum).

The North Fork and its tributaries exhibited zero exceedances of the 263 mg/L standard (n=73). However, out of 87 samples collected from the South Fork 35 exceeded the 158 daily maximum standard (40%). The smaller tributaries draining into the South Fork have been classified with the designated use (6) Warmwater marginal fish life propagation. This beneficial use has a TSS daily maximum standard of 263 mg/L. Thirty samples were collected from these smaller tributaries and only two exceedances were observed (6.7%). Table 10 shows the number of violations per site and fork.

Table 10. All TSS Exceedances for the Grand River.

Site	Fork	Total # of Exceed	Mean Conc of Exceed	Minimum Exceed	Maximum Exceed
Clarks Fork Creek	South	1	3150	3150	3150
Jones Creek	South	1	1380	1380	1380
SFG4	South	8	2642	170	6620
SFG6	South	8	850	166	2684
SFG7	South	10	465	173	1375
SFG8	South	9	503	160	1895

As indicated on Table 9 and Figure 17 the concentrations of the solids are significantly larger and more variable in the South Fork when compared to the North Fork (df=2,n=167,p=0.0000). The overall mean concentration for the South Fork was 488 mg/L whereas the mean concentration from the North Fork was 46 mg/L. In the South Fork, the average concentrations are significantly reduced as the sites progress downstream (Table 8 and Figure 17). Site SFG4 exhibited a mean of 1,017 mg/L whereas Site SFG8 exhibited a mean concentration of 261 mg/L. The high variability observed at each site is indicated by Figure 17. The smaller subwatersheds in the South Fork such as SFG4 and Clarks Fork Creek drain an area where the soils are of a highly erosive nature (Steele, 2000).

The soils become less erosive as they leave the Sagebrush Steppe ecoregion (43c) and enter the Missouri Plateau ecoregion (43a). Figure X, pg shows the ecoregions for the project area. The change in ecoregions and soil types may be a major factor in the reduced concentrations that occur for TSS concentrations in the downstream sites of the South Fork. As the stream carries the heavy sediment load downstream some of the material is deposited in areas in and along the streambed. If the suspended sediment supply is not sufficiently replenished, TSS will likely decrease downstream.

The TSS concentrations also are affected by the discharge in the stream. Each of the South Fork monitoring sites exhibited a significant relationship between flow and TSS concentrations (minimum $r^2>0.68$). Figure 18 shows the data collected from Site SFG7 from which the most significant relationship was observed. This same kind of relationship was not exhibited in the North Fork (maximum $r^2<0.26$). All of the regression analysis information for TSS vs. flow for each site can be found in Appendix X.

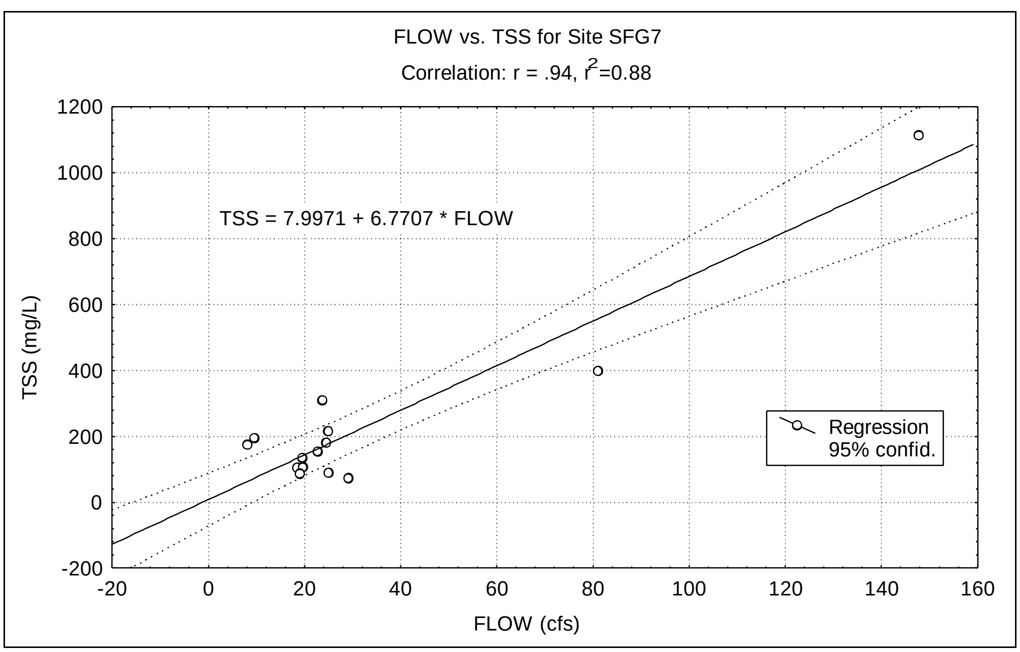


Figure 18. Flow vs. TSS Regression Analysis, Site SFG7.

The model from the regression analysis for Site SFG7 is: ***TSS* = 7.9971 + 6.7707*(*FLOW*)**

Using this equation, the maximum flow rate that could occur before the daily maximum concentration (158 mg/L) is reached would be 22.15 cfs. Based on the daily discharge data from USGS gauging station #06356500 near Cash, SD, which is the same location as Site SFG7, 22.15 cfs falls approximately near the 69th percentile (data from 1972 to present was used). This means that 31% of the time the flow is higher than this value and, consequently, the corresponding suspended solids concentration. If long-term daily discharge data was available for the remaining sites, similar relationships could be developed to determine how often the TSS standard would be exceeded for these other segments of the South Fork. The USGS (1964) investigated the sedimentation rates for the Grand River Basin using data that had been collected and estimated during the period 1946-1960. The annual sediment discharges during this period of investigation was extremely variable from year to year and highly dependent upon flow. When sediment discharges were plotted against streamflow during this time period, the data was extremely scattered and very difficult to make predictions for annual sediment load. The recommendations were for any accurate determinations to be made an unusually long period of record would be required for streamflow and sediment discharge (USGS, 1964).

3.1.17. Fecal Coliforms (Fecal)

Fecal coliform is an indicator of nutrient enrichment which may be caused by the input of human or animal sewage entering a stream at some point. Because of the lack of municipalities located within the Grand River watershed the cause of the increased coliform concentrations can be attributed to feedlots, and sheep and cattle grazing within the Grand River basin.

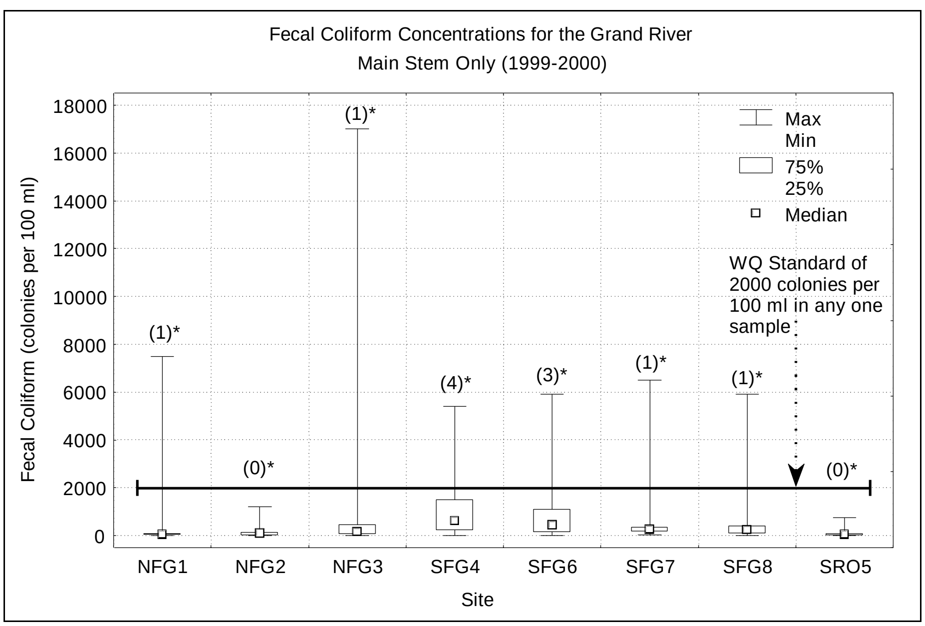


Figure 19. Fecal Coliform concentrations for the Grand River. Numbers in parentheses (1)* refer to number of samples exceeding the wq standard.

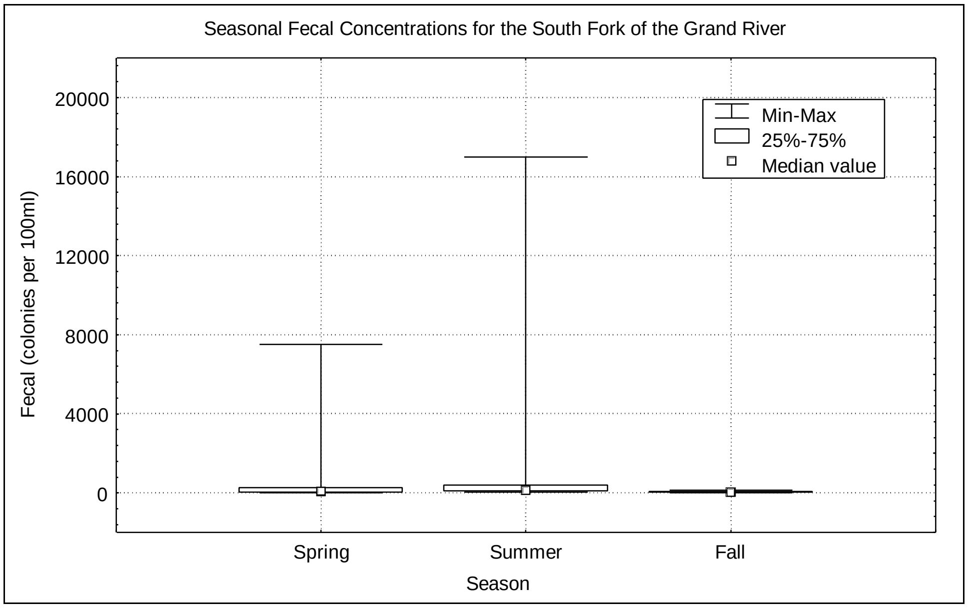


Figure 20. Seasonal Fecal Coliform Samples from the South Fork of the Grand River.

The fecal coliform samples collected from the North Fork of the Grand River ranged from a minimum of 10 to a maximum of 17,000 colonies per 100 ml. The mean for the North Fork was 541 colonies per 100 ml versus the South Fork mean concentration, which were 813 colonies per 100 ml. The South Fork concentrations ranged from 10 to 6,500 colonies per 100 ml. The two upstream monitoring sites for the South Fork exhibited consistently higher concentrations of fecal coliform bacteria (Table 8). Although the maximum concentration of 17,000 colonies was observed from the North Fork (Site NFG3) this was the only exceedance from this site during the course of the investigation. The median for Site NFG3 was significantly higher than the other

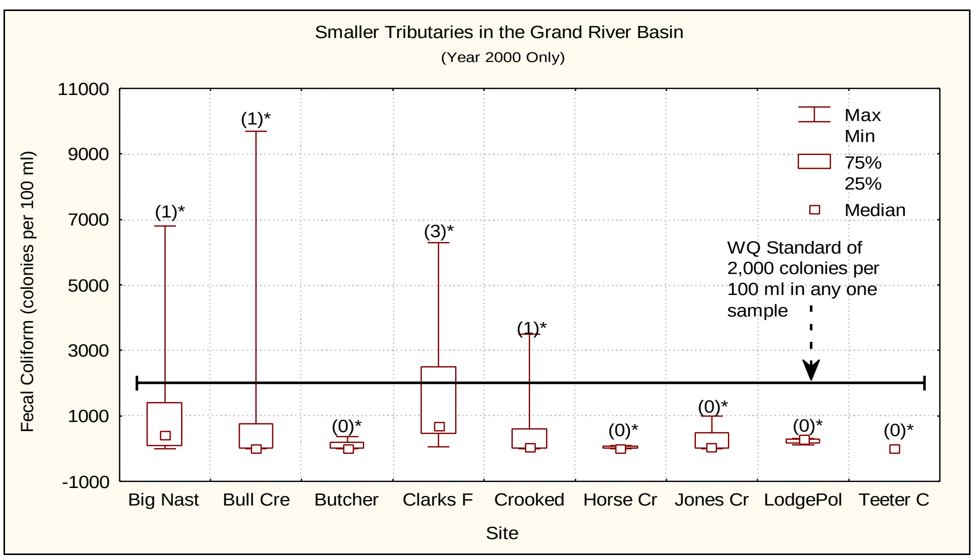


Figure 21. Numbers in parentheses (1)* refer to number of samples exceeding the Water Quality standard.

two sites from the North Fork because of this datapoint (Table 8). The median concentrations from the four monitoring sites from the South Fork were significantly higher than the North Fork median concentrations (Table 9).

The smaller tributaries, which were sampled during the spring of 2000, indicated a higher number of exceedances for those tributaries located in the SFG4 and SFG6 subwatersheds. Figure 21 shows those smaller tributaries where exceedances of the daily maximum concentrations (2,000 colonies per 100 ml) were observed. Big Nasty Creek drains into the subwatershed of Site SFG7. This creek, during the spring of 2000, exhibited one exceedance out of a total of eight samples collected (12.5%). However, Clarks Fork Creek which drains into the subwatershed of SFG6 exhibited three exceedances out of a total of nine samples collected (33%). The total number and rate (%) of exceedances per site can be found in Table 11.

Table 11. Fecal Coliform Exceedances for the Grand River.

Site	Total # samples	# of Exceed	Percent Exceed
Big Nasty Creek	8	1	13%
Butcher Creek	6	0	0%
Clarks Fork	9	3	33%
Crooked Creek	6	1	17%
Horse Creek	3	0	0%
Jones Creek	7	0	0%
Lodgepole Creek	4	0	0%
NFG1	22	1	5%
NFG2	23	0	0%
NFG3	21	1	5%
SFG4	23	4	17%
SFG6	21	3	14%
SFG7	21	1	5%
SFG8	22	1	5%
Teeter Creek	1	0	0%

3.1.18. Sodium (Na^+)

Sodium is a cation found in significant concentrations of several types of soils in the Grand River Basin. These “Sodium Affected” soils are part of a family of soils that contain excessive concentrations of either soluble salts (calcium and magnesium) or exchangeable sodium, or both. The presence of excessive amounts of sodium is a more permanent problem in that exchangeable sodium usually persists after the removal of other soluble salts from the soil profile through remedial measures or special management practices (USDA, 1954). The sodium concentrations in the North Fork and the South Fork did not differ significantly ($P>0.05$). The mean concentrations for the North and South Forks were 474 mg/L and 447 mg/L, respectively (Table 9). However, the outlet from Shadehill Reservoir (Site SRO5 = 331 mg/L) was significantly less than the mean concentrations from the upstream monitoring sites ($df=2, n=121, P=0.0001$). Figure 22 graphically shows the distribution of sodium concentrations at each site. As is indicated,

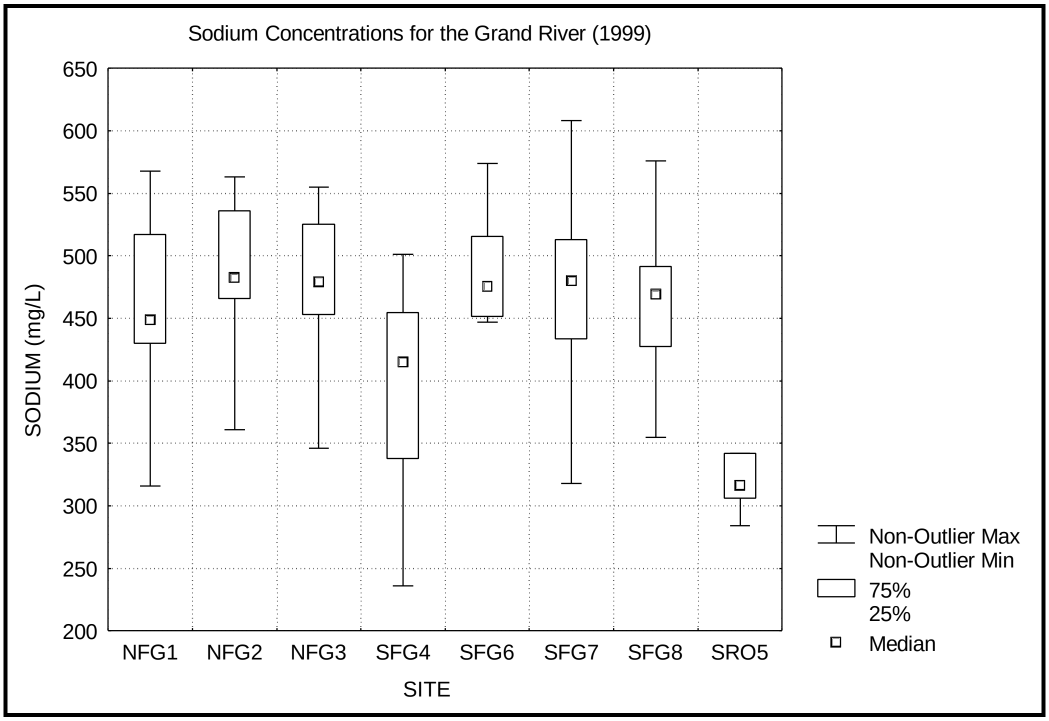


Figure 22. Sodium Concentrations for the Grand River, 1999.

Sites SRO5 exhibited the lowest mean concentrations for sodium which can be attributed to the chemical reactions in Shadehill Reservoir. The sediment and sodium settles out in the reservoir reducing the amount of these materials transported downstream.

Soil particles adsorb cations as a direct result of the electrical charges on the surface of the particle. The principal cations involved in this process are sodium, calcium, and magnesium. Even though the soil particle adsorbs a specific cation such as calcium, it can be readily exchanged depending on the concentration level of other cations that are present such as sodium. In some alkaline soil complexes, however, practically all of the cations are sodium resulting in that complex being classified “Sodium Affected” (USDA, 1954). This problem of excessive amounts of sodium can be exacerbated with the soils being exposed to the practice of irrigation. Due to the natural soil conditions and the corresponding water quality that exist in the Grand River basin, the USBOR, in conjunction with the State Agricultural Experiment Station, and the Agricultural Research Service, concluded that the water from the river basin could be used safely for sustained irrigation only on coarser, well-drained soils if irrigation practices were strictly controlled and gypsum (calcium) was periodically added to the exposed soils (USGS, 1964).

The sodium adsorption ratio (SAR) is a measure of the sodium or alkali hazard of water used for irrigation purposes (USGS, 1964). In the Water Quality Standards for the State of South Dakota it is defined as the following:

> SAR is a calculated value that evaluates the sodium hazard of irrigation water based on the Gapon equation and expressed by the mathematical expression:

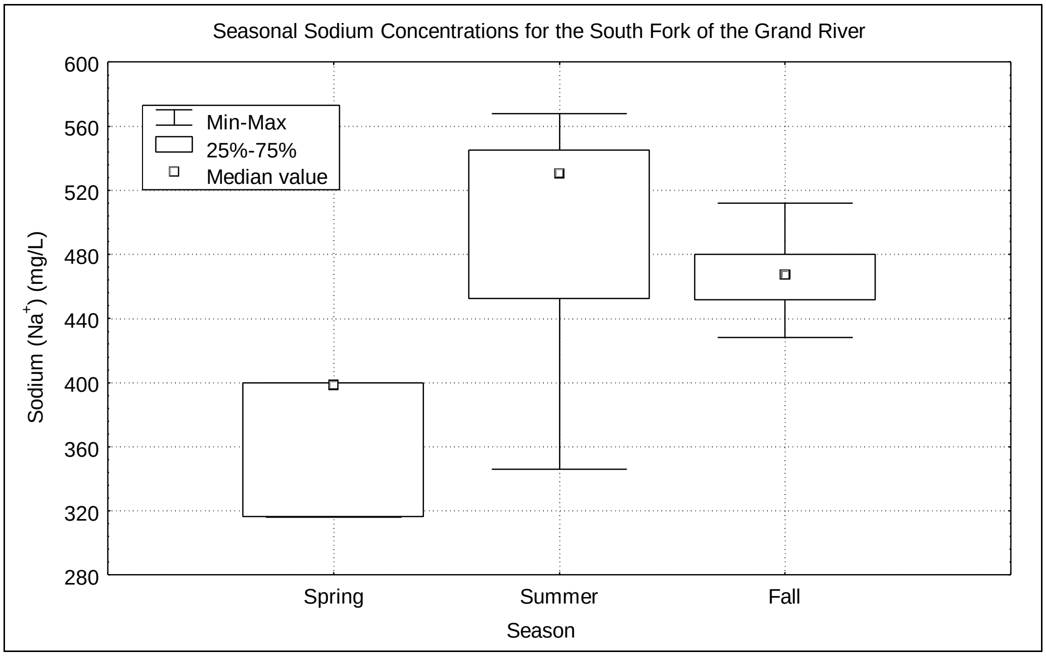


Figure 23. Seasonal sodium concentrations for the South Fork of the Grand River.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

All streams in South Dakota are assigned the beneficial uses of wildlife propagation and stock watering (9) and irrigation (10). The SAR is part of the criteria for the beneficial use irrigation waters (10) and cannot exceed 10 units (ARSD 74:51:03) (Table 4).

SAR data collected during the last 305(b) reporting cycle (1994-1998) indicated that ninety-one percent of the samples collected from the South Fork at Site SFG8 exceeded the standard of 10. Values ranged from 4.08 to 24.21. In the North Fork, samples collected from Site NFG3 ranged from 4.28 to 14.40 and with forty-five percent of the samples exceeding the SAR standard (Table 11). To supplement the current SAR information for the Grand River, samples collected since 1976 were reviewed to determine the consistency of the water quality samples exceeding SAR standard of 10. For the North Fork and the South Fork the rate of exceedance was roughly consistent with the current 305(b) reporting period at fifty-six and ninety-four percent, respectively (Table 12). The sodium loadings from each subwatershed are discussed in Section 3.??, pg X.

The sodium concentrations are not significantly different between sites (Figure 22) indicating that the sodium problem is relatively ubiquitous throughout the Grand River basin. The sodium also effects other parameters such as conductivity and pH and is a part of the high concentration of dissolved solids and total suspended solids, found within the Grand River. These results, in conjunction with literature discussions for sodium affected soils, show that this problem of

Table 12. Percent Exceedance of SAR Samples collected during the last 305(b) reporting cycle and collected since 1976.

Statistic	Site		
	NFG3	SFG8	SRO5
Total Number of Samples (1976 to Present)	34	33	
Number of Exceedances (1976 to Present)	19	31	
Percent Exceedance	56%	94%	
Minimum	4.28	4.08	
Maximum	16.32	45.07	
Mean	10.64	22.48	
Total Number of Samples (1994 to Present)*	11	11	10
Number of Exceedances (1994 to Present)	5	10	0
Percent Exceedance	45%	91%	0%
Minimum	4.28	4.08	5.96
Maximum	14.40	24.21	9.15
Mean	9.75	17.09	7.84
*305(b) Reporting Requirements regarding specific criteria for data used.			

excessive amounts of sodium is naturally occurring. The soils within the Grand River have been also been documented by Natural Resources Conservation Service (NRCS) Soils Survey as having extremely natric conditions (high amounts of exchangeable sodium). A more detailed discussion regarding the soil conditions for Harding and Perkins Counties can be found in the NRCS soil survey publications for each of these counties.

3.2 GROUNDWATER MONITORING

Groundwater was not monitored during this project.

3.3 STREAM PHYSICAL, BIOLOGICAL, OR HABITAT MONITORING

3.3.1. Habitat Assessment

The habitat assessment is used as an evaluation of the ecological integrity of a particular waterbody. In general, habitat, water quality, and biological diversity are closely linked (Barbour et al., 1999). This habitat assessment, in conjunction with the water quality data, can be used to help determine what may be the primary cause of impairment within a stream reach. In this habitat assessment for the Grand River there is a description and scoring of several different parameters at each one of the seven monitoring sites located on both forks of the Grand River. The habitat quality is critical to any assessment of ecological integrity and needs to be performed at each monitoring site. Ten different parameters are rated on a scale of 0 to 20 (highest). All parameters evaluated here are specifically designed for low gradient (prairie) streams. There is another set designed for high gradient (montane streams) as well (Barbour et al., 1999).

3.3.1.a. Epifaunal Substrate/Available Cover

Includes the relative quantity and variety of natural structures in the stream or river. This includes rocks, fallen trees, logs, and undercut banks. A large variety of submerged structures is optimal because the various habitats allow different kinds of organisms to colonize. The Grand River has a low variety of habitats due to natural circumstances. The Grand River is a prairie stream where trees are an infrequent habitat type. There is very little potential for submerged logs. There are areas of undercut banks and cobble and boulder-sized stones, which do provide habitat. The North Fork and South Fork are similar in the amount of material that is available for colonization.

On average, the North Fork reaches scored higher compared to the South Fork. Sites NFG1 and NFG3 on the North Fork were significantly higher than sites on the South Fork and the remaining site (NFG2) on the North Fork. The average rating for the North Fork was 12 whereas the South Fork average was only 9.75. The sites on the South Fork did not differ significantly from one another (Table 13). Although there were differences in the available cover they were not substantial. The Grand River is a low gradient prairie stream with a high percentage of gravel (0.1”-2.5”) and cobble (2.5”-10”). There is very little habitat for tree stands within the watershed. Subecoregion 43a in the Northwestern Great Plains ecoregion is a prairie-dominated ecoregion. Very few trees are found across the landscape. Grasses such as prairie cord grass (*Spartina spp*.) and bulrushes (*Scirpus spp*.) along with cattails (*Typha spp*.) are present in various stream reaches and dominate the riparian areas.

3.3.1.b. Pool Substrate Characterization (low gradient streams)

This parameter evaluates the type and condition of bottom substrates found within the pools. Firmer sediment types, i.e. gravel and rooted aquatic vegetation, support a wider variety of organisms (Barbour et al., 1999).

Table 13. 1999 RBP Habitat Assessment Values for the Grand River.

	Site							**Avg. Score NFork**	**Avg. Score SFork**	**Avg. Score for Overall**
Parameter	NFG1	NFG2	NFG3	SFG4	SFG6	SFG7	SFG8			
Epifaunal Substrate/Available Cover	**14**	9	13	10	10	10	9	**12**	**10**	**11**
Pool Substrate Characterization (Low Gradient)	16	9	**18**	11	17	17	8	**14**	**13**	**14**
Pool Variability (Low Gradient)	9	6	8	**10**	8	8	8	**8**	**9**	**8**
Sediment Deposition	13	16	**18**	12	8	9	8	**16**	**9**	**12**
Channel Flow Status	**18**	14	**18**	16	12	17	**18**	**17**	**16**	**16**
Channel Alteration	**19**	**19**	18	18	18	17	**19**	**19**	**18**	**18**
Channel Sinuosity (Low Gradient)	**13**	6	11	9	8	7	12	**10**	**9**	**9**
Bank Stability (Left Bank)	**9**	**9**	6	8	7	**9**	7	**8**	**8**	**8**
Bank Stability (Right Bank)	**9**	**9**	8	8	7	**9**	3	**9**	**7**	**8**
Bank Vegetation Protection (Left Bank)	**10**	8	7	8	8	8	7	**8**	**8**	**8**
Bank Vegetation Protection (Right Bank)	**10**	8	7	8	8	8	3	**8**	**7**	**7**
Riparian Vegetation Zone Width (Left Bank)	3	**7**	2	5	2	2	**7**	**4**	**4**	**4**
Riparian Vegetation Zone Width (Right Bank)	3	**7**	8	5	2	**7**	8	**6**	**6**	**6**
Total Habitat Value	**146**	127	142	**128**	115	**128**	117	**138**	**122**	**129**

There was almost no difference in the average rating for this parameter between both forks of the Grand River: North Fork = 14, South Fork = 13 (Table 13). However, there were two sites which scored significantly lower than the rest. Site NFG2 scored 9 and Site SFG8 scored 8. All other sites exceeded 11 for this parameter (Table 13).

3.3.1.c. Pool Variability (low gradient Streams)

This parameter evaluates the overall mixture of pool types found within the stream reach under assessment. The predominant pool type within the Grand River are large/long shallow pools.

Because the Grand River is relatively shallow for its entire length, all of the sites scored very similarly ranging from 6 to 10. The average scores for the North and South Forks were 8 and 9, respectively (Table 13). Site NFG2 scored the lowest overall with a 6 rating.

3.3.1.d. Sediment Deposition

Estimates the amount of sediment that has accumulated in the pools and measures the changes that have occurred to the stream bottom due to this accumulation. Sediment deposition within a stream may cause the formation of point bars or islands within the confines of the stream (Barbour et al., 1999).

The North Fork of the Grand River scored significantly higher than the South Fork, with an average score of 16 versus 9 for the South Fork (Table 13). Although the average score was lower on the South Fork, Site SFG4 rated a 12 compared to the three remaining downstream sites which scored 9 or lower. Site SFG4 exhibited the highest export coefficient for TSS concentrations but the stream is smaller and more confined in this subwatershed allowing the sediment to be transported further downstream.

3.3.1.e. Channel Flow Status

Channel flow status describes how much the channel is filled with water for either high or low gradient streams. Optimal scoring range indicates that a minimal amount of channel substrate is exposed whereas the poor scoring range describes channels that contain very little water, with most of the water contained in nearby pools (Barbour et al., 1999).

All of the sites scored in the lower optimal to suboptimal range. The North Fork sites averaged a score of 17 whereas the South Fork sites averaged 16 (Table 13). During the index period, which is the low flow period of the year (August 1 through October 1), the channels were full with minimal amount of channel substrate exposed. During a year with less precipitation the monitoring sites would have scored significantly lower.

3.3.1.f. Channel Alteration

Channel alteration measures any large changes that may have occurred in the stream channel resulting from small dams or channelization (Barbour et al., 1999). There was very little or no alteration exhibited by any of the sites. All seven monitoring sites were located upstream or downstream of highway bridges. These bridges were extremely large with a large amount of area between the pillars holding up the bridge. There was minimal disturbance in the actual channel itself due to the bridges. The average scores for the North Fork and the South Fork were 19 and 18, respectively (Table 13).

3.3.1.g. Channel Sinuosity (low gradient)

This parameter evaluates the extent of the meandering of the stream. If the stream exhibits more meandering there is more diversity in the habitat types that can be frequented by organisms (Barbour et al., 1999).

Although the North Fork and the South Fork did not differ significantly overall there was some within- fork variability exhibited between the sites (Table 13). The North Fork ranged from a low of 6 recorded from Site NFG2 to a high of 13 located at Site NFG1. The South Fork exhibited ratings within the marginal sinuosity range for the first three upstream sites (SFG4, SFG6, and SFG7).

3.3.1.h. Bank Stability

Bank stability estimates the extent of erosion on both sides of stream reach. Both sides can be rated on a scale of 1-10 and then are summed for a maximum possible score of 20. All but one of the sites scored in the suboptimal or higher range. The right bank at Site SFG8 scored much lower than the other sites scoring in the lower marginal range (3) due to a large eroding bank.

3.3.1.i. Bank Vegetation Protection

Bank vegetation protection is a measure of the amount or the extent of the vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone (Barbour et al., 1999). The same areas that scored high in bank stability scored high here as well. Site SFG8 had the same bank (right bank) score the lowest for all of the sites.

3.3.1.j. Riparian Vegetation Zone Width

This index measures the width of the riparian zone from the stream bank through the entire zone of riparian vegetation. A riparian zone provides adequate bank protection and acts as a filter for pollutants that are entering the stream. This parameter exhibited no differences between either fork of the Grand River (Table 13). Site NFG1 and Site SFG6 scored relatively low, scoring a total of 6 and 4, respectively (Table 13). Sites NFG2 and SFG8 scored the highest ratings with 14 and 15, respectively.

3.3.1.k. Total Habitat Value

The previous scores for the individual parameters were summed to determine the total habitat score. Table 13 shows the overall rating of each site indicating that the North Fork Site NFG1 scored the highest (146) out of a possible total of 200. Of the South Fork sites, both Site SFG4 and SFG7 scored 128. Site NFG2 scored lower primarily because of lack of channel sinuosity and pool substrate characterization (Table 13). The South Fork sites scored lower than the North Fork for most of the habitat parameters. However, Site SFG6 and SFG8 scored substantially lower for a variety of parameters. In contrast, Site SFG4, which exhibited significantly higher concentrations of suspended sediment, appeared to be only moderately impaired based on the habitat assessment.

In general, based on the RBP habitat assessment data, the Grand River seems to be moderately impaired. Although the North Fork is characterized by better riparian vegetation and bank stability when compared to the South Fork, the differences, in most cases, are not significant.

3.3.2. Benthic Macroinvertebrates and Metric Development

The biological data was collected over a 45-day period during late summer (July 15 through September 1). Rock baskets were the method of choice for collecting benthic macroinvertebrates during this designated index period. A description of the rock baskets and how they were deployed can be found in the standard protocols for the South Dakota Water Resources Assistance Program (SOP-SDWRAP). The macroinvertebrates were collected and shipped to a private consultant for identification and enumeration according to the SOP for SDWRAP. A standard count of 300 organisms was used in the calculation of 44 metrics (Table 14).

The raw data from the benthic macroinvertebrate sampling indicated that the top three taxa at each site are clingers, which is a result of the natural substrate that was used in the rock baskets. The most abundant taxa at Site NFG1 and NFG2 was *Hydropsyche morosa*, which is considered a facultative caddisfly, i.e. it can exist in a wide range of water quality conditions, but not heavily impacted sites. *Cheumatopsyche spp*., another facultative caddisfly, was the most abundant taxon at the remaining sites. The top three taxa at each indicate moderate impairment and/or enrichment that is typical of rivers this size. Stoneflies are absent from all sites indicating warmer temperatures during the summer and possible dissolved oxygen limitations for stoneflies.

Mayfly richness is moderate at all sites, which indicates that actual water quality is acceptable for this group of sensitive species. If metals, nitrogen or ammonia were causing impairment mayfly richness would be reduced dramatically, perhaps even eliminated.

The dominance of filter feeding individuals indicates that a major source of food for the benthic macroinvertebrate communities is fine particulate organic matter (FPOM). This is reflective of the extremely high concentrations of suspended sediment found in the Grand River. In general the North Fork sites have more taxa and higher diversity than the South Fork sites which may be reflection of the significantly less concentrations of suspended sediment. Tolerant taxa, expressed as a percent of the total number of individuals sampled, increases significantly from Site NFG1 to NFG3, as well as from Site SFG4 to SFG8. This indicates that there is a cumulative downstream impact on the biological community as the sediment accumulates and it is transported downstream (Lester, 2000). Raw data for the benthic macroinvertebrate sampling can be found in Appendix X.

3.3.2.a. Site Classification

Detection of changes in the biological assemblage must consider the impacts of human effects and the differences resulting from natural or geologic factors. There is natural variability in the benthic macroinvertebrate community that can be attributed to chemical and physical factors resulting from changes in the geology and vegetative conditions. These relatively homogeneous conditions can be classified into ecoregions. Ecoregions are a geographical method of delineating regions of similar geologic, climatic, and vegetative factors (Barbour et al., 1996).

There are five levels of ecoregions, which are based on their level of detail to the factors used to differentiate between them. Levels I and II are the broadest of ecoregions which divide the North American continent into 15 and 51 regions, respectively (Bryce et al., 1998). The geographic distribution of the Grand River monitoring sites was not sufficiently broad enough to cross level III ecoregion boundaries. However, the South Fork of the Grand River does meander through two level IV regions which are more detailed ecoregions for state-level applications (Figure 24). There were some changes in the macroinvertebrate community as a result of these natural geographic changes between level IV ecoregions. Not enough data (years) was collected overtime to determine with any degree of certainty if the variability between sites was due to the natural, geologic changes between level IV ecoregions but some water quality parameters suggest that this may be the case (suspended solids, pH).

There was no attempt at classifying the monitoring sites before data collection began. The data collected from all seven upstream (of Shadehill) was analyzed together. There was only one monitoring site on the South Fork of the Grand River which was located in another Level IV ecoregion (Site SFG4). The remaining six sites fell within Level IV 43a ecoregion (Missouri Plateau) (Figure 24).

In addition, there was no attempt made to classify the sites prior to data collection. There were no reference sites (least impacted conditions) that could be used to compare to the seven monitoring sites. This resulted in comparisons between sites and between both forks where the data from each fork was pooled together. These comparisons were conducted so that differences, if they existed, could be detected within the data set. As more data is collected in these ecoregions using the same methodology, least impacted sites as they exist in the Grand River basin will be identified and comparisons can be made at that time.

3.3.2.b. Testing of Candidate Metrics

The benthic macroinvertebrate community can be characterized through wide variety of metrics. Each metric detects differences in the benthic community. The goal of calculating the metrics and comparing them across varying site conditions and/or river basins is to be able to identify which metrics do a better job at discriminating between the site conditions.

A metric is a mathematical characterization of the aquatic macroinvertebrate community using the presence or absence of various genus/species of macroinvertebrates within a stream. Each group of insects (or lack thereof) can be used as indicators as to the health of the aquatic community and serve as long-term indicators of the water quality within the stream or lake.

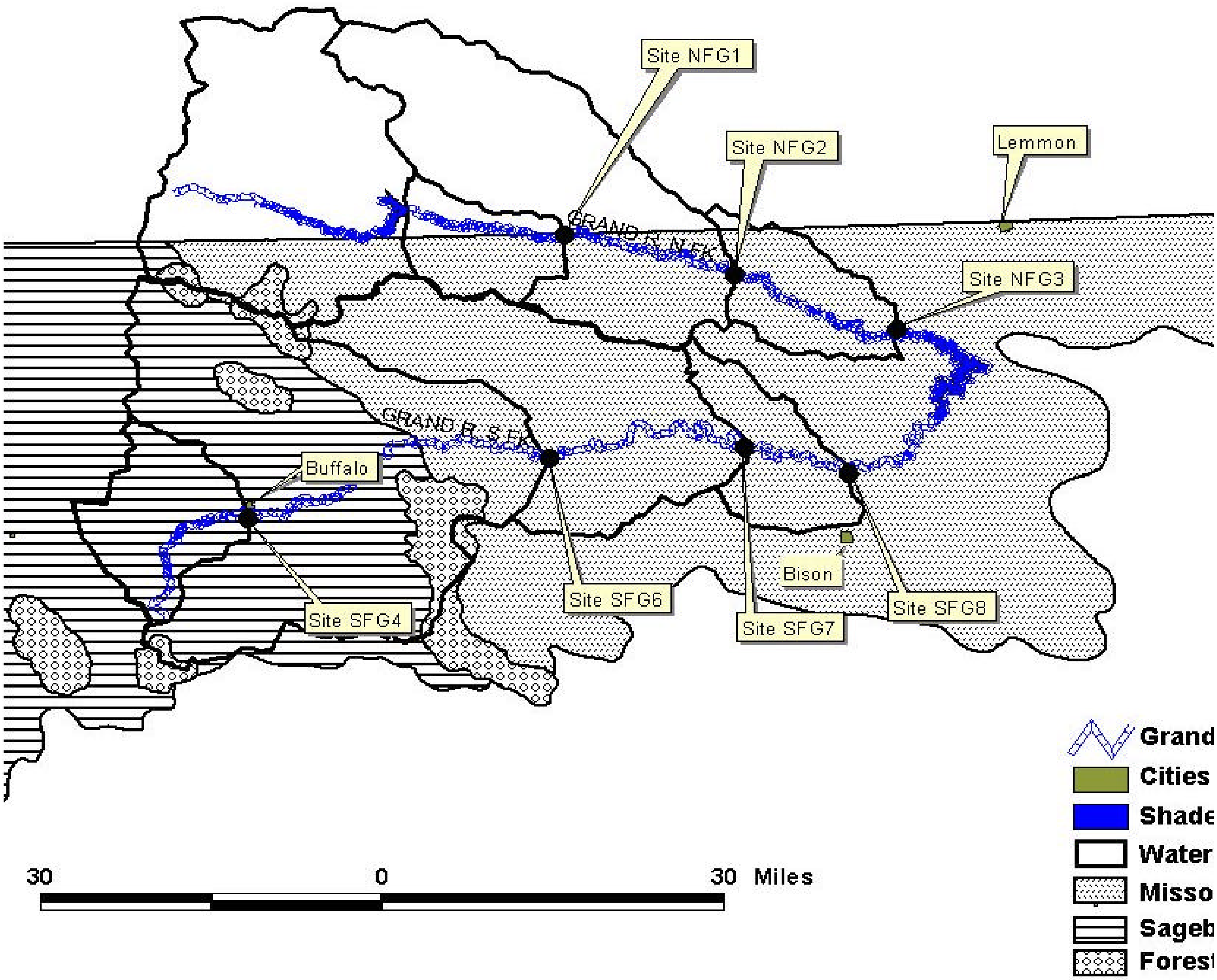


Figure 24. Level IV Ecoregions for the Grand River Basin.

Table 14. Metrics Calculated for the Grand River Watershed Assessment

Category	#	Metric	Expected Response to Increasing Disturbance
Abundance Measures	1	Corrected abundance	Variable
	2	EPT abundance	Decrease
	3	total taxa	Decrease
Dominance Measures	4	% 1 dominant taxon	Increase
	5	% 2 dominant taxa	Increase
	6	% 3 dominant taxa	Increase
Richness Measures	7	Species richness	Decrease
	8	EPT richness	Decrease
	9	Ephemeroptera richness	Decrease
	10	Trichoptera richness	Decrease
Community Composition	11	% Ephemeroptera	Decrease
	12	% Trichoptera	Decrease
	13	% EPT	Decrease
	14	% Coleoptera	Decrease
	15	% Diptera	Increase
	16	% Baetidae	Increase
	17	% Chironomidae	Increase
	18	% Ephemerellidae	Decrease
	19	% Hydropsychidae	Increase
	20	% Odonata	Increase
	21	% Simuliidae	Increase
Functional Group Composition	22	% filterers	Increase
	23	% gatherers	Decrease
	24	% predators	Decrease
	25	% scrapers	Decrease
	26	% shredders	Decrease
	27	filterer richness	Decrease
	28	gatherer richness	Decrease
	29	predator richness	Decrease
	30	scraper richness	Decrease
	31	shredder richness	Decrease
Diversity/Evenness Measures	32	Shannon-Weaver H' (log 10)	Decrease
	33	Shannon-Weaver H' (log 2)	Decrease
	34	Shannon-Weaver H' (log e)	Decrease
	35	Hilsenhoff Biotic Index	Increase
	36	Margalef's Richness	Decrease
	37	Metals Tolerance Index	Increase
	38	Pielou's J'	Decrease
	39	Simpson's Heterogeneity	Decrease
	40	Jaccard Similarity Index	Decrease
	41	Percent Similarity	Decrease
Habit Metrics	42	Long-lived taxa richness	Decrease
	43	Clinger richness	Decrease
	44	% tolerant taxa	Increase

The 44 metrics shown in Table 14 were calculated for each of the individual rock baskets (Five per site for a total of 35 rock baskets). The five replicates (baskets) helped to determine which metrics had greater sensitivity for detecting differences between least-impacted to most impacted conditions within the Grand River.

These 44 metrics were screened for their ability to detect changes between sites and forks of the Grand River (Table 14). All of the metrics fell into one of five general categories: taxonomic composition, taxonomic richness or abundance, feeding or trophic groups, life habit, and degree of tolerance to stress in the environment.

To help distinguish between conditions, the metrics in Table 14 were calculated for each of the five baskets placed at each site. There were five replicates per metric from each site which were then compared to five observations for the same metric from each of the six remaining monitoring sites to determine between site and among site variability. In addition to this site-by-site comparison, five observations per metric per site were pooled together for each fork of the Grand River. The North Fork with 15 observations per metric was then compared to the same metric with 20 observations from South Fork. This was to done to determine if pooling the data into two sets rather than between seven sets would help determine which metric is more capable of discriminating between conditions. A non-parametric test (Kruskal-Wallis) was conducted to determine if the metrics differed between sites (df=6, n=35) or between forks of the Grand River (df=1, n=35). Table 15 shows the various metrics that exhibited the strongest differences between all seven sites and both forks.

Table 15. Kruskal-Wallis Analysis P-values for five-core metrics chosen for the Grand River.

Metric	Differences between Sites (df=6, N=35) P values <0.05	Differences between Forks (df=1, N=35) P values < 0.05
Trichopteran Richness	0.0012	0.0010
Filterer Richness	0.0018	0.0004
HBI	0.0008	0.0000
Pielou's J	0.0008	0.0001
% Tolerant Taxa	0.0006	0.0009

After identifying which metrics exhibited the strongest differences between both forks and all seven monitoring sites, box and whisker plots were used to display these differences. Figure 25 illustrates how the statistical values are displayed for a box and whisker plot. This type of plot displays the minimum, maximum, and median values for a series of datapoints (metric values for the rock baskets). The outliers and extreme values are also calculated for the data set. The interquartile range or IQR in Figure 25 is that range of values between the 25th and 75th percentiles of the datapoints. The whiskers in the plot graphically refer to the minimum and maximum values that fall within the non-outlier range (Statsoft, 2000).

The box and whisker plots for all of the metrics shown in Table 12 were compared to determine the ability of each metric to discriminate between all seven monitoring sites and both forks of the Grand River. For the Species Richness metric values there is significant overlap between all seven monitoring sites (Figure 26B). There is also substantial overlap between both forks of the

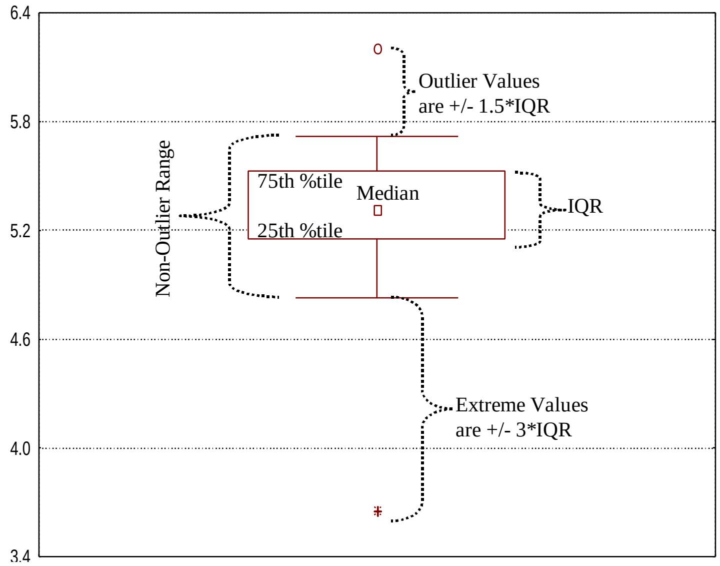


Figure 25. Example of a Box and Whisker Plot.

Grand River (Figure 26D). This metric (Species Richness) does not discriminate well for the changing conditions in the Grand River and was discarded. In contrast, Figures 26A and 26C illustrate the ability of the metric Trichopteran Richness to differentiate between the forks of the Grand River and between all seven monitoring sites. There was no overlap of the interquartile range (Figure 26C) between forks. There was some overlap of the IQR range when all seven sites were compared. However, there were still substantial differences exhibited between some of the sites. This metric was chosen as one of the final five core metrics.

The core metrics chosen need to be selected from the five main separate categories as well. In other words, there should not be five metrics chosen that fall within the taxonomic richness category. This is done to reduce the redundancy or the chance that two different metrics may be providing the same information.

3.3.2.c. Metric Standardization

After the core metrics were determined from the Grand River rock basket data, all five metrics were incorporated into a multimetric index. Each of the five metrics shown in Table 15 is a different measure of the benthic community. All five metrics were chosen because of their ability to show differences in conditions between sites and between the forks of the Grand River.

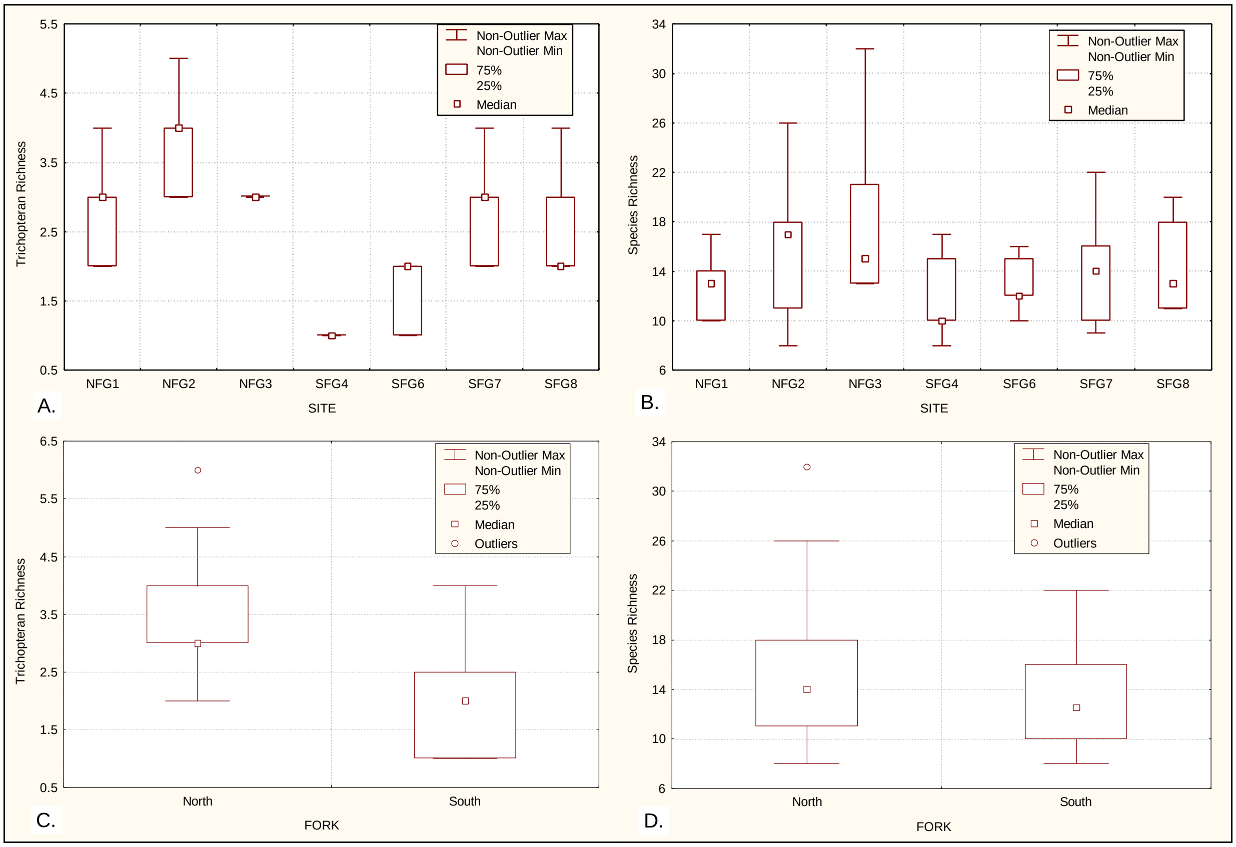


Figure 26. Metrics that discriminate well (A&C) versus those that don't (B&D).

The five individual metrics were averaged into a single multimetric index. Each metric was scored on a standardized scale of 0 to 100. This gives equal weight to each metric, i.e. no metric is more important than any other (Tetra Tech, 2000). Those metrics which have increasing values due to decreasing perturbation are easily converted to a 100-point scale using the following process. Of the five core metrics from the Grand River data, trichopteran richness, filterer richness, and Pielou's J are metrics that increase with decreasing perturbation. To convert these metrics to a standard 100-point scale (0=worst and 100=best) the following equation is used:

(Equation 1)

$$score = \left(\frac{X}{X_{95} - X_{min}} \right) \times 100$$

where, X = the metric value
X_{95} = the 95th percentile value
X_{min}= the minimum possible value, usually 0.

The 95th percentile (standard) value of the data distribution for each metric that increases with decreasing perturbation is used as the highest value possible. This is used as a quality control mechanism for reducing the influence that outlier and extreme values may have on the metric's data distribution (Tetra Tech, 2000).

Using this scoring method standardizes all the metrics to one scale giving each metric equal value. In some instances, using this equation may result in a value exceeding 100. When this happens, values greater than 100 should be scored no higher than 100. This is done to ensure equal weight for all metric values. No one metric can score higher than the maximum value of 100.

3.3.2.d. Reverse Metrics

Metrics which are expected to increase in value with increasing site perturbation (higher metric numbers represent worst sites) the 5th percentile value is used as the best score (100) when converting to a 100-point scale. Again, using the 5th percentile value instead of the minimum recorded value reduces the effect that outlier and extreme values may have on the data distribution. The minimum or 5th percentile (best) and maximum (worst) values for reverse metrics are converted to a 0 (worst) to 100 (best) point scale by using Equation 2.

(Equation 2)

$$score = \left(\frac{X_{max} - X}{X_{max} - X_5} \right) \times 100$$

where, X = the metric value
X_5 = the 5th percentile value
X_{max}= the maximum possible value; 100% for percentage metrics such as %tolerant taxa; 10 for HBI (Tetra Tech, 2000).

The Hilsenhoff Biotic Index or HBI metric and the % tolerant taxa metric are the remaining core metrics that have been termed reverse metrics, i.e. where the higher values indicate greater impairment (Table 13 and Table 14) (Tetra Tech, 2000).

3.3.2.e. Index Development (IBI)

By converting all of the core metrics in Table 15 over to a standard 100-point scale each metric contributes equally to the multimetric index (0-100). A single multimetric index was calculated by averaging the individual metric values for each site. Again, to ensure that each metric contributes equally to the final index, any individual metric scores exceeding the maximum 100 value were given a score of no more than 100. An example of the metric standardization using Equations 1 and 2, and the combining procedure is given in Table 16 for Site SFG4.

3.3.2.f. Index Application (IBI)

There were no criteria or distinctions made between reference and impaired sites prior to index development due to the minimal number of monitoring sites. The limited amount of data available in the development of the index was five rockbaskets per site at seven monitoring sites for a total number of 35 observations. The final Index of Biotic Integrity (IBI) developed from this data is very tentative and should only be used as a tool for ranking the monitoring sites

Table 16. Metric Standardization for Site SFG4 (South Fork)

Metric	Result due to increased impairment	Percentile for best value from data set	95th or 5th Percentile Value	Maximum or Minimum Value Possible	Measured Metric Value	Standardized Metric Score
Trichopteran Richness	Decrease	95th	5.00	0	1.00	20.00[a]
Filterer Richness	Decrease	95th	6.00	0	3.00	50.00[a]
HBI	Increase	5th	4.83	10	5.36	89.75[b]
Pielou's J	Decrease	95th	0.72	0	0.33	45.83[a]
%Tolerant Taxa	Increase	5th	0.94	100	49.08	51.40[b]
Final Index Score (IBI) for Site SFG4:						**51.40**
The [a] and [b] refer to equation 1 and equation 2, respectively (previous page).						
Table taken from West Virginia, 2000 report developed by Tetra Tech (Tetra Tech, 2000).						

within the Grand River Basin. As new data is collected in this level III ecoregion (43-Northwestern Great Plains) using the same collection methods, the IBI can be adjusted accordingly.

Data was not available to determine the sensitivity of the IBI. For the IBI to be valid it should be able to discriminate between impaired and non-impaired conditions. In order to determine how well this tentative IBI value is able to distinguish between differing site conditions, individual IBI values were calculated for each site by compositing all five rockbaskets at each site, i.e. all data from each site (five rockbaskets per site) were pooled together. Each of the five metrics in Table 15 was then calculated from this pooled data and then a corresponding IBI value was developed using equations 1 and 2 (Table 17). The resulting IBI values were ranked from highest to lowest for all seven sites. The pooled IBI value was compared to the average rock basket IBI for each site (Table 17). Based on this comparison, sites with lower IBI values were assumed to be more impaired than those with higher IBI values.

Ranking the forty-five day average water quality data with the habitat assessment data, and the IBI values, the three sites from the North Fork seem to be less impaired when compared to the South Fork sites (Table 18). The lowest pooled IBI value was exhibited by Site SFG4 with a score of 51.4. As is shown on Table 17, the lowest IBI value for the North Fork was 78.7 (Site NFG3) which is significantly higher. The pooled IBI values for each site were also compared to the five-basket average of the individual IBI values (Table 17). With the exception of the Site SFG4, all of the pooled IBI values fell within the 95% confidence interval of the five-basket average.

Table 17. IBI average values for five rock baskets and pooled basket data for each site.

Site	Confidence Levels (95.0%) (-)	Confidence Levels (95.0%) (+)	Basket Average	Pooled IBI
NFG1	72.10	89.20	80.7	81.7
NFG2	77.33	90.65	84.0	83.3
NFG3	70.97	94.14	82.6	78.7
SFG4	59.48	64.98	62.2	51.4
SFG6	60.98	71.89	66.4	58.4
SFG7	60.53	80.02	70.3	68.5
SFG8	47.47	69.79	58.6	62.3

Table 18. IBI values, average fecal and TSS concentrations and the habitat assessment values for seven monitoring sites on the Grand River.

Site	IBI Value	45 day Average Fecal	45 day Average TSS	Habitat Assessment
NFG1	**84**	**54**	77	**146**
NFG2	81	264	**53**	127
NFG3	81	2368	**53**	142
SFG4	51	**720**	1057	**128**
SFG6	57	948	381	115
SFG7	**65**	1015	**315**	**128**
SFG8	60	944	351	117

To determine a possible cause for the changes in the IBI values, the average TSS concentrations for each site that was produced from the total loadings (TSS load divided by total water and converting Kg/acre-foot to mg/L). This calculated TSS concentration was regressed against the IBI resulting in Figure 28. Although a relatively strong relationship exists between these two variables there were only seven data points for analysis (R^2=0.84). If more long-term data was available a different outcome could be exhibited, i.e. stronger relationship. When the IBI values were regressed against the total habitat values a significant relationship was not exhibited (R^2=0.42) (Figure 27). The effect of habitat assessment values on IBI values may be weak to moderate due to the lack of large differences between habitat assessment scores. This is in contrast to the significant differences that exist between sites regarding the total suspended solids concentrations. Although the data set is small, these relationships indicate that the TSS concentrations may be having a significant impact on the biological community of the Grand River.

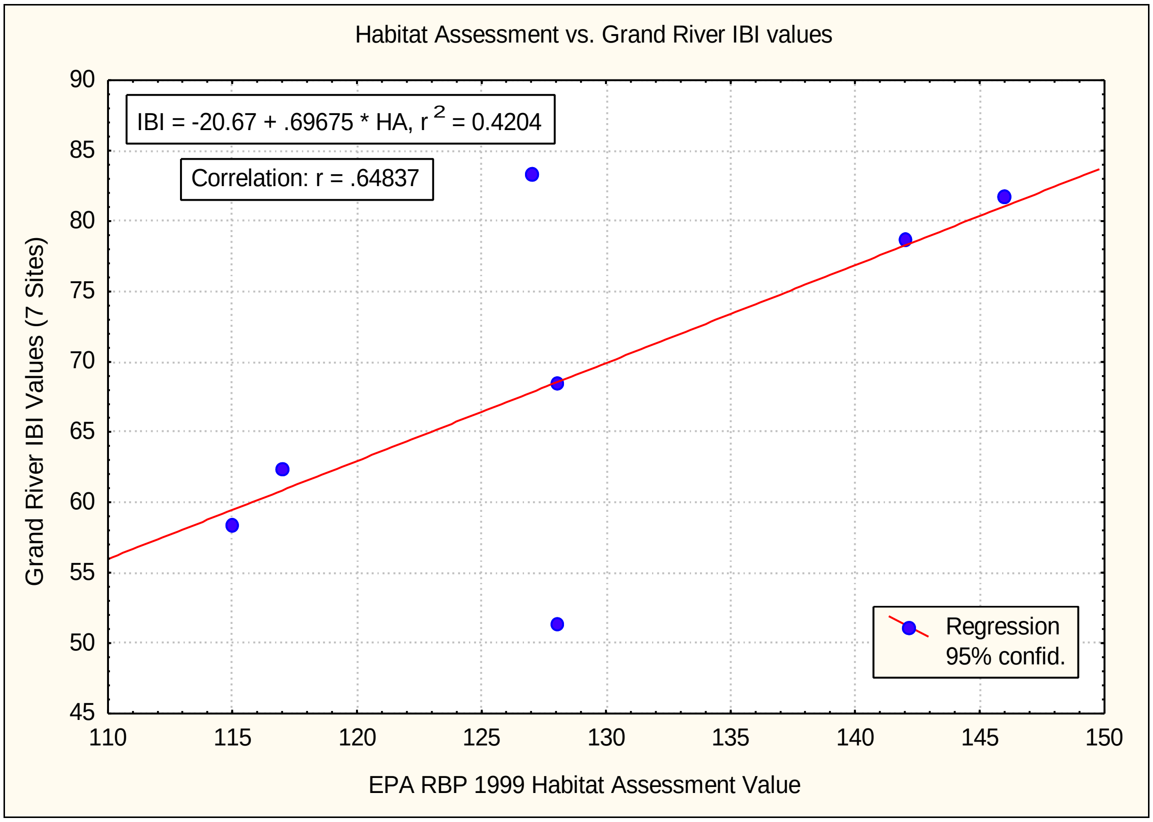


Figure 27. Habitat Assessment vs. Grand River IBI Values.

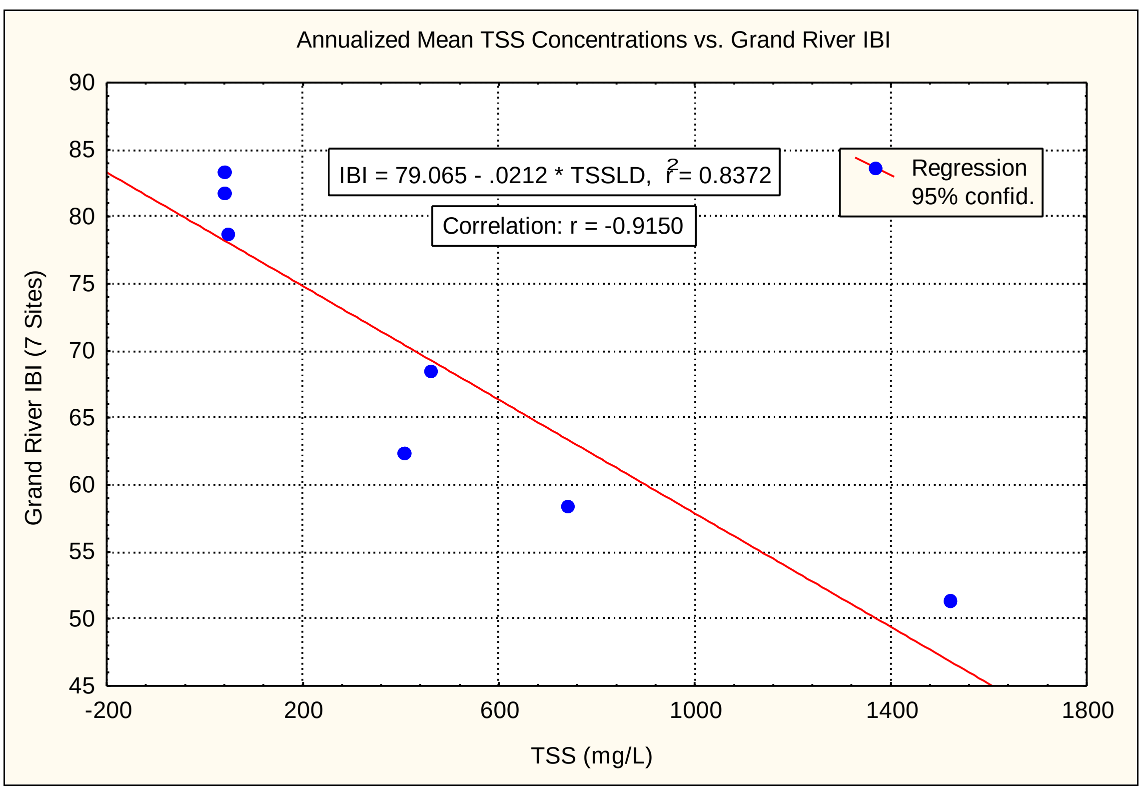


Figure 28. Mean TSS Concentrations vs. Grand River IBI Values.

3.3.3. Fisheries Assessments

During 1995 and 1996 the South Dakota Game, Fish and Parks (SDGFP) conducted fisheries surveys for the Grand River and several of it's smaller tributaries. These were the first surveys conducted on the Grand River and, as a result, no management options were recommended. The surveys were designed for the collection of baseline data. All current fisheries surveys can be found in Appendix X.

There were several species found within the South Fork and North Fork of the Grand River that have been designated as intolerant species. The 1999 USEPA Rapid Bioassessment Protocols has listed both the Longnose Dace (*Rhinichthys cataractae*) and the Stonecat (*Noturus flavus*) as intolerant fish species. However, these two species may be moderately tolerant to tolerant for sediment-laden streams such as the Grand River.

3.3.4. Threatened and Endangered Species (T&E)

Data for threatened and endangered species was provided by the SD Natural Heritage Database (Backlund, 2000). A table showing the entire list for threatened and endangered species that have been found within the Grand River watershed at one time or another can be found in Appendix X. The lack of records for any area of the watershed does not indicate that T&E species are absent. It is possible that T&E species could be found in other areas of the watershed if a survey was conducted. Migratory species such as the federally endangered whooping crane or federally threatened bald eagle could occur in the watershed temporarily. Bald eagles are actually quite likely to occur during migration and may occasionally winter in these areas. There have been some summer sightings of adult bald eagles in the lower Grand River, indicating possible nesting.

It is highly unlikely that black-footed ferrets or lynx still occur in the area. Both species are thought to be extirpated from this area of South Dakota. Sturgeon chub have not been found in the watershed for many years. Several fisheries surveys have been conducted in recent years but none have detected sturgeon chub in the Grand River. This species may be extirpated from the Grand River.

The US FWS has reported that Topeka shiners (federal endangered) were collected from the Grand River embayment of Lake Oahe based on this report: Beckman, L.G. and J.H. Elrod. 1971. Apparent Abundance and Distribution of Young-of-Year Fishes in Lake Oahe, 1965-1969. Reservoir Fisheries and Limnology Special Publication No. 8 1971 of the American Fisheries Society. pp. 333-347. The SDGFP does not accept this record as a valid report and it was not entered into the SD Heritage database. No specimens were kept and it is fairly certain that this was a case of misidentification.

3.4 OTHER MONITORING

3.4.1. Sediment and Nutrient Loadings

The FLUX model (Walker, 1996) was used to calculate the loadings for each of the sites that were monitored during 1999 and 2000. Spring data was not collected during the 1999 sampling year but was collected during 2000. This data was combined with the 1999 data to complete a full year of sediment and nutrient loadings. The FLUX model uses the concentration data and average daily flow to develop annual loadings using six calculation methods. Stratifying the data toward the convergence of the six model outputs optimized each model run for an individual monitoring site and parameter.

The parameter of concern for the Grand River Basin is sediment. The loadings for sediment were estimated by using the suspended solids concentrations for each monitoring site. Nutrient loadings, although not identified as a problem in either the North Fork or the South Fork of the Grand River, were also calculated using the FLUX program. Estimated loads were calculated by dividing the annual FLUX load by watershed area above each monitoring station. These loadings represent cumulative load to each reach, routed through the watershed. Export coefficients were also calculated for the reach located between monitoring sites to determine whether there was large influx of material between the sites. Figure 27 shows the subwatersheds located in both forks of the Grand River.

The subsequent tables in this discussion include the mass loadings, which are the estimated loadings delivered during the monitoring period (March 1- November 15, 1999) whereas the FLUX loadings are the estimated loadings delivered over the course of a one-year period (12 months).

Table 19 shows both the cumulative size of the watershed and the area of the subwatershed that is located between the monitoring sites. Bowman-Haley Reservoir is located in North Dakota in the subwatershed monitored by Site NFG1. Since no water quality data was available from the discharges of this reservoir it was assumed that there were minimal amounts of sediment and nutrient loadings provided to the subwatershed of Site NFG1 by this reservoir. The watershed of Bowman-Haley Reservoir was subtracted from the watershed of Site NFG1 increasing the size of each of the export coefficients for each parameter. (Export coefficient = total load divided by the drainage area, decreasing the size of the drainage area will increase the coefficient).

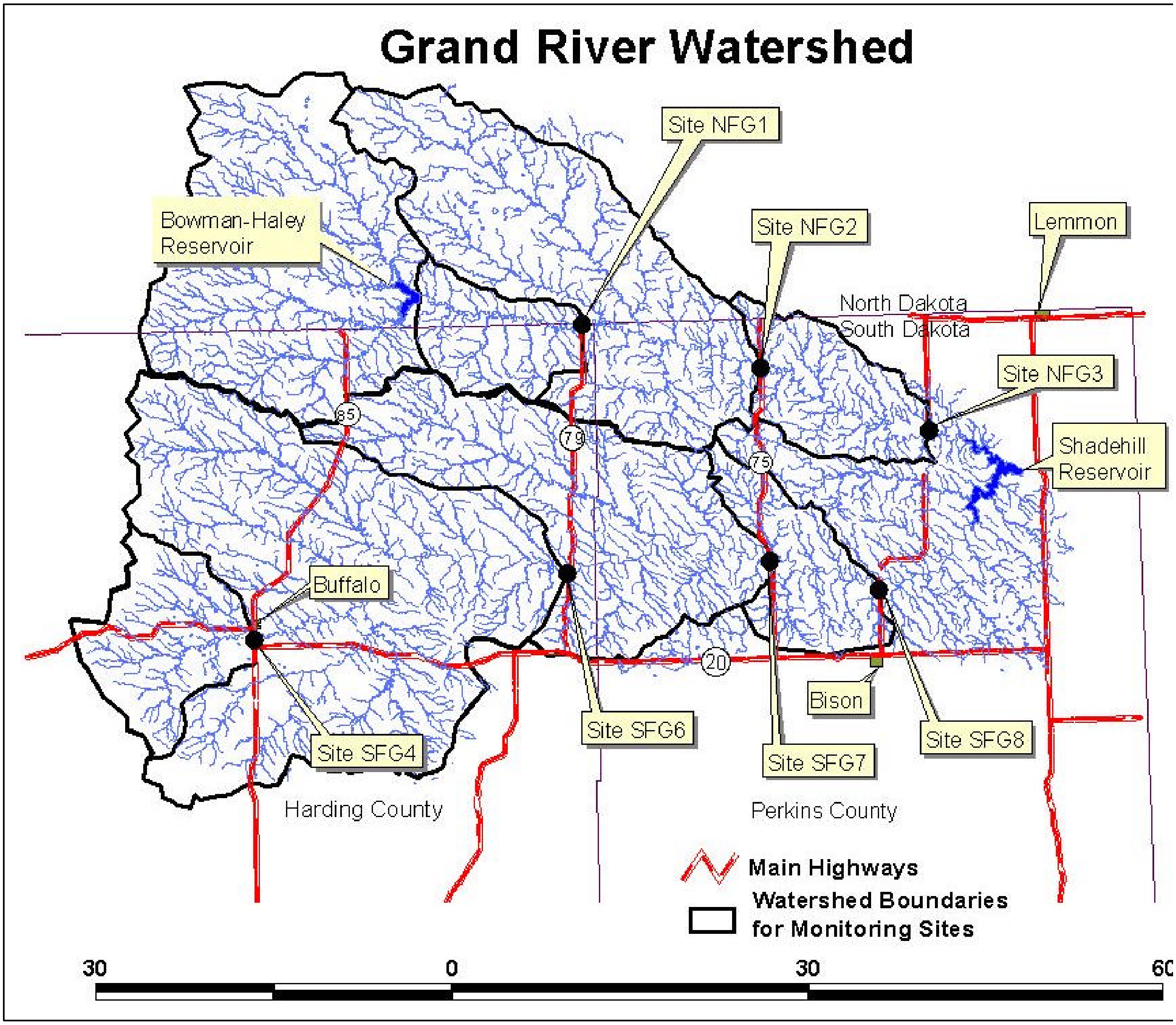


Figure 29. Grand River Watershed.

Table 19. Cumulative and sub-watershed drainage area above each monitoring site including Bowman-Haley Reservoir located in North Dakota.

Site	Fork	Cumulative Watershed Area (acres)	Sub-Watershed Area (acres)*
Bowman-Haley Res.	North	323,955	323,955
NFG1	North	396,422	72,467
NFG2	North	704,469	308,047
NFG3	North	792,114	87,645
SFG4	South	104,414	104,414
SFG6	South	607,412	502,998
SFG7	South	878,392	270,980
SFG8	South	962,451	84,059
Shadehill Res.	N/A		
* Sub-watershed is area located between monitoring stations			

3.4.1.a. Hydrologic Loadings

Seasonally, the amount of water discharged from the Grand River basin is consistently higher during spring as a result of spring snowmelt and spring rains. After this period the flow drops off substantially (Figure 30A-C). All monitoring sites for both forks of the Grand River discharged

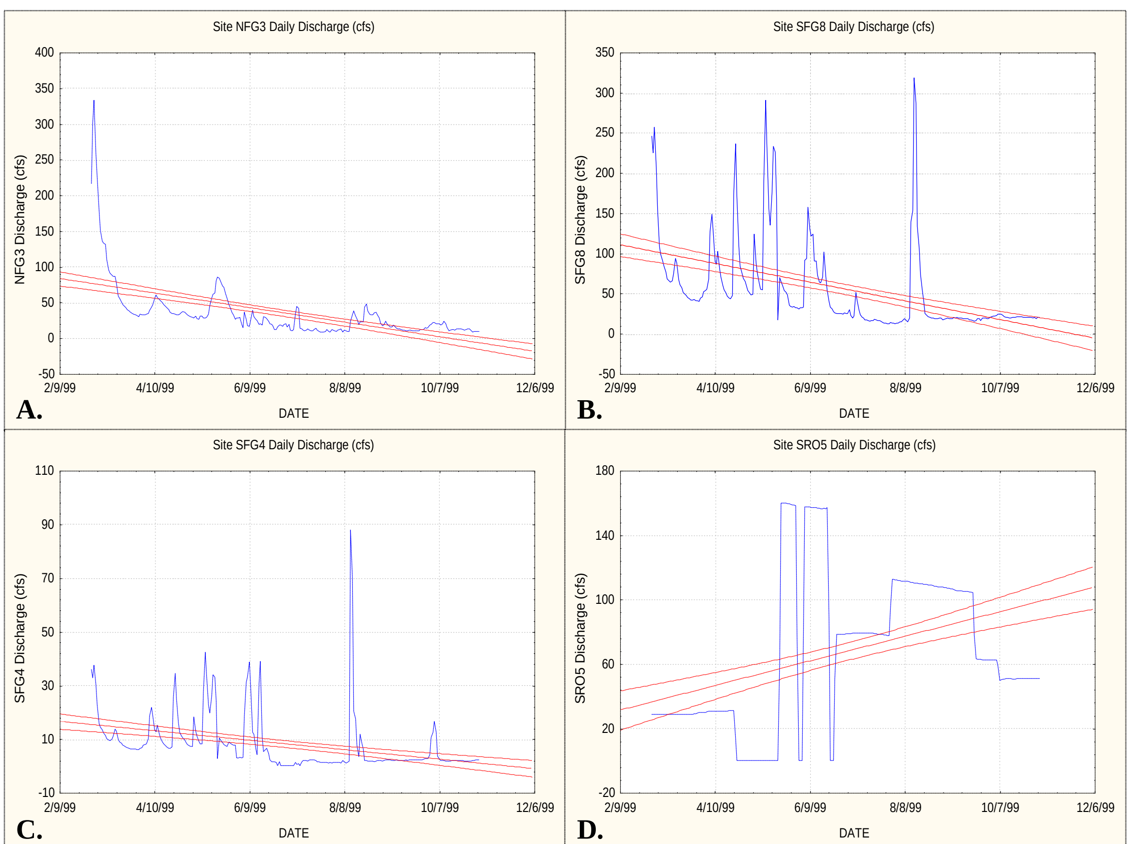


Figure 30. Flow duration curves for four sites within the Grand River Basin.

approximately 60% of their water during the spring of the year (March 1 - May 31). The reservoir outlet site (SRO5) did not exhibit this trend as is shown in Figure 30D. The discharge from Shadehill Reservoir is based on storage during the spring of the year, reducing the potential for flooding, and discharging during the summer and fall to maintain flow in the lower Grand River as is indicated in the figure.

3.4.1.b. Total Dissolved Phosphorus Loadings

Higher annual loadings of total dissolved phosphorus were observed on the upper watershed of each fork of the Grand River. Site NFG1 exhibited the highest export coefficient of total dissolved phosphorus at 0.03 lbs/acre/yr. Downstream of NFG1 the export coefficients dropped significantly for dissolved phosphorus (Table 20). The higher export coefficient for Site NFG1 could be attributed to the discharge from Bowman-Haley Reservoir and the possibility of greater percentage of cropland in this subwatershed. The reservoir allows biological productivity/decomposition that may result in a higher concentration of dissolved phosphorus. Concentrations and loadings were not significantly high in any of the reaches of the North Fork or the South Fork. Although there may be a higher percentage of cropland in the subwatershed NFG1, there is still an overall scarcity of cultivated cropland in the watershed of the Grand River.

The subwatersheds above sites SFG4 and SFG7 exhibited higher export coefficients for dissolved phosphorus. The accepted numeric level as to when a nuisance algae bloom may develop only in lakes has been identified in the literature as 0.02 mg/L (Wetzel, 1983). The mean concentrations of dissolved phosphorus correlate well with the export coefficients in most instances. In fact, the maximum concentration of 0.292 mg/L of TDP was collected from Site SFG4. The higher dissolved phosphorus loadings are associated with suspended solids loadings which increase with flow. Although dissolved phosphorus is not attached to soil particles, the higher concentrations were associated with higher concentrations of suspended solids. The highest mean concentrations of dissolved phosphorus occurred at Site SFG4 where most of the other parameters exhibited the highest concentrations.

Table 20. FLUX model loading estimates of total dissolved phosphorus to sampled reaches within each fork of the Grand River, 1999.

Site	**Mass** (lbs)	FLUX (lbs/yr)	Cumulative Watershed Area (acres)	Cumulative Export Coefficient (lbs/acre/yr)	Sub-Watershed Area (acres)	Sub-Watershed Export Coefficient* (lbs/acre/yr)
NFG1	**1,491**	**2,205**	**396,422**	**0.006**	**72,467**	**0.030**
NFG2	1,023	1,519	704,469	0.002	308,047	>0.000**
NFG3	1,104	1,639	792,114	0.002	87,645	0.001
SFG4	**991**	**1,471**	**104,414**	**0.014**	**104,414**	**0.014**
SFG6	2,915	4,328	607,412	0.007	502,998	0.006
SFG7	5,439	8,076	878,392	0.009	270,980	0.014
SFG8	2,855	4,239	962,451	0.004	84,059	>0.000**

* The subwatershed export coefficient is the amount of material that is delivered from just the subwatershed above the monitoring site. It doesn't include the cumulative drainage are a or the cumulative loading. For example, Site NFG2 loadings are subtracted from Site NFG1 and then divided by the size of the subwatershed area which would be 308,047 acres in this case.

** These export coefficients were less than 0. This means for exam ple that the material delivered from Site NFG2 was derived in the NFG1 subwatershed resulting in a negative number. There would be some loading from the NFG 2 subwatershed but when subtracted from upper watershed loadings it becomes nonexistent.

3.4.1.c. Total Phosphorus Loadings

Table 21 shows the total phosphorus loadings for both forks of the Grand River. As is indicated, the higher export coefficients occur in subwatersheds NFG1 in the North Fork and SFG4 in the South Fork. The loadings are delivered from the upper portions of the watersheds and are then deposited in various areas in the downstream watersheds or transported to Shadehill Reservoir. This upstream to downstream phenomenon is indicated on Table 21 where in the North Fork Site NFG3 exhibited the lowest overall loading and the lowest export coefficients.

The South Fork of the Grand River exhibited the same trend. Because the watershed above Site SFG4 is substantially smaller in drainage area the total mass loadings are going to be smaller. However, on a per unit area (acre) basis the export coefficient is significantly higher. Progressing downstream the mass and FLUX loadings peak at Site SFG6 and drop substantially through the next two subwatersheds (SFG7 and SFG8). Because the phosphorus is bound to the soil particles, the suspended solids loadings follow this trend as well, as is shown by Table 23. This stretch of river immediately above Site SFG6 is located on the boundary between two level IV ecoregions. This shift in geology may be the primary reason for the significant reductions in export coefficients for the downstream sites. The geology, meandering of the river, and the contribution of groundwater or recharge areas of various aquifers play a role in the amount of material that is ultimately transported to Shadehill Reservoir (USGS, 1964).

Table 21. FLUX model loading estimates of total phosphorus to sampled reaches within each fork of the Grand River, 1999.

Site	**Mass** (lbs)	FLUX (lbs/yr)	Cumulative Watershed Area (acres)	Cumulative Export Coefficient (lbs/acre/yr)	Sub-Watershed Area (acres)	Sub-Watershed Export Coefficient* (lbs/acre/yr)
NFG1	**3,544**	**5,241**	**396,422**	**0.013**	**72,467**	**0.072**
NFG2	4,036	5,992	704,469	0.009	308,047	0.002
NFG3	3,376	5,011	792,114	0.006	87,645	>0.000*
SFG4	**7,026**	**10,432**	**104,414**	**0.100**	**104,414**	**0.100**
SFG6	21,881	32,488	607,412	0.053	502,998	0.044
SFG7	20,755	30,816	878,392	0.035	270,980	>0.000*
SFG8	16,999	25,238	962,451	0.026	84,059	>0.000*
* and ** please review Table 19.						

3.4.1.d. Total Nitrogen Loadings

Total nitrogen loadings included all forms of nitrogen, both inorganic and organic. The same trends previously discussed with phosphorus were also exhibited by total nitrogen. Higher export coefficients were located in the upper subwatersheds on both forks of the Grand River. Site NFG1 exhibited a much higher overall loading which can be attributed to higher nitrogen concentrations delivered from Bowman-Haley Reservoir. Although Site NFG1 did not exhibit the maximum concentration for total nitrogen during the project it did exhibit the highest mean concentration (Table 8, pg. 31). Total nitrogen loadings gradually decreased downstream resulting in a significantly reduced export coefficient from the NFG2 subwatershed (Table 22).

The South Fork exhibited an opposite trend from that documented for the North Fork (Table 22). The loadings became progressively larger in the downstream monitoring sites. However, the subwatershed export coefficients became lower as the size of the drainage area increased. The highest mean concentration and maximum concentration (8.09 mg/L) for the South Fork was collected from Site SFG4. The majority of the nitrogen (>80%) was organic. This may be attributed to the large increases in flows that occur in a short period of time in this small subwatershed located above Site SFG4 (Table 22). The high flows rip vegetation from the landscape and transport it downstream.

Table 22. FLUX model-loading estimates of total nitrogen to sampled reaches within either fork of the Grand River, 1999.

Site	**Mass** (lbs)	FLUX (lbs/yr)	Cumulative Watershed Area (acres)	Cumulative Export Coefficient (lbs/acre/yr)	Sub-Watershed Area (acres)	Sub-Watershed Export Coefficient* (lbs/acre/yr)
NFG1	**77,500**	**114,603**	**396,422**	**0.289**	**72,467**	**1.581**
NFG2	53,235	79,041	704,469	0.112	308,047	>0.000**
NFG3	60,977	90,536	792,114	0.114	87,645	0.131
SFG4	**21,994**	**32,655**	**104,414**	**0.313**	**104,414**	**0.313**
SFG6	103,531	153,718	607,412	0.253	502,998	0.241
SFG7	121,338	180,157	878,392	0.205	270,980	0.098
SFG8	125,216	185,916	962,451	0.193	84,059	0.069
* and ** please review Table 19.						

3.4.1.e. Total Suspended Solids Loadings

The United States Geological Survey (USGS) completed an investigation regarding the chemical quality of surface waters and related sediment discharge for the Grand River in 1964. From the data that was collected during the period of 1947-60, the yearly sediment discharges were even more variable than the yearly streamflow. A very long period of record would normally be required for an accurate determination of the average sediment discharge.

The suspended sediment data for 1999-2000 was also extremely variable. The South Fork ranged from a maximum concentration of 6,620 mg/L collected from Site SFG4 to a minimum of 42 mg/L, which was also collected from the same site. The previous discussion regarding the water quality data showed the mean concentration in the South Fork was 488 mg/L as compared to the North Fork which was 46 mg/L. Flows were slightly different between years but with the varying soil types and the presence of Bowman-Haley Reservoir in the upper watershed of the North Fork, the difference in suspended solids concentrations can be attributed to these two factors. To compare crop acreages and landuse percentages for the North fork and South Fork please review the PSIAC modeling sections, pages X.X.

The loadings for the North Fork exhibited higher loadings per unit area (export coefficients) for the subwatershed between Bowman-Haley Reservoir and Site NFG1 (Table 22). The loadings between Site NFG1 and NFG2 dropped slightly resulting in an extremely low export coefficient. At Site NFG3 the TSS export coefficient increased indicating some potential contributions from some smaller tributaries or erosion along the banks of the river. Locations of these subwatersheds can be seen on Figure 29, page 57. The North Fork Watershed is in a different ecoregion (Missouri Plateau) where the soils exhibit higher fertility which is more conducive to grasses and Forbes that hold soils in place.

In comparison, the upper watershed of the South Fork is in the Sagebrush Steppe ecoregion which is dominated by soils that are typically more flocculent and more dispersive by nature resulting in higher concentrations of suspended solids. They are also less conducive to high densities of grasses and do not exhibit high rates of infiltration.

The highest export coefficient of 239.7 lbs/acre/year was calculated from the Site SFG4. Although the total loadings increased by 254% from subwatershed SFG4 to subwatershed SFG6 the export coefficient dropped 311%. In addition, the total loadings for the remaining downstream sites for the South Fork dropped substantially. This is due, in part, to lower concentrations. The mean concentrations for TSS were significantly lower downstream when compared to Site SFG4 and SFG6 (Table 8, page 31).

Although the within-site and between-site variability is extremely high, the trends indicate that most of the erosion and contribution of sediment into the South Fork is occurring in subwatersheds SFG4 and SFG6. The downstream sites are significantly lower when export coefficients are compared.

Table 23. FLUX model-loading estimates of total suspended solids to sampled reaches within either fork of the Grand River, 1999.

Site	**Mass** (tons)	FLUX (tons/yr)	Cumulative Watershed Area (acres)	Cumulative Export Coefficient (lbs/acre/yr)	Sub-Watershed Area (acres)	Sub-Watershed Export Coefficient* (lbs/acre/yr)
NFG1	**1,025**	**1,516**	**396,422**	**7.65**	**72,467**	**41.8**
NFG2	810	1,202	704,469	3.41	308,047	>0.0**
NFG3	1,097	1,629	792,114	4.11	87,645	9.8
SFG4	**8,427**	**12,513**	**104,414**	**239.7**	**104,414**	**239.7**
SFG6	**21,462**	**31,865**	**607,412**	**104.9**	**502,998**	**77.0**
SFG7	15,762	23,402	878,392	53.3	270,980	>0.0**
SFG8	14,952	22,200	962,451	46.1	84,059	>0.0**
For * and ** please review Table19.						

The influx of sediment from Ecoregion 43e (Sagebrush Steppe) is further evidenced by Table 23. Samples were collected from the smaller tributaries that drain to the forks of the Grand River. The three tributaries that drain through Ecoregion 43e are all located above Site SFG6 and have significantly higher concentrations of TSS.

Table 24. TSS concentrations for the smaller tributaries draining to the forks of the Grand River.

SITE	Fork	Ecoregion	Count	Mean	Maximum	Minimum	St Dev
Big Nasty	South	43a	6	42	72	20	20.66
Butcher Creek	South	43a	6	13	24	5	6.75
Crooked Creek	North	43a	5	51	68	30	14.28
LodgePole Creek	Shadehill	43a	4	58	188	10	86.97
Bull Creek	South	**43e**	5	98	158	46	45.10
Clarks Fork Creek	South	**43e**	6	602	3150	52	1249.24
Jones Creek	South	**43e**	6	332	1380	46	518.18

The loadings results indicate that there is a significantly higher contribution of sediment and nutrients occurring in the upper watersheds of both forks. Table 25 shows the export coefficients for all parameters.

Table 25. Comparison of all export coefficients for all sites within the Grand River.

	Cumulative Export Coefficients lbs/acre/year				Sub-Watershed Export Coefficients lbs/acre/year			
Site	TN	TDP	TP	TSS	TN	TDP	TP	TSS
NFG1	**0.29**	**0.006**	**0.013**	**7.7**	**1.58**	**0.030**	**0.072**	**41.8**
NFG2	0.11	0.002	0.009	3.4	-0.12	-0.002	0.002	-2.0
NFG3	0.11	0.002	0.006	4.1	0.13	0.001	-0.011	9.75
SFG4	**0.31**	**0.014**	**0.100**	**239.7**	--	--	--	--
SFG6	0.24	0.007	0.053	104.9	0.25	0.006	0.044	77.0
SFG7	0.21	0.009	0.035	53.3	0.10	0.014	-0.006	-62.5
SFG8	0.19	0.004	0.026	46.1	0.07	-0.046	-0.066	-28.6

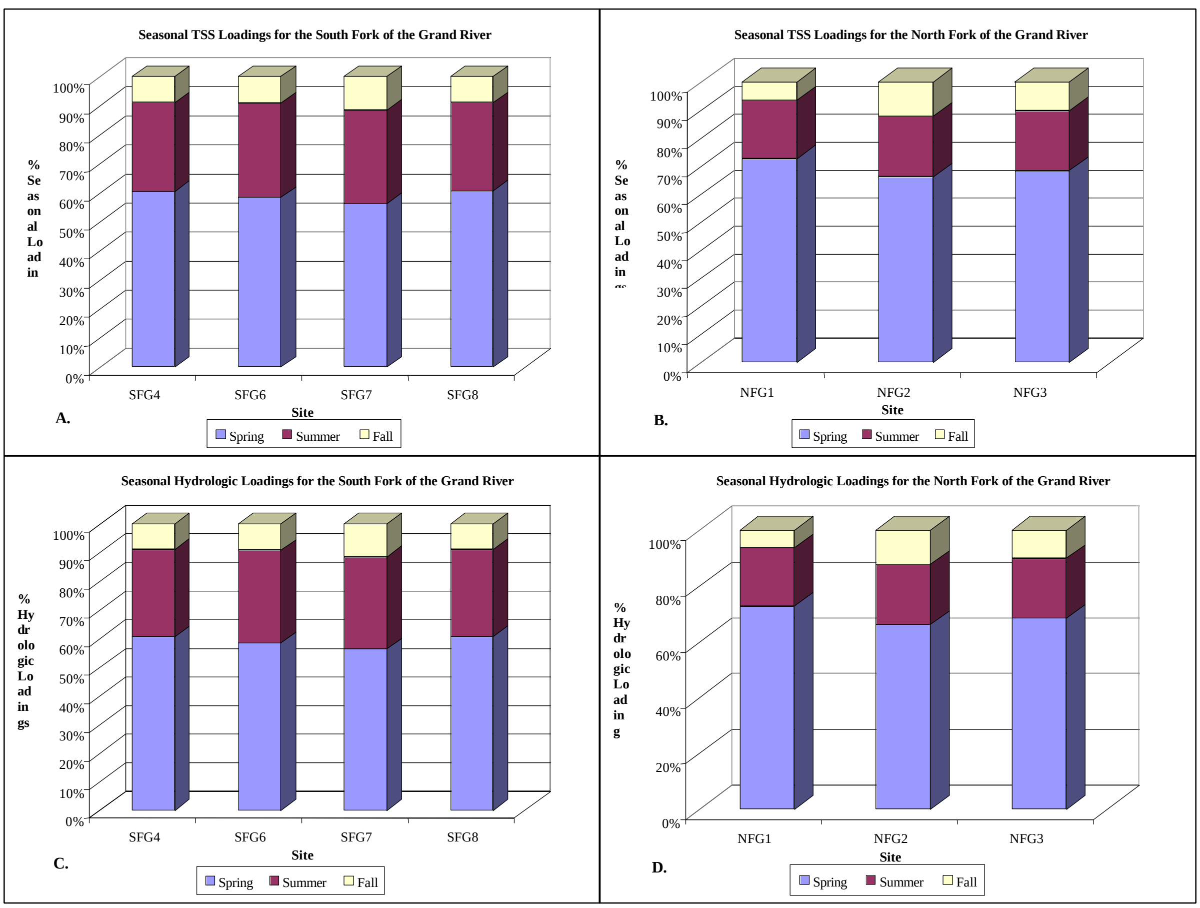


Figure 31. Seasonal hydrologic loadings for four sites within the Grand River.

3.4.1.f. Sodium Loadings

Sodium Loadings are a reflection of the sodium affected soils within the Grand River Basin. The cumulative export coefficients were not significantly different between the North and South Forks. However, the subwatersheds that are providing most of the sodium are located in the upper watersheds of both forks. A similar trend was observed for the total suspended solids loadings in the previous discussion. As Table 26 indicates, most of the sodium for the North Fork was derived above Site NFG1. A substantial portion of the sodium load settles out before it reaches Site NFG2 located downstream (439.54 to 0.00 lbs/acre/yr). More sodium is then delivered to the North Fork of the Grand River between Sites NFG2 and NFG3 increasing the export coefficient from >0.00 to 47.50 lbs/acre/yr (Table 26).

The South Fork of the Grand River exhibited a similar trend. The first two subwatersheds (SFG4 and SFG6) exhibited the highest export coefficients and then loadings dropped significantly between Site SFG6 and SFG7. Another significant drop occurred in the loadings for the subwatershed located between Site SFG7 and SFG8 (Table 26). As presented in the discussion of the sodium concentration data and total suspended solids loadings, the soils found within the subwatersheds of Site SFG4 and SFG6 are more erosive in nature and exhibit a higher content of sodium (USDA, 1980 and 1988). More discussion on the soils is presented in the following section of the PSIAC Modeling process.

Table 26. FLUX model-loading estimates of sodium to sampled reaches within either fork of the Grand River, 1999.

Site	**Mass** (tons)	FLUX (tons/yr)	Cumulative Watershed Area (acres)	Cumulative Export Coefficient (lbs/acre/yr)	Sub-Watershed Area (acres)	Sub-Watershed Export Coefficient* (lbs/acre/yr)
NFG1	**10,647**	**15,745**	**396,422**	**79.43**	**72,467**	**434.54**
NFG2	9,705	14,409	704,469	40.91	308,047	>0.00**
NFG3	11,107	16,491	792,114	41.64	87,645	47.50
SFG4	**1,788**	**2,655**	**104,414**	**50.85**	**104,414**	**50.85**
SFG6	**11,377**	**16,892**	**607,412**	**55.62**	**502,998**	**56.61**
SFG7	14,534	21,580	878,392	49.13	270,980	34.60
SFG8	14,551	21,605	962,451	44.90	84,059	0.61
For * and ** please review Table19.						

3.5 PSIAC MODELING (GRAND RIVER)

The Grand River/Shadehill Watershed Assessment Project is the initial phase of a proposed watershed-wide restoration project. The North and South Forks of the Grand River and Shadehill Reservoir were identified by the South Dakota Department of Environment and Natural Resources (DENR) on the 303(d) Water Quality Assessment list as impaired waterbodies. Agricultural non-point source pollution, specifically sediment, has been identified as a source of water quality impairment in the watersheds of the North and South Forks of the Grand River. The water quality of the Grand River directly affects the Shadehill Reservoir beneficial use designation. The long-term goal of the assessment project is to identify and document sources of agricultural non-point source pollution in the Grand River watershed and develop feasible land treatment alternatives.

The South Dakota DENR has previously relied on computer simulation to analyze non-point source pollution in agricultural watersheds. In South Dakota the most commonly used tool to assess agricultural non-point sources of pollution has been the Agricultural Nonpoint Source (AGNPS) model. AGNPS results have proved to be useful in watersheds that are predominantly cropland, however, it is not well adapted for evaluating watersheds that are primarily rangeland, hayland and/or pastureland.

Rangeland, hayland, pastureland, and Conservation Reserve Program (CRP) acres account for approximately 87 percent of the total land use in the study area. The Pacific Southwest Interagency Committee (PSIAC) sediment evaluation method was determined to be the most effective tool to use in an effort to determine total sediment loads and the sediment contributions from each of the different agricultural land uses. PSIAC is presently the only method available that is recognized as an evaluation tool capable of assessing sediment loads from large watersheds that have permanent vegetative cover as the predominant land use.

3.5.1. Project Setting for PSIAC Model

The Grand River Watershed Assessment project area is located in northwest South Dakota (Figure 30). The Grand River basin lies within the Cretaceous Tablelands section of the Missouri Plateau division of the Great Plains physiographic province. This region is part of the unglaciated portions of the Missouri Plateau. The Cretaceous Tablelands region in western South Dakota has the characteristics of an old plateau modified by valley terraces, local badlands, and isolated buttes. Slopes ranging from nearly level to very steep characterize the terrain of the Grand River drainage area. The general topography is a rolling plain with long smooth slopes on the uplands, and shorter, steeper slopes along the channels of the North and South Forks of the Grand River and the major tributaries. Natural drainage systems are poorly to well developed. Typically, major streams flow from west to east. Buttes and associated badlands are prominent local features of the landscape.

The Grand River is the second largest of five major river basins in western South Dakota that drain into the Missouri River. The study area is located in two Major Land Resource Areas (MLRA), 54 and 58D. The Watershed Assessment project covers 1,720,246 acres of drainage area in two counties, Perkins and Harding (Figure 32).

3.5.2. Land Use

Agriculture is the principal economic activity in the study area. Production of small grains, sunflowers, corn, hay, and raising beef cattle and sheep are the major enterprises in the watershed.

Approximately 87 percent of the study area has some type of permanent vegetative cover. Large acreages of native rangeland and interspersed tracts of pasture, hayland, and Conservation Reserve Program (CRP) occur throughout the study area.

Cropland comprises about 12 percent of the land use in the project area. Ranging from one percent of the land use in the Clarks Fork sub-watershed to 20 percent in the Big Nasty subwatershed. The most commonly raised crops are small grains and alfalfa. Approximately 75 percent of the cropland acres (154,660 acres) have been designated as Highly Erodible Land (HEL). Wind erosion is the predominant type of erosion associated with cropland in the study area. Ninety-five percent of the cropland acres with the HEL designation have some form of residue management (greater than 15 percent ground cover after planting), is managed using minimum till or no-till conservation tillage systems, or have wind erosion control practices as part of an approved HEL plan. Water erosion is a minor resource concern due to the relatively low amount of annual precipitation. Any significant water erosion is associated with the infrequent, localized, thunderstorms that are of high intensity but short duration.

Cropland soil erosion, although a resource concern, is not a major source of the sediment transported by the drainage system. The majority of the cropland is located in the uplands and there is little sediment delivered to the drainage system from this area. Since cropland overall does not contribute a significant amount of sediment and the majority of the acres are already managed for erosion control an evaluation of the change in sediment with change in management was not necessary for the entire watershed. If future assessments were made on a sub-watershed basis it would be appropriate to conduct a more detailed evaluation if cropland is a significant segment of the land use.

Table 27. Land Use within the Grand River Watershed.

WATERSHED	TOTAL ACRES	RANGELAND ACRES	CROPLAND ACRES	PASTURE HAY/CRP ACRES	OTHER ACRES
Lower S. Fork	195,860	133,891	31,794	26,845	3,330
Butcher Creek	96,782	66,847	15,355	12,935	1,645
Grand River	66,695	43,218	12,005	10,338	1,134
Whitney Creek	49,734	32,228	8,952	7,709	845
Thunder Hawk Creek	44,073	28,559	7,933	6,832	749
Lodge Pole Creek	61,075	41,775	9,894	8,368	1,038
Upper N. Fork	105,807	76,180	15,235	12,592	1,800
Lower N. Fork	90,467	62,922	14,135	11,872	1,538
Teeter Creek	46,373	39,415	4,668	1,780	510
Big Nasty Creek	142,860	100,000	24,774	16,516	1,570
Crooked Creek	79,502	67,575	8,002	3,050	875
Bull Creek	116,175	104,560	7,483	2,852	1,280
Jones Creek	92,452	73,960	12,653	4,842	1,015
Upper S. Fork	179,977	143,980	13,607	20,410	1,980
Pine Spring Creek	114,721	107,785	4,109	1,567	1,260
Clarks Fork Creek	157,177	153,890	1,127	430	1,730
Flat Creek	80,516	52,174	14,493	12,480	1,369
TOTAL	1,720,246	1,328,959	206,219	161,400	23,668

OTHER includes roads, railroad-right-of-way, farmsteads, and urban areas.

3.5.3. Evaluation Methods

<u>3.5.3.a. Sediment</u>

The Pacific Southwest Interagency Committee (PSIAC) sediment evaluation method was developed as the result of an interagency cooperative effort to assess the average annual sediment yield from watersheds larger than ten square miles. PSIAC evaluations quantify and characterize the watershed sediment yield at a downstream delivery point based on nine physical features within the watershed. It is a method intended for use as an aid to develop and support broad-based resource planning strategies. No other method is currently available to use as a rapid assessment tool for evaluating sediment yield at the watershed level. Sediment surveys and monitoring studies would require more intensive, long term, and costly investigation procedures.

The Natural Resources Conservation Service (NRCS - formerly Soil Conservation Service) Midwest National Technical Center sedimentation geologist approved the use of the PSIAC method of sediment yield evaluation in South Dakota (1993). PSIAC evaluations correlate well with measured results from historic sediment surveys and United States Geological Survey (USGS) gage station data previously collected by various agencies in South Dakota. NRCS has used PSIAC to evaluate sediment yield from agricultural sources for the purpose of broad-based resource planning in river basin studies, watershed plans, and resource assessment reports.

PSIAC has previously been used in South Dakota by NRCS to evaluate sediment loads for the following projects:

Little Minnesota River - Big Stone Lake Watershed Project (1995).
Lower Bad River — River Basin Study (1994).
Upper Bad River — River Basin Study (1998).
Upper Big Sioux — River Basin Study (2000).
Lake Louise and Cottonwood Lake Watershed Assessment (2000)
Medicine Creek and Counselor Creek Watershed Assessment (2000)
Bear Butte Creek Watershed Assessment (2000)

3.5.3.b. Water Quality Monitoring

Seven water quality monitoring sites were established along the North and South Forks of the Grand River. Water quality samples were taken during the 1999 water year and the spring runoff of 2000. The samples were analyzed for various physical and chemical properties that characterize water quality.

3.5.4. PSIAC Evaluation

Each sub-watershed was evaluated separately to determine the average annual sediment yield delivered to the point of discharge into the North or South Fork of the Grand River. An interdisciplinary planning team [*] evaluated the nine factors used in the PSIAC assessment method to determine sediment yield. The physical features evaluated are: surface geology, soils, climate, runoff, topography, ground cover, land use and management, upland erosion, and channel development and sediment transport. The sediment yield characteristics of each factor are evaluated and then assigned a numerical value representing the relative significance in the sediment yield rating. The sediment yield rating is a sum of the values for each of the nine factors.

[*] Appendix X List of Interdisciplinary Team Participants

Eight of the nine factors have a “paired influence” the exception is topography. **Surface geology and soils** are directly related; that is, the “parent material” (the geologic formation in which the soil formed) determines the soil characteristics. The other factors that influence each other are **climate and runoff; ground cover and land use;** and **upland erosion and channel development**. Ground cover and land use can have a negative influence on sediment production. The ground cover and/or land use impact on sediment yield is therefore indicated as a negative value when affording better protection than average.

Land treatment measures used for erosion and sediment control will affect the following factors: runoff, land use and management, ground cover, upland erosion, and channel development and sediment transport. The other factors are related to the physical characteristics of the geographical area and do not change with land use or treatment.

Efforts to reduce erosion and sediment production can be measured on a watershed basis by comparing the existing conditions against the expected changes in one or more of the PSIAC factors that relate to the proposed land treatment. An example would be the changes expected when 20 percent of the present rangeland acres are improved by one condition class. This action would reduce runoff, improve ground cover, improve the level of land use and management, and can affect upland erosion and channel development. The total effect is measured as a percent reduction of delivered sediment in the present condition compared to the expected change in sediment delivered after conservation measures are implemented.

3.5.4.a. Surface Geology

The general geology of MLRA 54 and MLRA 58D is a result of the different periods of inundation by a large inland sea during the Cretaceous period. Sedimentary rocks formed in this marine environment underlie most of the project area. The bedrock of the western part of the project area consists of the Fox Hills and the Hell Creek Formations. The formations are mainly soft sandstone and siltstone, with some areas of limestone and chalk. The Hell Creek Formation overlies the Fox Hills Formation and is the more extensive of the two. The Ludlow Formation, also sandstone and siltstone, is directly above the Hell Creek Formation and is found in the eastern part of the project area. .

Widely scattered tablelands have been eroded from the soft fluvial deposits of sand, clays, and silt. Locally the tablelands are referred to as “hills” (Cave Hills) or “buttes” (Slim Buttes). A sizeable area of rugged terrain or “Badlands” (Jump Off Area) has also been eroded from the poorly consolidated bedrock.

3.5.4.b. Soils

The soils in the study are placed into broad groups called soil associations. Each association has a distinctive pattern of soils, relief, drainage and natural landscape. The dominant soils within the study area are residual sands and clays in the uplands and alluvial clays on floodplains and terraces. The majority of the soils in the study area are nearly level to steeply sloping silty clay loams.

Rock outcrops formed in mixed materials are present in significant amounts in the Pine Springs Creek and Clark Fork sub-watersheds (Jump-Off Area) and occur as only minor amounts in some of the other sub-watersheds. The rock outcrop consists of unweathered bedrock layers of sandstone, siltstone, or shale in the Hell Creek Formation. The associated soils formed from this type of parent material are mainly highly dispersive clays (sodium affected) and calcareous loams and sandy clay loams that readily form colloidal suspensions during runoff events. These soils are poorly developed, shallow, and friable with low fertility and organic matter content. Many alluvial soils below the bedrock in the landscape are sodium affected at the surface and have gypsum and other salts in the subsurface layers.

This area has moderately steep to very steep slopes forming a highly dissected drainage area with many channels and gullies. Runoff is rapid and water erosion is a major hazard. Vegetative cover is generally sparse, and is hard to reestablish once it has been removed. Sediment delivery from the Jump-off area is approximately 5.5 to 12.5 times greater than other sub-watersheds in the western part of the study area.

More detailed information for the individual soils is available in the published soil surveys for both Harding and Perkins counties at the local NRCS field offices.

3.5.4.c. Climate

The climate of northwest South Dakota is arid and continental, characterized by large seasonal fluctuations in temperature, moderate to low relative humidity, and frequent high winds. Recurring periods of drought or near drought conditions are common. Less frequent periods of short duration can yield higher than normal amounts of precipitation. The average annual precipitation is 16 inches with 76 percent occurring during the period April to September, which is the growing season for most of the crops raised in this area. The growing season ranges from 115 days to 130 days. The average last killing frost occurs in mid-May and the first killing frost generally occurs in mid-September. Seasonal fluctuations in temperatures range from well below zero in winter to 100 + degree-days in July or August. Many freeze-thaw events occur in the fall and early spring.

3.5.4.d. Runoff

Precipitation and runoff rates in South Dakota differ annually and with season and location. Storms are generally of moderate intensity and short duration, and localized thunderstorms of high intensity and short duration are common. Approximately 70 percent of runoff occurs as a result of snowmelt and rainfall in the spring and early summer. The study area is located in an area that the U.S. Geological Survey has designated as Hydrologic sub-region C which on the average has a moderate rating for runoff. Localized areas associated with the buttes and tableland and the Jump Off Area have a higher rate of runoff due to the steeper slopes, sparse vegetation, and lower infiltration rates of the related soils.

3.5.4.e. Topography

The study area lies in the Cretaceous Tablelands section of the Great Plains Physiographic Division. The gently rolling terrain, typical of the northern plains prairie, characterizes the topography for the majority of the study area. Local relief is influenced by the scattered buttes and tablelands found throughout the project area. The slopes vary widely from the nearly level to moderately steep, but those near drainage ways and on the sides of flat-topped buttes or tablelands are steep or very steep.

The Jump Off Area in the Pine Springs and Clark Fork sub-watersheds is a localized area of Badlands topography sparsely vegetated, with steep slopes and highly dissected terrain incised through the Hell Creek Formation. Entrenched channels and gullies and remnant buttes are the predominant landscape features in this area. Local relief ranges from 25 to 500 feet, runoff potential is very high, and geologic erosion is active.

Elevations in the project area range from 3,800 feet mean sea level (msl) in the west and north to about 2,600 feet msl in the eastern part.

3.5.4.f. Ground Cover

Ground cover is described as anything on or above the surface of the ground, which alters the effect of precipitation on the soil surface and soil profile. Included in this factor are vegetation, litter, and rock fragments. A good ground cover acts to dissipate the energy of rainfall before it strikes the soil surface, deliver water to the soil at a relatively uniform rate, impede the overland flow of water, and promote infiltration by the action of roots within the soil. Conversely, the absence of ground cover, whether through natural growth habits or the effects of overgrazing, tillage, or fire, leaves the land surface open to the worst effects of storms.

Differences in vegetative type have a variable effect on erosion and sediment yield, even though percentages of total ground cover may be the same. For instance, the sod forming short grasses can have vastly different rates of runoff from the same range sites when compared to the intermediate/tall grasses. The sod forming grasses, which have a shallow, dense root system, have a lower rate of infiltration and therefore higher rates of runoff. The intermediate/tall grasses have a deeper root system that promotes a greater rate of infiltration and less runoff. Even though the ground cover is effective at both sites, there is the potential to impact sediment yield off-site due to the differences in amount of runoff and infiltration.

3.5.4.g. Land Use and Management

The use of land has a widely variable impact on sediment yield, depending largely on the susceptibility of the soil and rock to erosion, the amount of stress exerted by climatic factors and the type and intensity of use. In almost all instances, the land use either removes or reduces the amount of natural vegetative cover, which in turn affects the varied relationships within the environment. In certain instances, the loss or deterioration of vegetative cover may have little noticeable on-site impact but may increase off-site erosion, an effect of a higher volume and an acceleration of runoff.

3.5.4.h. Upland Erosion

Upland erosion occurs on sloping watershed lands beyond the confines of valleys. Sheet erosion, which involves the removal of a thin layer of soil over an extensive area, is usually not visible to the eye. This erosion type is evidenced by the formation of rills. Experience indicates that soil loss from sheet and rill erosion can be seen if it amounts to about five tons or more per acre.

A gully is defined as a small channel with steep sides caused by erosion from concentrated but intermittent flow of water usually during and immediately following heavy rains or after ice/snow melt. Significant gully erosion contributing to sediment loads is evidenced by the presence of numerous raw cuts along the hill slopes or areas of concentrated flow and sediment deposition in gently sloping or nearly level cropland areas. Shallow soils or unconsolidated material on moderately steep to steep slopes usually provide an environment for gully development.

Downslope soil movement due to slumping or mass wasting can be an important factor in sediment yield on steep slopes that are underlain by unstable geologic formations.

Wind erosion from upland slopes and the deposition of the eroded material in stream channels can be a significant factor. The material deposited in channels is readily moved by subsequent runoff. Wind erosion is the major source of sediment from cropland in the study area.

3.5.4.i. Channel Erosion and Sediment Transport

Channel erosion and sediment transport are a function of the drainage network that has developed within the watershed. A healthy, well-developed drainage network will efficiently transport "normal" sediment loads. Networks that are healthy will transport runoff and sediment loads with no adverse effects from incised channels or floodplain degradation. Drainage networks that are unstable have channels that are down cutting and producing sediment loads that cannot be handled by the channel system. Poorly developed drainage networks characterize areas that serve as natural sediment retention basins.

3.5.5. Watershed Assessment

The Grand River Watershed Assessment study area was divided into sub-watersheds to determine relative contributions of sediment delivered from each area. Seventeen sub-watersheds were identified and named for the major tributary stream in the respective 11-digit hydrologic unit (Figure 32). Water quality samples were collected at seven sites along the North and South Forks of the Grand and one site on the Grand River below the outlet of Shadehill Reservoir. The sub-watershed boundaries and acreage were determined using existing Geographic Information System (GIS) data (Table 28).

The Grand River is formed by the confluence of the North Fork and the South Fork in Perkins County, South Dakota. The headwaters of the North Fork lie near the North Dakota-Montana state line west of Haley in Bowman County North Dakota. The North Fork of the Grand River drains a 642,149-acre watershed in Montana, North Dakota, and South Dakota. The North Fork travels south and east through the northern parts of Harding and Perkins County. The study

Table 28. Grand River Watershed Assessment PSIAC Study Area

GIS Acreages Generated from 1:250,000 11-Digit Hydrologic Unit Data, 9/08/1999

Subwatershed	Harding County acres	Perkins County acres	Total acres
Lower South Fork Grand River		195,860	195,860
Butcher Creek		96,782	96,782
Grand River		66,695	66,695
Whitney Creek		49,734	49,734
Thunder Hawk Creek		44,073	44,073
Lodge Pole Creek		61,075	61,075
Upper North Fork Grand River	11,554	94,253	105,807
Lower North Fork Grand River		90,467	90,467
Teeter Creek	46,373		46,373
Big Nasty Creek	117,145	25,715	142,860
Crooked Creek	79,502		79,502
Bull Creek	116,175		116,175
Jones Creek	92,452		92,452
South Fork Grand River	133,129	46,848	179,977
Pine Springs	114,721		114,721
Clark Fork	157,177		157,177
Flat Creek		80,516	80,516
TOTAL	868,228	891,023	1,720,246

area only includes the 322,149 acres in South Dakota. The South Fork of the Grand River originates near the Montana-South Dakota state line west of Buffalo in Harding County. The watershed includes 1,157,079 acres in Harding and Perkins County. Shadehill reservoir is located at the confluence of the two forks of the Grand River. The Grand River a 241,018 acre drainage area below Shadehill reservoir is also part of the study area. The Grand River is a major tributary in the drainage network of the central part of the Missouri River watershed that is located in South Dakota.

3.5.6. PSIAC Results

The inventoried sub-watersheds had a sediment production range of 0.45 tons per acre for the Crooked Creek sub-watershed to 10.86 tons per acre in the Jump Off area in the Pine Creek and Clark Fork Creek sub-watersheds. The average for the seventeen sub-watersheds is approximately 1.58 tons per acre sediment delivery rate. The wide range of sediment production rates is a function of the differences in geology, slope, vegetative cover, and the resulting runoff /hydrology. Watersheds with similar physical and cultural characteristics were evaluated together.

The PSIAC sediment delivery rates for the study area compare well with two NRCS (SCS) sediment survey completed in 1964 on Cole and Wenner Reservoirs in Perkins County, South Dakota. Both reservoirs are located within the drainage area of the North Fork of the Grand River. The Cole Reservoir has a drainage area of 2.2 square miles (1,410 acres) in the Lodge Pole Creek sub-watershed. The Wenner Reservoir has a drainage area of 0.5 square miles (320 acres) in the Thunder Hawk sub-watershed. These reservoir watersheds are representative of the geology, soils, climate, topography, hydrology, and land use in the Grand River drainage area. During the 27-year interval from 1937 to 1964 measured sediment accumulations in Cole Reservoir amounted to an average annual 0.9 tons per acre of sediment delivered from the drainage area. The Wenner Reservoir measured an average annual rate of 0.93 tons per acre of delivered sediment from its watershed over a 13-year interval. This correlates closely to the PSIAC sediment delivery rate of 0.96 tons per acre in the Lodge Pole Creek sub-watershed. The measured sediment accumulation in the Wenner Reservoir was evaluated between the years of 1951 to 1964 which pre-dates the large changes in land use during the 1970's. The Thunder Hawk sub-watershed had a significant increase in cropland, while the Lodge Pole Creek sub-watershed remained in native rangeland.

Table 29. PSIAC Sub-Watershed Sediment Delivery.

WATERSHED	TOTAL ACRES	TONS/ACRE	TONS
Lower S. Fork	195,860	0.84	164,522
Butcher Creek	96,782	0.84	81,297
Grand River	66,695	0.69	46,020
Whitney Creek	49,734	0.69	34,317
Thunder Hawk Creek	44,073	1.35	59,499
Lodge Pole Creek	61,075	0.96	58,632
Upper N. Fork	105,807	0.96	101,575
Lower N. Fork	90,467	0.96	86,848
Teeter Creek	46,373	1.98	91,819
Big Nasty Creek	142,860	1.98	282,863
Crooked Creek	79,502	0.45	35,776
Bull Creek	116,175	1.56	181,233
Jones Creek	92,452	1.56	144,225
Upper S. Fork	179,977	0.87	156,580
Pine Spring Creek Jump-Off Area	51,378 63,343	0.81 10.86	41,616 687,905
Clarks Fork Creek Jump-Off Area	128,885 28,292	0.81 10.86	104,397 307,251
Flat Creek	80,516	0.72	57,972
TOTAL	**1,720,246**		**2,724,347**

3.5.7. Sediment Evaluations

PSIAC evaluations of the sub-watersheds estimate the sediment yield from all sources delivered to the main fork of the Grand River. Additional **analysis is needed** in order to apportion the sediment load among the different land use types and to develop land treatment strategies. Each sub-watershed was inventoried for the land use (Table 27) and sediment contributions were determined for each type of land use (Table 30).

Table 30. Grand River Sub-Watershed Sediment Evaluations.

WATERSHED	TOTAL ACRES	TOTAL TONS	RANGELAND	CROPLAND	PASTURE HAY/CRP	OTHER
Lower S. Fork	195,860	119,297	39,459	5,100	666	**164,522**
Butcher Creek	96,782	59,561	18,949	2,458	329	**81,297**
Grand River	66,695	30,729	13,514	1,550	227	**46,020**
Whitney Creek	49,734	22,286	10,706	1,156	169	**34,317**
Thunder Hawk	44,073	30,373	27,610	1,366	150	**59,499**

Lodge Pole Creek	61,075	38,287	18,631	1,506	208	**58,632**
Upper N. Fork	105,807	69,819	29,130	2,266	360	**101,575**
Lower N. Fork	90,467	57,667	26,736	2,137	308	**86,848**
Teeter Creek	46,373	78,784	12,541	392	102	**91,819**
Big Nasty Creek	142,860	176,500	102,415	3,634	314	**282,863**
Crooked Creek	79,502	27,109	8,065	427	175	**35,776**
Bull Creek	116,175	167,975	12,317	685	256	**181,233**
Jones Creek	92,452	117,263	25,597	1,162	203	**144,225**
Upper S. Fork	179,977	124,182	27,308	4,694	396	**156,580**
Pine Spring Creek Jump-Off Area	51,378 63,343	33,998 687,905	7,053	313	252	**41,616** **687,905**
Clarks Fork Creek Jump-Off Area	128,885 28,292	101,722 307,251	2,254	86	335	**104,397** **307,251**
Flat Creek	80,516	37,566	18,260	1,872	274	**57,972**
TOTAL	**1,720,246**	**2,288,274**	**400,545**	**30,804**	**4,724**	**2,724,348**

In each sub-watershed, the acres of rangeland were divided into four condition classes; poor, fair, good, and excellent, in order to assess reduction in sediment yield with improved range condition (Table 31).

Table 31. Acres of Four Condition Classes of Rangeland in the Grand River Basin.

PRESENT CONDITION						
WATERSHED	TOTAL ACRES	RANGELAND ACRES	POOR ACRES	FAIR ACRES	GOOD ACRES	EXCELLENT ACRES
Lower S. Fork	195,860	133,891	13,389	60,251	53,556	6,695
Butcher Creek	96,782	66,847	6,685	30,081	26,739	3,342
Grand River	66,695	43,218	6,483	15,126	19,448	2,161
Whitney Creek	49,734	32,228	3,223	14,503	12,891	1,611
Thunder Hawk Creek	44,073	28,559	4,284	9,996	12,851	1,428
Lodge Pole Creek	61,075	41,775	6,266	14,621	18,799	2,089
Upper N. Fork	105,807	76,180	11,427	26,663	34,281	3,809
Lower N. Fork	90,467	62,922	9,438	22,023	28,315	3,146
Teeter Creek	46,373	39,415	5,912	17,737	13,795	1,971
Big Nasty Creek	142,860	100,000	15,000	40,000	40,000	5,000
Crooked Creek	79,502	67,575	3,379	20,273	33,787	10,136
Bull Creek	116,175	104,560	10,456	47,052	41,824	5,228
Jones Creek	92,452	73,960	7,396	29,584	33,282	3,698
Upper S. Fork	179,977	143,980	14,398	43,194	79,189	7,199
Pine Spring Creek	51,378	44,442	4,444	17,777	19,999	2,222
Jump-Off Area	63,343	63,343	6,334	25,337	28,505	3,167
Clarks Fork Creek	128,885	125,598	12,560	50,239	56,519	6,280
Jump-Off Area	28,292	28,292	2,829	11,317	12,731	1,415
Flat Creek	80,516	52,174	7,826	20,870	20,870	2,608
TOTAL	**1,720,246**	**1,328,959**	**151,729**	**516,644**	**587,381**	**73,205**

The sediment production from the different range condition classes was determined for each of the sub-watersheds based on standard NRCS procedures from the Engineering Field Manual for South Dakota, Chapter 11, Amendment 15 (Table 32).

Table 32.Sediment Production under Present Conditions for four condition classes for rangeland in the Grand River Basin.

PRESENT CONDITION							
WATERSHED	TOTAL ACRES	RANGELAND ACRES	POOR TONS	FAIR TONS	GOOD TONS	EXCELLENT TONS	TOTAL TONS
Lower S. Fork	195,860	133,891	22,494	56,033	36,954	3,816	119,297
Butcher Creek	96,782	66,847	11,231	27,975	18,450	1,905	59,561
Grand River	66,695	43,218	8,363	10,891	10,502	973	30,729
Whitney Creek	49,734	32,228	4,158	10,442	6,961	725	22,286
Thunder Hawk Creek	44,073	28,559	8,225	10,796	10,409	943	30,373
Lodge Pole Creek	61,075	41,775	10,527	13,598	12,971	1,191	38,287
Upper N. Fork	105,807	76,180	19,197	24,797	23,654	2,171	69,819
Lower N. Fork	90,467	62,922	15,856	20,481	19,537	1,793	57,667
Teeter Creek	46,373	39,415	15,962	39,021	22,072	1,729	78,784
Big Nasty Creek	142,860	100,000	40,500	80,000	52,000	4,000	176,500
Crooked Creek	79,502	67,575	4,055	11,398	10,136	1,520	27,109
Bull Creek	116,175	104,560	31,054	79,047	52,698	5,176	167,975
Jones Creek	92,452	73,960	21,966	49,701	41,935	3,661	117,263
Upper S. Fork	179,977	143,980	18,717	47,513	55,432	2,520	124,182
Pine Spring Creek	51,378	44,442	5,333	15,999	11,999	667	33,998
Jump-Off Area	63,343	63,343	81,075	291,376	299,302	16,152	687,905
Clarks Fork Creek	128,885	125,598	15,060	45,215	39,563	1,884	101,722
Jump-Off Area	28,292	28,292	36,211	130,146	133,677	7,217	307,251
Flat Creek	80,516	52,174	10,096	15,026	11,270	1,174	37,566
TOTAL	**1,720,246**	**1,328,959**	**380,080**	**979,455**	**869,522**	**59,217**	**2,288,274**

Table 33. Sediment Production after twenty-percent of the rangeland has been enrolled in some type of conservation measures for the same four condition classes for rangeland in the Grand River Basin.

20 PERCENT PARTICIPATION RATE							
WATERSHED	TOTAL ACRES	RANGELAND ACRES	POOR TONS	FAIR TONS	GOOD TONS	EXCELLENT TONS	TOTAL TONS
Lower S. Fork	195,860	133,891	17,995	47,317	37,878	9,921	113,111
Butcher Creek	96,782	66,847	8,985	23,624	18,911	4,953	56,473
Grand River	66,695	43,218	6,690	9,647	10,035	2,723	29,095
Whitney Creek	49,734	32,228	3,326	8,818	7,136	1,885	21,165
Thunder Hawk Creek	44,073	28,559	6,580	9,562	9,947	2,639	28,728
Lodge Pole Creek	61,075	41,775	8,422	12,044	12,395	3,334	36,195
Upper N. Fork	105,807	76,180	15,359	21,962	22,603	6,079	66,003
Lower N. Fork	90,467	62,922	12,684	18,142	18,669	5,021	54,516
Teeter Creek	46,373	39,415	12,768	33,821	23,333	4,257	74,179
Big Nasty Creek	142,860	100,000	32,400	70,000	52,000	10,400	164,800
Crooked Creek	79,502	67,575	3,244	9,292	9,325	2,534	24,395
Bull Creek	116,175	104,560	24,844	66,751	54,015	13,457	159,067
Jones Creek	92,452	73,960	17,574	42,245	41,004	10,251	111,074
Upper S. Fork	179,977	143,980	14,973	41,179	50,393	8,063	114,608
Pine Spring Creek	51,378	44,442	4,266	13,600	11,732	1,867	31,465
Jump-Off Area	63,343	63,343	64,858	247,676	292,646	45,227	650,407
Clarks Fork Creek	128,885	125,598	12,058	38,433	38,684	5,275	94,450
Jump-Off Area	28,292	28,292	28,966	110,630	130,704	20,201	290,501
Flat Creek	80,516	52,174	8,007	13,148	11,270	3,052	35,547
TOTAL	**1,720,246**	**1,328,959**	**228,044**	**696,540**	**835,858**	**263,020**	**2,053,979**

Table 34. Sediment Production after forty-percent of the rangeland has been enrolled in some type of conservation measures for the same four condition classes for rangeland in the Grand River Basin.

40 PERCENT PARTICIPATION RATE							
WATERSHED	TOTAL ACRES	RANGELAND ACRES	POOR TONS	FAIR TONS	GOOD TONS	EXCELLEN T TONS	TOTAL TONS
Lower S. Fork	195,860	133,891	13,495	38,602	38,802	16,027	106,926
Butcher Creek	96,782	66,847	6,739	19,272	19,372	8,002	53,385
Grand River	66,695	43,218	5,018	8,401	9,569	4,473	27,461
Whitney Creek	49,734	32,228	2,495	7,194	7,309	3,045	20,043
Thunder Hawk Creek	44,073	28,559	4,934	8,329	9,484	4,336	27,083
Lodge Pole Creek	61,075	41,775	6,315	10,490	11,818	5,477	34,100
Upper N. Fork	105,807	76,180	11,518	19,129	21,552	9,987	62,186
Lower N. Fork	90,467	62,922	9,514	15,800	17,801	8,249	51,364
Teeter Creek	46,373	39,415	9,577	28,615	24,595	6,740	69,527
Big Nasty Creek	142,860	100,000	24,300	60,000	52,000	16,800	153,100
Crooked Creek	79,502	67,575	2,432	7,434	8,514	3,548	21,928
Bull Creek	116,175	104,560	18,634	54,454	55,333	21,738	150,159
Jones Creek	92,452	73,960	13,181	34,789	40,072	16,841	104,883
Upper S. Fork	179,977	143,980	11,231	34,843	45,354	13,606	105,034
Pine Spring Creek	513,378	44,442	3,199	11,201	11,465	3,067	28,932
Jump-Off Area	63,343	63,343	48,640	203,964	286,010	74,297	612,911
Clarks Fork Creek	128,885	125,598	9,043	31,650	37,805	8,666	87,164
Jump-Off Area	28,282	28,282	21,722	91,103	127,733	33,191	273,749
Flat Creek	80,516	52,174	6,057	11,270	11,270	4,930	33,527
TOTAL	**1,720,246**	**1,328,959**	**228,044**	**696,540**	**835,858**	**263,020**	**2,023,462**

3.5.8. Strategies for Sediment Reduction

There are numerous combinations of conservation practices that can be used to reduce sediment. The measures that are used for erosion and sediment control in South Dakota may be classified by purpose into several groups: 1.) To intercept and/or conserve moisture; 2.) To increase infiltration capacity; 3.) To reduce or eliminate stress on existing cover; 4.) To preserve existing cover regarded as adequate or in the process of becoming adequate with time; 5.) To increase the protection of the soil by a change in the type as well as density of vegetation.

As part of the assessment for the Grand River study area, three different levels of resource management practice application were assessed. The first level (low) considered was the continuation of present conditions with no additional special projects or funding for sediment and erosion control conservation practices (Table 32). Two other levels of consideration (moderate and high) were based on an increase in the total number of acres with improved rangeland grazing management for erosion and sediment control. The moderate and high levels of participation were selected to represent a reasonable expectation of change if there were assistance for a special project. A comparison between the different levels of participation provides a guide to the expected decrease in sediment versus the number of acres that would need to be treated to achieve any goals set for sediment reduction.

Additional conservation practices used in conjunction with rangeland management would greatly enhance the overall reduction of sediment from the study area. An example would be the use of fencing riparian areas for dormant season grazing in conjunction with proper grazing use. It was beyond the scope of this assessment to evaluate individual, site-specific conservation practices.

3.5.9. Present Condition – Low Participation Rate

If there are no significant changes in the present land use and on-going conservation programs remain funded at the present level there will be no significant changes in the amount of sediment produced in the watershed. Range condition will probably remain as is, with no long term trend either up or down. Presently XX percent of the rangeland is under some type of range management. Approximately 75 percent of the cropland acres have some level of residue management. Since the majority of the land use is rangeland, the increase in residue management will not significantly affect reductions in total sediment.

3.5.10. Moderate Participation Rate

The moderate level of participation is an estimate of sediment reduction that can be expected if 20 percent of the rangeland in the watershed is managed to improve these acres one condition class. Typical range management practices would include grazing distribution, proper grazing use, and prescribed grazing systems. This would achieve a 5.0 percent reduction in sediment from the rangeland.

3.5.11. High Participation Rate

The high participation for rangeland was assumed to be increased management on 40 percent of the acres resulting in an improvement in the range condition one-condition class. This would result in a 10 percent reduction in sediment from rangeland.

The estimated reductions in sediment based on the Low, Moderate, or High participation rates are very conservative. This would be the minimum amount of reduction that could be expected. The changes for the different participation rates were prorated by percentage of existing land use and condition for each sub-watershed. This means that rangeland acres already managed at the higher levels were included when sediment reductions were calculated. There was no allowance for improving conditions by more than one class, (i.e. poor range condition was assumed to only improve to fair condition and not good or excellent). This reflects a generalized "across the board" type of change.

A more detailed evaluation would need to be made to assess additional reductions based on other assumptions. This would be appropriate if there is a specific project or study proposed for a sub-watershed. Based on recent NRCS River Basin studies (Lower Bad River, Upper Bad River) significant sediment reductions can be expected from implementing a combination of conservation practices in addition to management systems.

Table 35. Percentage reductions in sediment delivery from seventeen subwatersheds for the Grand River Basin for twenty percent and forty percent participation rate in conservation practices.

			PRESENT CONDITION	20 PERCENT	PERCENT CHANGE	40 PERCENT	PERCENT CHANGE
WATERSHED	TOTAL ACRES	RANGELAND ACRES	TOTAL TONS	TOTAL TONS	FROM PRESENT	TOTAL TONS	FROM PRESENT

Lower S. Fork	195,860	133,891	119,297	113,111	5.2	106,926	10.4
Butcher Creek	96,782	66,847	59,561	56,473	5.2	53,385	10.4
Grand River	66,695	43,218	30,729	29,095	5.3	27,461	10.6
Whitney Creek	49,734	32,228	22,286	21,165	5.0	20,043	10.1
Thunder Hawk Creek	44,073	28,559	30,373	28,728	5.4	27,083	10.8
Lodge Pole Creek	61,075	41,775	38,287	36,195	5.5	34,100	10.9
Upper N. Fork	105,807	76,180	69,819	66,003	5.5	62,186	10.9
Lower N. Fork	90,467	62,922	57,667	54,516	5.5	51,364	10.9
Teeter Creek	46,373	39,415	78,784	74,179	5.8	69,527	11.7
Big Nasty Creek	142,860	100,000	176,500	164,800	6.6	153,100	13.3
Crooked Creek	79,502	67,575	27,109	24,395	10.0	21,928	19.1
Bull Creek	116,175	104,560	167,975	159,067	5.3	150,159	10.6
Jones Creek	92,452	73,960	117,263	111,074	5.3	104,883	10.6
Upper S. Fork	179,977	143,980	124,182	114,608	7.7	105,034	15.4
Pine Spring Creek	513,378	44,442	33,998	31,465	7.5	28,932	14.9
Jump-Off Area	63,343	63,343	687,905	650,407	5.5	612,911	10.9
Clarks Fork Creek	128,885	125,598	101,722	94,450	7.1	87,164	14.3
Jump-Off Area	28,282	28,282	307,251	290,501	5.5	273,749	10.9
Flat Creek	80,516	52,174	37,566	35,547	5.4	33,527	10.8
TOTAL	**1,720,246**	**1,328,959**	**2,288,274**	**2,155,779**	**5.8**	**2,023,462**	**11.6**

3.5.12. PSIAC Conclusions

The PSIAC sediment evaluations for the study area can provide a baseline for developing conservation practice implementation strategies for sediment reduction. In order to achieve a more substantial reduction in sediment delivered to the Grand River, it will take more than grazing management alone. Other conservation practices for sediment and erosion control in combination with proper management are needed to effectively change sediment yield. Total Resource Management Systems or Progressive Conservation Planning in conjunction with the implementation of Best Management Practices would help to achieve the desired sediment reduction.

3.6 MONITORING AND MODELING CONCLUSIONS

The water quality and biological data, and the PSIAC results indicate that the Grand River is an extremely variable system that is heavily impacted by sediment. During the course of this study and other investigations (USGS, 1964) the sediment dynamics of the South Fork exhibit extreme fluctuations from year to year. The sediment concentrations and loadings for the South Fork were identified as being a major nonpoint source above Site SFG6 located in the Sagebrush Steppe ecoregion (43e). Above these sites were the Pine Springs Jump off area which was monitored by Site SFG4, and the Clarks Fork Creek subwatershed which converges with the South Fork of the Grand River approximately 20 miles above Site SFG6 (see PSIAC discussion). Both of these monitoring sites had extremely high concentrations (mg/L) of suspended sediment as well as high export coefficients (TSS lbs/acre). Fecal coliform concentrations were slightly higher from these two subwatersheds as well (Table 36). Fecal coliforms are due to the cattle grazing in and around the stream. With the levels of concentrations, although in some instances were high (17,000 colonies per 100 ml), most of the samples collected were less than 2,000 colonies per 100 ml (Table 36).

The pH values for the South Fork were significantly higher than the North Fork. Sixty-six percent of the variability for these higher values was attributed to a very complex chemical relationship that involved flow, water temperature, and dissolved solids. The concentration of the suspended solids, temperature, flow, and sodium all have some effect on the pH levels.

Sodium was not significantly different between stations. Seasonally the sodium concentrations were higher during the summer period than at any other time during the year. Sodium is a cation found in significant concentrations of several types of soils in the Grand River Basin. These "Sodium Affected" soils are part of a family of soils that contain excessive concentrations of either soluble salts (calcium and magnesium) or exchangeable sodium, or both. The presence of excessive amounts of sodium is a more permanent problem in that exchangeable sodium usually persists after the removal of other soluble salts from the soil profile through remedial measures or special management practices (USDA, 1954).

Nutrients in the Grand River basin are not considered a problem. Nitrogen concentrations were found to be extremely low (Total Nitrogen mean $\leq$1.89) and the phosphorus concentrations, although sometimes high, were correlated with the suspended solids and were primarily attached to the soil particles.

The biological information and the resulting metric development and Index of Biotic Integrity (IBI) scores indicated that these areas of the South Fork were the most impaired of all the sites located on the both the South Fork and North Fork. The extent of the impairment can be gaged by the low IBI scores in the South Fork when compared to the North Fork (51 vs. 83) (Table 36). The IBI scores also exhibited a correlation with the average TSS concentrations. However, there was not enough data to determine whether or not this relationship was due to chance alone. Further monitoring would be required to see if this relationship holds true over several years exhibiting differing meteorological conditions. The highly dispersive clays and sodium affected soils located in the Pine Springs and Clarks Fork subwatersheds as described in the PSIAC modeling section of this report are the primary cause of the impairment.

The PSIAC modeling results describe the erosional rates of the subwatersheds within the Grand River basin. Areas providing the highest export coefficients (tons/acre) were the Pine Springs subwatershed (Jump off area) and the Clarks Fork Creek Subwatershed (Jump off area). The sodium affected soils and the resulting PSIAC calculations for these areas indicated that 85% of the loadings are due to natural background causes. An estimated five percent of the loadings can be reduced through a variety of remedial measures such as grazing management systems, increased riparian width along the stream channel, alternative watering systems for cattle, and stream exclusions reducing the impact that livestock may be having on the water quality of the

stream. According to the FLUX loadings program the North Fork of the Grand River is providing an estimated 1,639 tons of sediment to Shadehill Reservoir compared to 22,2000 tons from the South Fork. Eighty-five percent of the impairment is attributed to a natural geologic process and the biological community seems to have adapted to these periodic pulses of sediment influx. Total Resource Management Systems or Progressive Conservation Planning in conjunction with the implementation of Best Management Practices would help to achieve the desired sediment reduction.

Table 36. Comparison of export coefficients, and mean water chemistry and biological data values for all South and North Fork sites within the Grand River.

	Cumulative Export Coefficients		**PSIAC Sediment Delivery***	**Water Quality Parameters**						
	TP	TSS		TSS	TP	SOD	pH	Fecal	IBI	Habitat Assessment
Site	lbs/acre	lbs/acre	Tons/acre	mg/L	mg/L	mg/L	su	Colonies/100ml	Unitless	Unitless
NFG1	**0.013**	**7.7**	**1.98**	**46**	**0.073**	**461**	**8.44**	**407**	**84**	**146**
NFG2	0.009	3.4	0.96	42	0.104	486	8.36	148	81	127
NFG3	0.006	4.1	0.96	51	0.068	476	8.45	1110	81	142
SFG4	**0.100**	**239.7**	**6.36**	**1017**	**0.442**	**387**	**8.88**	**1020**	51	**128**
SFG6	0.053	104.9	1.64**	385	0.227	467	8.79	1010	57	115
SFG7	0.035	53.3	1.98	283	0.201	471	8.72	669	**65**	**128**
SFG8	0.026	46.1	0.84	261	0.135	461	8.80	544	60	117
* estimates determined from Table 29, pg 76, PSIAC Sediment Delivery Rates.										
** estimate includes Clarks Fork Creek which exhibited a 10.86 tons/acre sediment delivery rate.										

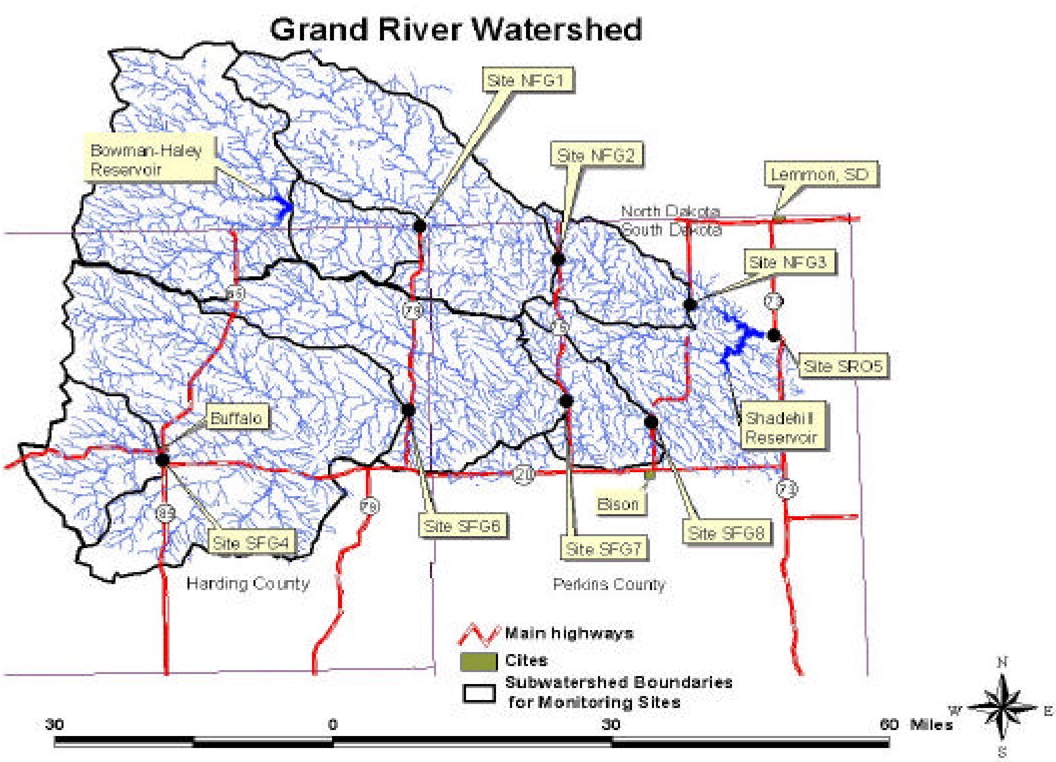


Figure 32. Grand River Watershed.

3.7 QUALITY ASSURANCE REPORTING

Quality assurance and quality control (QA/QC) samples were collected during the course of the project in accordance with the Quality Assurance Project Plan (QAPP) and the Sampling Analysis Plan (SAP). These approved plans state that a minimum of 10% of the samples collected during a Section 319 project shall be blank samples and a minimum of 10% of the samples collected shall be duplicate samples. The QAPP and SAP also require that approved standard operating procedures shall be used for data collection and analytical techniques for each water quality sample collected. The Standard Operating Procedures (SOP) for the South Dakota Water Resources Assistance Program were strictly followed to maintain sampling consistency between samples and projects.

During the 1999 and 2000 sampling year, a total of 121 and 86 water quality samples were collected, respectively. The percent difference was the difference between the actual sample and the duplicate sample. Some high percent differences were observed in the data set. The higher differences were observed for those chemical parameters that are extremely small in concentration such as ammonia, total phosphorus and dissolved phosphorus (Table 37). Fecal coliform is another parameter that can show extremely high differences between samples simply because it can be an extremely variable parameter. Although there were some problems with the sampling process, continual or chronic problems with the sample procedures were not identified. All blank, duplicate and original QA/QC samples can be found in Appendix X.

Table 37. Quality Assurance/Quality Control Sampling Results for the Grand River Watershed Assessment.

		FECAL	TALK	TS	TSS	AMMONIA	NITRATE	TKN	TP	TDPO4P	SOD
%Difference	Mean	11.82	0.74	1.90	8.86	18.62	10.16	24.48	26.88	43.68	9.80
Duplicate	Max	36.59	1.01	9.77	33.33	100.00	105.00	100.00	100.00	400.00	98.58
	Min	2.84	0.28	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		FECAL	TALK	TS	TSS	AMMONIA	NITRATE	TKN	TP	TDPO4P	SOD
Blank	Mean	10.00	12.25	45.15	2.20	0.05	0.14	0.26	0.00	0.01	28.35
	Max	10.00	15.00	82.00	6.00	0.19	0.35	1.60	0.04	0.04	400.80
	Min	10.00	10.00	17.00	1.00	0.00	0.01	0.00	-0.04	0.00	0.80

4.0 PUBLIC INVOLVEMENT AND COORDINATION

Public involvement and coordination were the responsibility of the Perkins Conservation District. As local sponsor for the project they were responsible for issuing press releases and/or news bulletins. The project was discussed at the monthly meetings of the Perkins Conservation District Board which is also a public setting where the general public is invited to attend.

The Perkins Conservation District is the appropriate lead project sponsor for this project. The conservation district is important to this project because of their relationship with the watershed landowners.

4.1 State Agencies

Because the South Dakota Department of Environment and Natural Resources (DENR) is the statewide pollution control agency, it was the appropriate lead state agency for this project. DENR is responsible for tracking the Section 319 funds and the state and local match for federal funding. It (DENR) is also responsible for data collection for the assessment projects and implementation follow-through.

The South Dakota Department of Agriculture (DOA) provided state funding in the amount of $14,738 through a funding application that was approved by the South Dakota Conservation Commission Board.

The South Dakota Department of Game, Fish, and Parks provided data for the project.

4.2 Federal Agencies

This project coordinated efforts between the Natural Resources Conservation Service (NRCS) and the Bureau of Reclamation (BOR).

NRCS - Provided technical assistance for the project and completed the PSIAC modeling process for the assessment project. NRCS is the contact for local landowners involved with conservation plans. NRCS needs to be involved up front during the implementation process as well as throughout the entire implementation project period.

BOR – Provides financial assistance for the project. The BOR provided $24,940 in funding for the laboratory analysis costs. Because the BOR manages a considerable area of land within the Grand River watershed they need to be involved in the development of the implementation project.

USFWS – did not provide financial or technical assistance during the assessment project. However, they should be contacted prior to the implementation project regarding their role in the implementation of the TMDL and the potential impact on any endangered species (consultation process).

4.3 Local Governments, Industry, Environmental, and Other Groups; Public-at-large

The conservation districts within the Grand River watershed (Perkins and Harding) will need to take a leading role during the implementation project. This was evident during the assessment phase and becomes more important during the implementation phase when conservation practices need to be implemented with local landowners.

4.4 Other Sources of Funds

The Grand River Watershed and TMDL Assessment project was funded primarily through Section 319. However, there were significant contributions made towards the project through the NRCS, BOR, the South Dakota Conservation Commission (DOA), and the local match derived through Perkins and Harding County Conservation Districts (see budget table below).

FUNDING CATEGORY	SOURCE	TOTAL
EPA SECTION 319 FUNDS		$33,076
OTHER FEDERAL FUNDS	BOR TECHNICAL ASSISTANCE	$24,940
	NRCS TECHNICAL ASSISTANCE	$31,000
STATE MATCH	SD CONSERVATION COMMISSION	$14,738
LOCAL MATCH	PERKINS/HARDING CONSERVATION	$7,313

	DISTRICTS	
TOTAL BUDGET		**$111,067**

5.0 Aspects of the Project That Did Not Work Well

After the project implementation plan (PIP) was approved the funding was not released until early May which resulted in a setback for the data collection phase. Fortunately there was enough funding at the end of the first year so that the spring snowmelt water quality data could be captured the following spring. This delay could have been avoided had the funding been released in early March of 1999. The deadlines identified in the objectives/tasks and the milestone schedule would have had an increased chance of being met.

Another aspect of the project that provided some difficulty was the distance between monitoring stations. It literally took two days to service the seven automatic samplers during the 1999 sampling year. However, despite this problem enough data was gathered to identify critical areas within the Grand River watershed.

6.0 Future Activity Recommendation

The Grand River watershed is an estimated 768,930 ha (1.9 million acres) in size. This assessment project documented critical areas for most of that watershed. As indicated in the report, certain subwatershed areas in the Grand River basin have been identified as areas of concern. Implementation efforts should be undertaken to install best management practices (BMPs) on these identified critical areas.

With the existing natural background conditions for the North and South Forks of the Grand River, achieving reductions large enough to bring about the designation of these waterbodies back to within water quality standards is not possible. The soils are a fine, erosive type (badlands type soil) which are located in the upper watershed of the South Fork of the Grand River (Cooley, 2000). This portion of the Grand River is located in the Sagebrush Steppe ecoregion (43e) which is characterized by eroded buttes, Hell Creek badlands, scoria (burnt coal) mounds, and salt pans. Vegetation consists of a thick mat of shortgrass prairie and dusky gray sagebrush. The principal landuse is cattle grazing and wildlife habitat with minimal cultivation (Bryce, et al., 1997). This area is contributing an excessive amount of sediment loadings which is transported downstream resulting in the exceedance of the total suspended solids water quality standard. The mean concentration for TSS in the upper drainage of the South Fork was 1,017 mg/L. The mean concentration for TSS dropped off substantially in the three monitoring stations located downstream. The loadings per unit area (lbs/acre) also dropped substantially for the subwatersheds located downstream when compared to the upstream subwatersheds of Sites SFG4 and SFG6. Those best management practices identified in the PSIAC portion of this report and are located in the table below . Recommendations from PSIAC and myself need to occur here with a summarization of the results which justify all of the recommendations and tmdl data.

Although grazing is the predominant form of landuse most of this has been classified as fair condition. With an improvement of only one grazing class the SFG4 subwatershed will achieve only a X% reduction in the sediment loadings. According to the data that has been present a reduction of 90 percent would be required to sufficiently bring down the suspended solids loadings down to within a reasonable chance of maintaining the 158 mg/L TSS standard.

An implementation project should focus on the areas identified in the PSIAC report within the NFG2 of North Fork etc. and all along the South Fork of subwatersheds SFG4-SFG8.

Future efforts need to first focus on working in those areas providing the highest rate of sediment to the South Fork of the Grand River (SFG4 and SFG6 subwatersheds). Once these efforts have started areas of less concern can than be focused on.

7.0 LITERATURE CITED

Backlund, D. 2000. Personal Communication. South Dakota Heritage Database, South Dakota Game, Fish, and Parks. Pierre, SD.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999 . *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*, 2nd Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Bryce, S.A., J.M. Omernik, D.E. Pater, M. Ulmer, J. Schaar, J. Freeouf, R. Johnson, P. Kuck, and S.H. Azevedo. 1998. *Ecoregions of North Dakota and South Dakota*. Map. U.S. Environmental Protection Agency, Office of Research and Development, Regional Applied Research Effort (RARE) program.

Lester, G. 2000. Personal Communication. Ecoanalysts, President. Moscow, Id.

NATURAL RESOURCES CONSERVATION SERVICE, 1981. Land Resource Regions and Major Land Resource Areas of the United States. U. S. Department of Agriculture.

NATURAL RESOURCES CONSERVATION SERVICE, 1995. Lower Bad River – River Basin Study. U. S. Department of Agriculture.

NATURAL RESOURCES CONSERVATION SERVICE, 1998. Upper Bad River – River Basin Study. U. S. Department of Agriculture.

NATURAL RESOURCES CONSERVATION SERVICE, 1995. Little Minnesota River – Big Stone Lake PL-566 Planning Report. U. S. Department of Agriculture.

PACIFIC SOUTHWEST INTER-AGENCY COMMITTEE, 1968. Report of the Water Management Subcommitte on Factors Affecting Sediment Yield in the Pacific Southwest Area and Selection and Evaluation of Measures for Reduction of Erosion and Sediment Yield.

Smith, M. 2000. Personal Communication. South Dakota State Health Laboratory, Director. Pierre, SD.

South Dakota Administrative Rules, *Article 74:51:01, Surface Water Quality Standards*.

South Dakota Department of Environment and Natural Resources. 2000 . *The 2000 South Dakota Report to Congress: 305(b) Water Quality Assessment*. South Dakota Water Quality WaterYears 1995-1999.

South Dakota Department of Environment and Natural Resources. 2000. *South Dakota Water Resources Assistance Program Standard Operating Procedures for Field Samplers*. January, 2000.

South Dakota Department of Environment and Natural Resources. 1998 . *The 1998 South Dakota 303(d) Waterbody List and supporting documentation.*

StatSoft, 2000. Statistica for Windows, Volume I-III. 2nd edition. Tulsa, Oklahoma.

Tetra Tech, Inc. 2000. *A Stream Condition Index for West Virginia Wadeable Streams*. Report Prepared for U.S. EPA Region 3 Environmental Services Division,, and U.S. EPA Office of Science and Technology, Office of Water.

USDA. 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. U.S. Salinity Laboratory, Agriculture Handbook No. 60. 159 pgs.

USDA-NRCS. 1988. *Soil Survey of Harding County, South Dakota.*

USDA-NRCS. 1980. *Soil Survey of Perkins County, South Dakota.*

USGS, 1998. Techniques for Estimating Peak-Flow Magnitude and Frequency Relations for South Dakota Streams. U.S. Department of Interior.

USGS, 1980. Geology and Water Resources of Hand and Hyde Counties, South Dakota, Part II: Water Resources. U.S. Geological Survey, U.S. Department of Interior.

USGS. 1964. *Chemical Quality of Surface Waters, and Sedimentation in the Grand River Drainage Basin North and South Dakota.* Geological Survey Water-Supply Paper 1769, U.S. Government Printing Office, Washington, D.C..

Walker, W.W. 1999. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual*. Instruction Report W-96-2, September 1996. Updated April 1999. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Wetzel, R.G. 1983. *Limnology* 3rd Edition. Saunders College Publishing, Philadelphia.

8.0 LIST OF TABLES

9.0 LIST OF FIGURES

10.0 LIST OF APPENDICES

APPENDIX I – Total Maximum Daily Load (TMDL) Summary for the Grand River

TOTAL MAXIMUM DAILY LOAD EVALUATION

PARAMETER OF CONCERN
TOTAL SUSPENDED SOLIDS (TSS)

WATERBODY
SOUTH FORK OF THE GRAND RIVER

WATERSHED
SOUTH FORK (GRAND RIVER) WATERSHED

(HUC 10130302)

HARDING AND PERKINS COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

March, 2001

Grand River (South Fork) Total Maximum Daily Load

Waterbody Type:	River
303(d) Listing Parameters:	Total Suspended Solids (TSS)
Designated Uses:	(5) Warmwater semipermanent fish life propagation; (8) Limited contact recreation; (9) Fish and wildlife Propagation and stock watering; (10) irrigation
Size of Waterbody:	134 total stream miles.
Location:	HUC = 10130302
Size of Watershed:	962,451 acres
Water Quality Standards:	Numeric and Narrative
Indicators:	pH, Fecal Coliform Bacteria, and Sodium Adsorption Ratio (SAR)
Analytical Approach:	FLUX (in-stream loadings), PSIAC (landuse impacts), TSS (mg/L) vs. Flow (cfs) Regression Analysis
<u>TMDL GOAL by Parameter</u>	
Total Suspended Solids:	5% Reduction in annual sediment loadings
<u>TMDL TARGET by Parameter</u>	
Total Suspend Solids vs. Flow Regression Analysis:	5% reduction in slope and intercept for the TSS vs. Flow regression equation TSS = 6.7426(Flow) + 13.238

Objective:

The intent of this summary is to clearly identify the components of the TMDL submittal to support adequate public participation and facilitate the US Environmental Protection Agency (EPA) review and approval. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

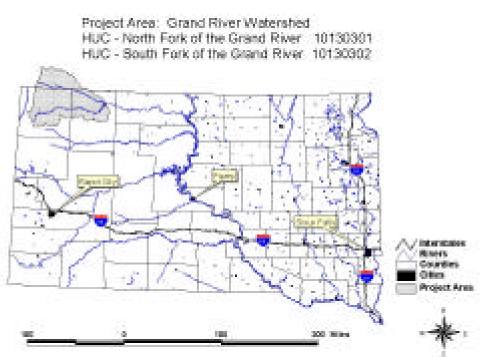


Figure 1. Watershed location in South Dakota

Introduction

The South Fork of the Grand River is a 134-mile segment of the Grand River with a watershed of approximately 962,451-acres in size. The South Fork eventually merges with the North Fork where a Bureau of Reclamation (BOR) impoundment was constructed in 1951 creating Shadehill Reservoir. The river is located in the Northwestern part of the South Dakota in Harding and Perkins County (Figure 1). The 1998 South Dakota 303(d) Waterbody List (page 21) identified the South Fork of the Grand River for TMDL development for total suspended solids (TSS).

The upper Grand River (North and South Forks) has a predominantly agricultural land use with grazing and wheat farming composing the major uses. Landuse within the South Fork watershed is primarily agricultural. Approximately 25 percent of the land use is cropland and 75 percent grass or pasture. Winter feeding areas for livestock are present within the watershed.

Problem Identification

The South Fork of the Grand River is one of two primary tributaries draining to Shadehill Reservoir. The South Fork watershed contains erosive soils that contribute sediment causing elevated levels of TSS in the river. This heavy sediment (TSS) load reduces the ability of the stream to support the beneficial use (5) Warmwater semipermanent fish life propagation. During 1999, the South Fork of the Grand River transported an estimated 22,200 tons of sediment

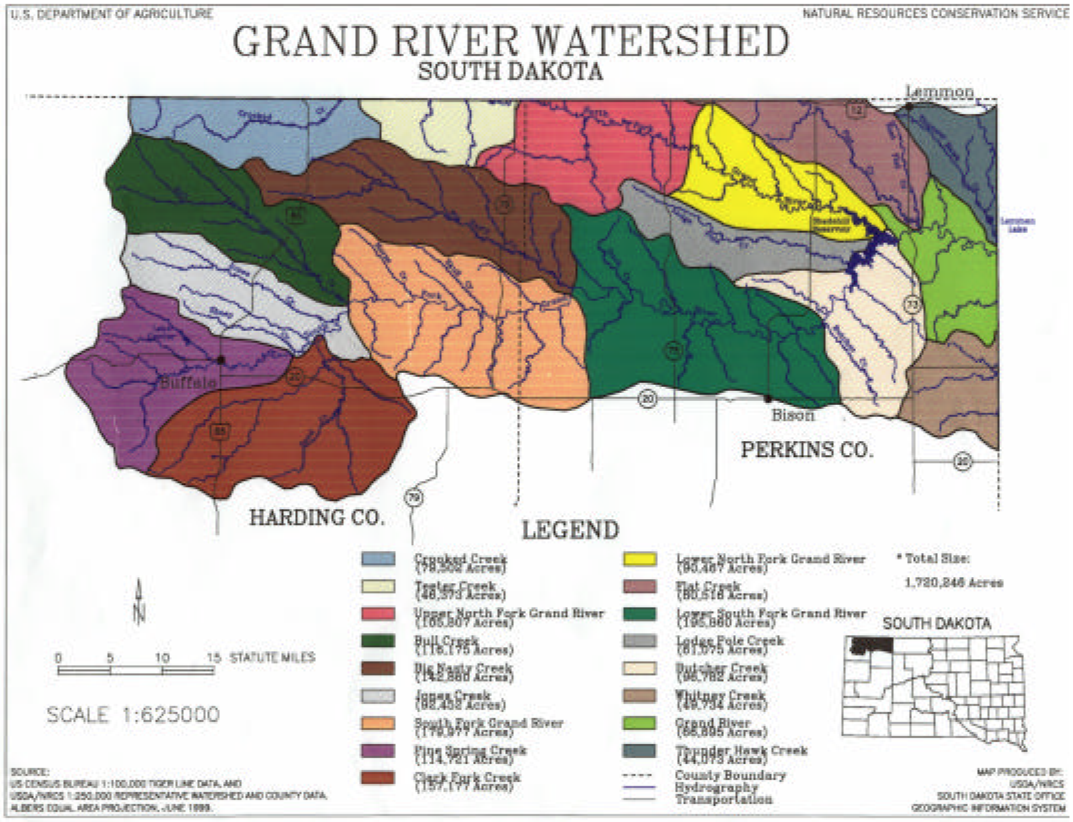


Figure 2. Grand River Watershed

resulting in 35 exceedances of 87 TSS samples collected (40% exceedance rate). The upstream subwatersheds were identified as providing more material. A 30% reduction in total loadings was observed downstream compared to upstream loadings.

The PSIAC modeling process identified the Jump Off Area in the Pine Springs and Clark Fork sub-watersheds, which are both located in the upper watershed areas, as a localized area of Badlands topography sparsely vegetated, with steep slopes and highly dissected terrain incised through the Hell Creek Formation. Entrenched channels and gullies and remnant buttes are the predominant landscape features in this area. Local relief ranges from 25 to 500 feet, runoff potential is very high, and geologic erosion is active.

Rock outcrops formed in mixed materials are present in significant amounts in the Pine Springs Creek and Clark Fork sub-watersheds (Jump-Off Area) and occur as only minor amounts in some of the other sub-watersheds.

The rock outcrop consists of unweathered bedrock layers of sandstone, siltstone, or shale in the Hell Creek Formation. The associated soils formed from this type of parent material are mainly highly dispersive clays (sodium affected) and calcareous loams and sandy clay loams that readily form colloidal suspensions during runoff events. These soils are poorly developed, shallow, and friable with low fertility and organic matter content. Many alluvial soils below the bedrock in the landscape are sodium affected at the surface and have gypsum and other salts in the subsurface layers.

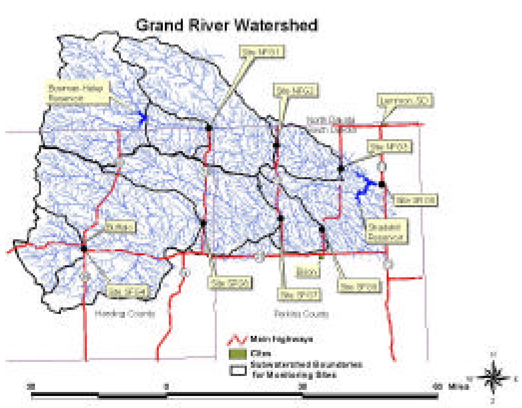
This area has moderately steep to very steep slopes forming a highly dissected drainage area with many channels and gullies. Runoff is rapid and water erosion is a major hazard. Vegetation is hard to reestablish once it has been removed. Sediment delivery from the Jump-off area is approximately 5.5 to 12.5 times greater than other sub-watersheds in the western part of the study area. watershed. In order to achieve full support of the most stringent beneficial use, (5) Warmwater semipermanent fish life propagation, the annual total suspended solids loadings must be reduced by an estimated 90%. However, due to the existing geologic conditions that exist in the western part of the study area only 5% is attributable to nonpoint sources and is thereby, controllable. The remaining 85% is attributable to natural (background) conditions that exist in the watershed.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

The South Fork of the Grand River has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations. Along with these assigned uses are narrative and numeric criteria that define the desired water quality of the river. These criteria must be maintained to satisfy its assigned beneficial uses, which are listed below:

(5) Warmwater semipermanent fish life propagation water;
(8) Limited contact recreation water; and
(9) Fish and wildlife propagation, recreation and stock watering.
(10) Irrigation

Individual parameters, including total suspended



solids, pH, and the sodium adsorption ratio (SAR) determine the support of beneficial uses and compliance with standards. The entire length of the South Fork of the Grand River experiences sporadic exceedances which are typical signs of the natural geologic erosional process. The South Fork was identified only in the 1998 South Dakota 303(d) Waterbody List.

South Dakota Surface Water Quality Standards for warmwater semipermanent fish life propagation is $\leq$ 158 mg/L for any one sample or a geometric mean of $\leq$ 90 mg/L on a minimum of five samples collected during separate 24-hour periods for a 30-day period. They may not exceed this value in more than 20 percent of the samples in the same 30-day period (Chapter 74:51:01:48).

The Jump Off Area in the Pine Springs and Clark Fork sub-watersheds exhibited increased TSS loadings and concentrations. These upstream subwatersheds are located in the extreme southwestern portion of the South Fork watershed (Figure 2). The mean concentrations for the two monitoring sites located here were 1,017 mg/L and 385 mg/L. The 85% Due to the natural background influences. Water quality target will be an increase the flow at the USGS gaging station from 22.14 cfs to Xcfs reflecting the 5% reduction in loadings thereby increasing the flow rate before an water quality standards were violated.

South Dakota has several applicable narrative standards that may be applied to the undesired influx of sediment that may be causing aquatic habitat impairment. Administrative Rules of South Dakota Article 74:51 contains language that all waters of the state must be free from substances, whether attributable to human induced point source discharges or nonpoint source activities, in concentrations or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.

A tentative Index of Biological Integrity (IBI) for the South Fork was developed from benthic macroinvertebrates collected during the summer of 1999. When sites were compared the upstream watersheds where higher concentrations and loadings for suspended solids were observed a lower IBI score was also observed. The lowest IBI score of 51 (on a 100-point scale) was observed upstream whereas downstream sites increased to a score maximum score of 65 for the South Fork sites. Although 85% of the TSS loadings are attributed to natural background sources an increase in the IBI may be expected with the estimated 5% reduction in the nonpoint source loadings. It is difficult to determine the extent of the increase but the upstream IBI scores (51) should more closely reflect the current downstream IBI conditions (score = 65). This can be validated in future monitoring efforts.

Fecal coliforms, SAR, pH all have adequate water quality standards that are specifically designed to insure the South Fork of the Grand River supports its beneficial uses.

South Dakota Surface Water Quality Standards for limited contact recreation is $\leq$ 2000 colonies/100 mL for any one sample or a geometric mean of $\leq$ 1,000 colonies/100 mL on a minimum of five samples collected during separate 24-hour periods for a 30-day period. They may not exceed this value in more than 20 percent of the samples in the same 30-day period (Chapter 74:51:01:51).

During 1999, the South Fork exhibited 9 samples from a total of 87 collected that exceeded the daily maximum (10%). Seven of these samples were collected from the two upstream watersheds. The maximum concentration for all 87 samples collected from the South Fork was 6,500 colonies/100 mL. This exceedance rate wasn't enough to allow the South Fork to be place on the 303(d) list for fecal coliforms. However, an expected benefit from implementation for the suspended solids reduction with riparian work and grazing management systems a reduction in the number of exceedances should be expected.

Although the South Fork of the Grand River has been listed in the year 2000 305(b) report as fully supporting for pH, the data collected during this project seems to indicate that this segment does exhibit periodic exceedances of the pH standard.

The soils within the watershed of the South Fork are highly erosive in nature and have higher pH levels in comparison to the North Fork. Multiple regression analysis was used to determine which physical or chemical factors explained most of the variability in the pH measurements for the South Fork of the Grand River. Results from this analysis indicated that 58% of the variability in the pH values can be attributed to changes in flow and the concentration of dissolved solids (Table 7).

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

Analysis of the watershed through the use of the Pacific Southwest Interagency Committee (PSIAC) model indicated that approximately 2% of the phosphorus load was the result of feeding area discharge, 5% from inadequate cropland tillage practices and 1.5% from fertilizer. See the PSIAC section of the final report, Section 3.5, pages 8, 10 and 11.

Other tributary phosphorus loads were estimated using published percent reductions expected for Best Management Practices (BMPs) on priority subwatersheds. These included inadequate buffers 28.1%, riparian management 8.5% and streambank stabilization 0.9% which contributes to the phosphorus load to South Fork of the Grand River (assessment final report, pages 38 through 40).

Inlake phosphorus reduction percentages were estimated using in-house and published data. Phosphorus reduction recommendations include mechanical aerator/circulator 5% and aluminum sulfate treatment 30% (assessment final report, pages 112 through 114).
The remaining phosphorus loading (120 kg/yr.) was attributed to background sources in the South Fork of the Grand River watershed.

The load allocation for fecal coliform bacteria appeared to have minimal impact swimming beach fecal coliform concentrations. The majority of the loading was attributed (localized) to the swimming beach (assessment final report, pages 115 and 116). The load allocation from the swimming beach was estimated at 30%, based on 140 beach samples collected by South Dakota Game Fish and Parks during 1999.

Fecal coliform bacteria background sources in the watershed were considered 140 colonies/100 mL.

Linkage Analysis

Water quality data was collected from 10 monitoring sites within the South Fork of the Grand River/ Nine Mile Creek watershed. Samples collected at each site were taken according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on approximately 10% of the samples according to South Dakota's EPA approved Clean Lakes Quality Assurance/ Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed on pages 4 through 11 and 41 through 44 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AGNPS (Agricultural Nonpoint Source) model was used to estimate potential nutrient load reductions from feedlots, minimum tillage and fertilizer reduction within the watershed through the implementation of various best management practices. See the AGNPS section of the final report, Appendix E.

Other watershed (buffer strips, riparian management and streambank stabilization) and inlake (aerator/circulator and aluminum sulfate treatment) BMPs were also used to estimate phosphorus reductions. Estimates were based on conservative percent reductions applied to priority subwatersheds (assessment final report, pages 38 through 40 and 112 through 115).

Reducing the current phosphorus load (1147 kg/yr.) a minimum of 67% (768 kg/yr.) will reduce the mean TSI value from 79.57, non-supporting, to 64.95 fully supporting its beneficial uses. This can be accomplished by implementing tributary and inlake BMPs that includes a 14% margin of safety to support the TMDL target.

Fecal coliform loading was attributed to the swimming beach. Reductions in coliform through an information and education program and select tributary BMPs should reduce fecal coliform to 200 colonies/100 mL which fully supports beneficial uses (assessment final report, pages 115 through 116).

An estimated 140-colonies/100 mL was attributed to background sources based upon long term (1992 through 2000) fecal coliform beach samples.

TMDL and Allocations

TMDL

Phosphorus (kg/yr) = 67% reduction

0 kg/yr.	(WLA)
+ 206 kg/yr.	(LA)
+ 120 kg/yr.	(Background)
+ 53 kg/yr. Implicit and Explicit	(MOS)
379 kg/yr.	(TMDL) [1]

[1] = Equation implies a 81% phosphorus reduction with all possible implementation BMPs. A 67% phosphorus reduction is needed to restore beneficial uses. Thus, the TMDL includes a 14% margin of safety.

Fecal Coliform (South Fork of the Grand River)

During 1999, inlake fecal coliform samples did not exceed 200 colonies/100 mL. Based upon the assessment report, inlake fecal coliform concentrations are not a problem in South Fork of the Grand River.

Fecal Coliform (swimming beach)

0 colonies/100 mL	(WLA)
+ 60 colonies/100 mL	(LA) [1]
+ 140 colonies/100 mL	(Background)
+ Implicit	(MOS)
200 colonies/100 mL	(TMDL)

[1] = The swimming beach load was estimated at 30% of the TMDL based on the number of fecal samples exceeding the public beach standard divided by number of sample in compliance with the standard over a nine year period (1992 through 2000).

Wasteload Allocations (WLAs)

There are no point sources of pollutants of concern in this watershed. Therefore, the "wasteload allocation" component of these TMDLs is considered a zero value. The TMDLs are considered wholly included within the "load allocation" component.

Load Allocations (LAs)

The results of the AGNPS model indicates that a 4.3% (49 kg/yr.) and 3.4% (39 kg/yr.) reductions in phosphorus loading to the lake could be achieved by minimum tillage (2,000 acres) and reduced fertilizer application (1,600 acres), respectively, within the watershed.

Removal of 5 animal feeding operations within the watershed would account for an additional 2% (23 kg/yr.) of the phosphorus load to the lake.

Tributary phosphorus reductions for riparian management 8.5% (97 kg/yr.), streambank stabilization 0.9% (10 kg/yr.) and buffer strips 28.1% (322 kg/yr.) were estimated using various methods and BPJ.

Inlake phosphorus reductions were also estimated for South Fork of the Grand River. They include mechanical circulator/ aerator 5% (57 kg/yr.) and an alum treatment 30% (344 kg/yr.).

A total of 67% reduction in phosphorus is needed to restore the beneficial uses of South Fork of the Grand River.

The load from the swimming beach was estimated at 30%, based on 140 beach samples collected by South Dakota Game Fish and Parks from 1992 through 2000.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and agricultural practices. To determine seasonal differences, South Fork of the Grand River samples were separated into spring (March-May), summer (June-August), fall (September-November) and winter (December).

Margin of Safety

All phosphorus reductions were calculated based on extremely conservative estimations built into the model and conservative phosphorus reduction percentages using best professional judgement. Phosphorus reductions were also explicit in that an 81% phosphorus reduction is possible using all possible BMPs and South Fork of the Grand River only needs a 67% phosphorus reduction to restore beneficial uses. The additional 14% is the explicit margin of safety (assessment final report, pages 38 through 40 and 115 through 117, and the load allocation section).

The margin of safety for fecal coliform bacteria for the swimming beach was also implicit.

Critical Conditions

Based upon the 1999 assessment data, impairments to South Fork of the Grand River are most severe during the late summer and early fall. This is the result of warm water temperatures, stratification and increased algal growth. Beach closures tend to occur in early summer.

Follow-Up Monitoring

South Fork of the Grand River should remain on the round robin statewide lake assessment project and on the South Dakota Game Fish and Parks normal lake survey and swimming beach sampling to monitor and evaluate the long term trophic status, biological community and ecological trend. It is recommended that the statewide lake assessment survey for South Fork of the Grand River include fecal coliform samples to periodically monitor long term fecal coliform concentrations.

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

Public Participation

The water quality assessment project was initiated during the spring of 1999 with EPA Section 604(b) and 104 (b)(3) funds. South Fork of the Grand River was on the priority list of Section 319 Nonpoint Pollution Control projects. The Lincoln Conservation District agreed to sponsor the project and provided local matching funds and in-kind services. The federal grant funds totaled $44,675.00, and the local in-kind match totaled $18,576.00. Funds were used for water quality analyses, equipment, supplies, travel, and wages for the local coordinator.

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

1. Lincoln County Conservation District Board Meetings (13)
2. Lincoln County Commission Meeting (1)
3. City of Tea Board Meetings (1)
4. City of Harrisburg Board Meetings (1)
5. Individual contact with landowners in the watershed.
6. Articles in the Canton Sioux Valley News (2) and The Argus Leader (2)

The findings from these public meetings and comments have been taken into consideration in development of the South Fork of the Grand River TMDL.

Implementation Plan

The South Dakota DENR is working with the Lincoln County Conservation District to initiate an implementation project beginning in 2002. It is expected that a local sponsor will request project assistance during the fall 2001 EPA Section 319 funding round.

TOTAL MAXIMUM DAILY LOAD EVALUATION

PARAMETERS OF CONCERN
pH and Temperature

WATERBODY
GRAND RIVER (Shadehill to Corson County Line)

WATERSHED
GRAND RIVER WATERSHED

(HUC 10130303)

HARDING AND PERKINS COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

March, 2001

Grand River (South Fork) Total Maximum Daily Load

Waterbody Type:	River
303(d) Listing Parameters:	Total Suspended Solids (TSS)
Designated Uses:	(3) Coldwater marginal; (8) Limited contact recreation; (9) Fish and wildlife Propagation and stock watering; (10) irrigation
Size of Waterbody:	18 total stream miles.
Location:	HUC = 10130303
Size of Watershed:	962,451 acres
Water Quality Standards:	Numeric
Indicators:	Fecal Coliform Bacteria, and Sodium Adsorption Ratio (SAR)
Analytical Approach:	FLUX (in-stream loadings), PSIAC (landuse impacts), Regression analysis (TSS vs Flow)
TMDL GOAL by Parameter	
Total Suspended Solids:	5% Reduction in annual sediment loadings
TMDL TARGET by Parameter	
Total Suspend Solids vs. Flow Regression Analysis:	Move Average Annual Concentration of 1,017 mg/L to 966 mg/L

Objective:

The intent of this summary is to clearly identify the components of the TMDL submittal to support adequate public participation and facilitate the US Environmental Protection Agency (EPA) review and approval. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

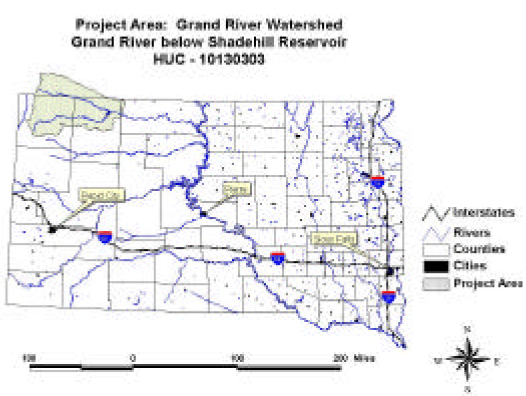


Figure 1. Watershed location in South Dakota

Lake Alvin is a 107-acre man-made impoundment located in northeastern Lincoln County, South Dakota. The 1998 South Dakota 303(d) Waterbody List (page 19) identified Lake Alvin for TMDL development for trophic state index (TSI), increasing eutrophication trend and fecal coliform bacteria.

The damming of Nine Mile Creek one half mile upstream of the confluence of the Big Sioux River created the lake, which has an average depth of 3.38 meters (11.1 feet) and over 5.95 kilometers (3.7 miles) of shoreline. The lake has a maximum depth of 7.01 meters (23 feet), holds 1,002 acre-feet of water, and is subject to periods of stratification during the summer. The outlet for the lake empties back into Nine Mile Creek, which eventually reaches the Big Sioux River south of Sioux Falls.

Problem Identification

Nine Mile Creek is the primary tributary to Lake Alvin and drains predominantly agricultural land (85 percent). Winter feeding areas for livestock are present within the watershed. The stream carries nutrient (phosphorus) loads, which degrade the water quality of the lake and cause increased eutrophication. Currently, the phosphorus load to Lake Alvin is 1,147 kilograms per year, which does not allow the lake to meet designated uses. Phosphorus loads

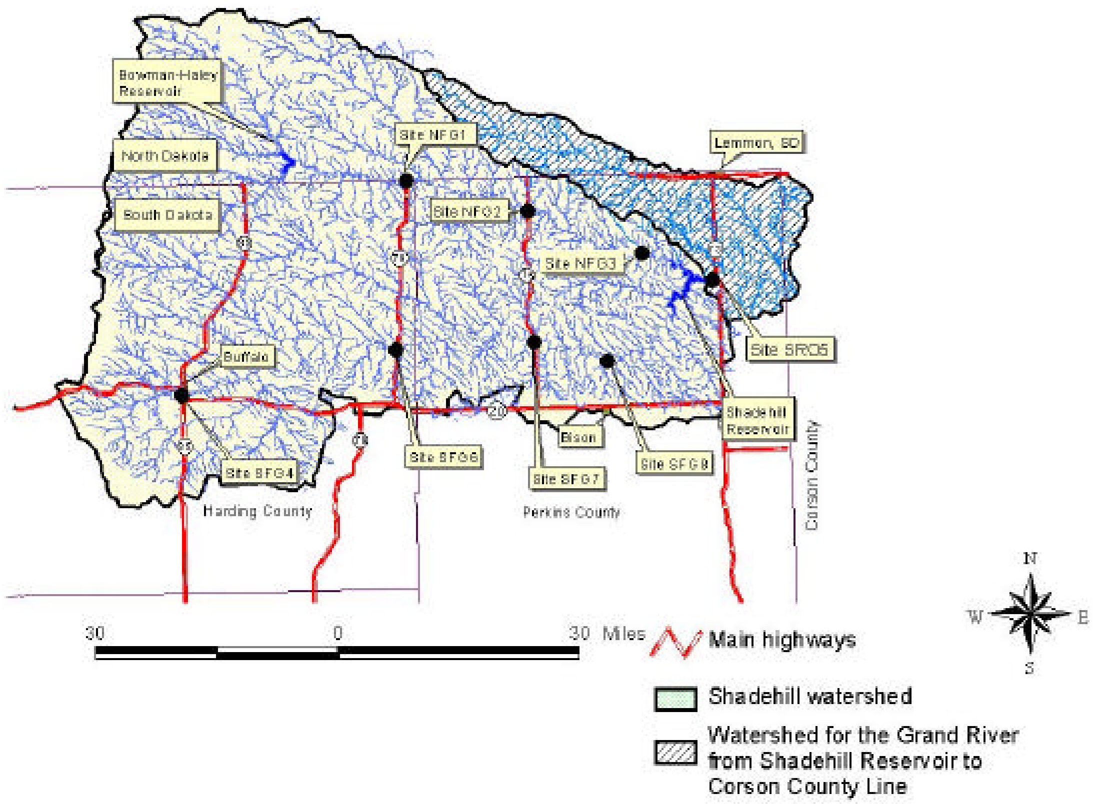


Figure 2. Watershed boundary for the Grand River from Shadehill Reservoir to Corson County Line.

need to be reduced 768 kilograms (67 %), resulting in a phosphorus TMDL for Lake Alvin of a mean TSI of 64.95 (379 kilogram per year) which fully supports beneficial uses.

Sporadic beach closures occur due to fecal coliform counts. Three consecutive samples exceeded 200 colonies/100 mL in June, resulting in one beach closure (June 7 through 23, 1999). Beach fecal coliform colonies will have to be reduced through selective BMPs which will result in the beach complying with South Dakota Water Quality for Public Beach Standards $\leq$ 200 colonies/100 mL for three consecutive samples, which fully supports beneficial uses.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Lake Alvin has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations. Along with these assigned uses are narrative and numeric criteria that define the desired water quality of the lake. These criteria must be maintained for the lake to satisfy its assigned beneficial uses, which are listed below:

(6) Warmwater permanent fish life propagation water;
(7) Immersion recreation water;
(8) Limited contact recreation water; and
(9) Fish and wildlife propagation, recreation and stock watering.

Figure 2.

Individual parameters, including the lake's mean TSI value, determine the support of beneficial uses and compliance with standards. Lake Alvin experiences nutrient enrichment, sporadic beach closures and some nuisance algal blooms which are typical signs of the eutrophication process. Lake Alvin was identified in both the 1998 South Dakota 303(d) Waterbody List and "Ecoregion Targeting for Impaired Lakes in South Dakota" as not supporting its beneficial uses.

South Dakota has several applicable narrative standards that may be applied to the undesired eutrophication of lakes and streams. Administrative Rules of South Dakota Article 74:51 contains language that prohibits the existence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life.

If adequate numeric criteria are not available, the South Dakota Department of Environment and Natural Resources (SD DENR) uses surrogate measures to assess the trophic status of a lake. SD DENR uses the mean Trophic State Index or TSI (Carlson, 1977) which incorporates secchi depth, chlorophyll-*a* and phosphorus concentrations. SD DENR has developed an EPA approved protocol that establishes desired TSI levels for lakes based on an ecoregion approach. This protocol was used to assess impairment and determine a numeric target for Lake Alvin.

Lake Alvin currently has a phosphorus TSI of 80.47, a chlorophyll-*a* TSI of 81.75 and a Secchi TSI of 76.48 and a mean TSI of 79.57, which is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of high productivity is high phosphorus loads from the watershed.

SD DENR-recommended specific TSI parameters for Lake Alvin are: 64.55 for phosphorus, 65.93 for chlorophyll-*a* and 64.38 for Secchi visibility. The TMDL numeric target established to improve the eutrophic status of Lake Alvin is a mean TSI of 64.95 (assessment final report, pages 115-117).

South Dakota Surface Water Quality Standards for immersion recreation is $\leq$ 400 colonies/100 mL for any one sample or a geometric mean of $\leq$ 200 colonies/100 mL on a minimum of five samples collected during separate 24-hour periods for a 30-day period. They may not exceed this value in more than 20 percent of the samples in the same 30-day period (Chapter 74:51:01:50). The South Dakota Water Quality for Public Beaches are $\leq$ 1,000 colonies/100 mL for any one sample, $\leq$ 300 colonies/100 mL for two consecutive samples or $\leq$ 200 colonies/100 mL for three consecutive samples (Chapter 74:04:08:07).

During 1999, one beach closure event occurred in June due to three separate samples. Two of the three samples exceeded 1,000 colonies/100 mL for any one sample and all three exceeded 300 colonies/100 mL for two consecutive samples and 200 colonies/100 mL for three consecutive samples.

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

Analysis of the watershed through the use of the Agricultural Non Point Source (AGNPS) model indicated that approximately 2% of the phosphorus load was the result of feeding area discharge, 5% from inadequate cropland tillage practices and 1.5% from fertilizer. See the AGNPS section of the final report, Appendix E, pages 8, 10 and 11.

Other tributary phosphorus loads were estimated using published percent reductions expected for Best Management Practices (BMPs) on priority subwatersheds. These included inadequate buffers 28.1%, riparian management 8.5% and streambank stabilization 0.9% which contributes to the phosphorus load to Lake Alvin (assessment final report, pages 38 through 40).

Inlake phosphorus reduction percentages were estimated using in-house and published data. Phosphorus reduction recommendations include mechanical aerator/circulator 5% and aluminum sulfate treatment 30% (assessment final report, pages 112 through 114).

The remaining phosphorus loading (120 kg/yr.) was attributed to background sources in the Lake Alvin watershed.

The load allocation for fecal coliform bacteria appeared to have minimal impact swimming beach fecal coliform concentrations. The majority of the loading was attributed (localized) to the swimming beach (assessment final report, pages 115 and 116). The load allocation from the swimming beach was estimated at 30%, based on 140 beach samples collected by South Dakota Game Fish and Parks during 1999.

Fecal coliform bacteria background sources in the watershed were considered 140 colonies/100 mL.

Linkage Analysis

Water quality data was collected from 10 monitoring sites within the Lake Alvin/ Nine Mile Creek watershed. Samples collected at each site were taken according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on approximately 10% of the samples according to South Dakota's EPA approved Clean Lakes Quality Assurance/ Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed on pages 4 through 11 and 41 through 44 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AGNPS (Agricultural Nonpoint Source) model was used to estimate potential nutrient load reductions from feedlots, minimum tillage and fertilizer reduction within the watershed through the implementation of various best management practices. See the AGNPS section of the final report, Appendix E.

Other watershed (buffer strips, riparian management and streambank stabilization) and inlake (aerator/circulator and aluminum sulfate treatment) BMPs were also used to estimate phosphorus reductions. Estimates were based on conservative percent reductions applied to priority subwatersheds (assessment final report, pages 38 through 40 and 112 through 115).

Reducing the current phosphorus load (1147 kg/yr.) a minimum of 67% (768 kg/yr.) will reduce the mean TSI value from 79.57, non-supporting, to 64.95 fully supporting its beneficial uses. This can be accomplished by implementing tributary and inlake BMPs that includes a 14% margin of safety to support the TMDL target.

Fecal coliform loading was attributed to the swimming beach. Reductions in coliform through an information and education program and select tributary BMPs should reduce fecal coliform to 200 colonies/100 mL which fully supports beneficial uses (assessment final report, pages 115 through 116).

An estimated 140 colonies/100 mL was attributed to background sources based upon long term (1992 through 2000) fecal coliform beach samples.

TMDL and Allocations

<u>TMDL</u>

Phosphorus (kg/yr) = 67% reduction

0 kg/yr.	(WLA)
+ 206 kg/yr.	(LA)
+ 120 kg/yr.	(Background)
+ 53 kg/yr. Implicit and Explicit	(MOS)
379 kg/yr.	(TMDL) [1]

[1] = Equation implies a 81% phosphorus reduction with all possible implementation BMPs. A 67% phosphorus reduction is needed to restore beneficial uses. Thus, the TMDL includes a 14% margin of safety.

Fecal Coliform (Lake Alvin)

During 1999, inlake fecal coliform samples did not exceed 200 colonies/100 mL. Based upon the assessment report, inlake fecal coliform concentrations are not a problem in Lake Alvin.

Fecal Coliform (swimming beach)

0 colonies/100 mL	(WLA)
+ 60 colonies/100 mL	(LA) [1]
+ 140 colonies/100 mL	(Background)
+ Implicit	(MOS)
200 colonies/100 mL	(TMDL)

[1] = The swimming beach load was estimated at 30% of the TMDL based on the number of fecal samples exceeding the public beach standard divided by number of sample in compliance with the standard over a nine year period (1992 through 2000).

Wasteload Allocations (WLAs)

There are no point sources of pollutants of concern in this watershed. Therefore, the "wasteload allocation" component of these TMDLs is considered a zero value. The TMDLs are considered wholly included within the "load allocation" component.

Load Allocations (LAs)

The results of the AGNPS model indicates that a 4.3% (49 kg/yr.) and 3.4% (39 kg/yr.) reductions in phosphorus loading to the lake could be achieved by minimum tillage (2,000 acres) and reduced fertilizer application (1,600 acres), respectively, within the watershed.

Removal of 5 animal feeding operations within the watershed would account for an additional 2% (23 kg/yr.) of the phosphorus load to the lake.

Tributary phosphorus reductions for riparian management 8.5% (97 kg/yr.), streambank stabilization 0.9% (10 kg/yr.) and buffer strips 28.1% (322 kg/yr.) were estimated using various methods and BPJ.

Inlake phosphorus reductions were also estimated for Lake Alvin. They include mechanical circulator/ aerator 5% (57 kg/yr.) and an alum treatment 30% (344 kg/yr.).

A total of 67% reduction in phosphorus is needed to restore the beneficial uses of Lake Alvin.

The load from the swimming beach was estimated at 30%, based on 140 beach samples collected by South Dakota Game Fish and Parks from 1992 through 2000.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and agricultural practices. To determine seasonal differences, Lake Alvin samples were separated into spring (March-May), summer (June-August), fall (September-November) and winter (December).

Margin of Safety

All phosphorus reductions were calculated based on extremely conservative estimations built into the model and conservative phosphorus reduction percentages using best professional judgement. Phosphorus reductions were also explicit in that an 81% phosphorus reduction is possible using all possible BMPs and Lake Alvin only needs a 67% phosphorus reduction to restore beneficial uses. The additional 14% is the explicit margin of safety (assessment final report, pages 38 through 40 and 115 through 117, and the load allocation section).

The margin of safety for fecal coliform bacteria for the swimming beach was also implicit.

Critical Conditions

Based upon the 1999 assessment data, impairments to Lake Alvin are most severe during the late summer and early fall. This is the result of warm water temperatures, stratification and increased algal growth. Beach closures tend to occur in early summer.

Follow-Up Monitoring

Lake Alvin should remain on the round robin statewide lake assessment project and on the South Dakota Game Fish and Parks normal lake survey and swimming beach sampling to monitor and evaluate the long term trophic status, biological community and ecological trend. It is recommended that the statewide lake assessment survey for Lake Alvin include fecal coliform samples to periodically monitor long term fecal coliform concentrations.

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

Public Participation

The water quality assessment project was initiated during the spring of 1999 with EPA Section 604(b) and 104 (b)(3) funds. Lake Alvin was on the priority list of Section 319 Nonpoint Pollution Control projects. The Lincoln Conservation District agreed to sponsor the project and provided local matching funds and in-kind services. The federal grant funds totaled $44,675.00, and the local in-kind match totaled $18,576.00. Funds were used for water quality analyses, equipment, supplies, travel, and wages for the local coordinator.

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

1. Lincoln County Conservation District Board Meetings (13)
2. Lincoln County Commission Meeting (1)
3. City of Tea Board Meetings (1)
4. City of Harrisburg Board Meetings (1)
7. Individual contact with landowners in the watershed.
8. Articles in the Canton Sioux Valley News (2) and The Argus Leader (2)

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

Implementation Plan

The South Dakota DENR is working with the Lincoln County Conservation District to initiate an implementation project beginning in 2002. It is expected that a local sponsor will request project assistance during the fall 2001 EPA Section 319 funding round.

APPENDIX II – FLUX MODELING DESCRIPTION

Instruction Report W-96-2
September 1996
(Updated April 1999)

US Army Corps
of Engineers
Waterways Experiment
Station

Water Operations Technical Support Program

Simplified Procedures for Eutrophication Assessment and Prediction: User Manual

by William W. Walker

WES

Prepared for Headquarters, U.S. Army Corps of Engineers

Water Operations Technical Support Program

Instruction Report W-96-2
September 1996
(Updated April 1999)

Simplified Procedures for Eutrophication Assessment and Prediction: User Manual

by William W. Walker
1127 Lowell Road
Concord, MA 01742

Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Monitored by U.S. Army Engineer Waterways Experiment Station
Vicksburg, MS 39180-6199

1 Introduction

Background

This report describes simplified procedures for eutrophication assessment and prediction. These techniques, initially developed for use at U.S. Army Corps of Engineer (CE) reservoirs, are based upon research previously described in a series of technical reports. These reports describe database development (Report 1; Walker 1981); model testing (Report 2; Walker 1982); model refinement (Report 3; Walker 1985); and applications procedures (Report 4; Walker 1987). Reported here is detailed information concerning application of the latest versions of these techniques using a DOS-based personal computer and also reported is an update of the original applications manual (i.e., Report 4).

Three computer programs facilitate data reduction and model implementation. While the assessment procedures and programs can be "run" based upon the information contained in this report, their intelligent "use" requires an understanding of basic modeling concepts and familiarity with the supporting research. Review of the above research reports and related references on this topic (see References and Bibliography) will facilitate proper use of the techniques described below.

Eutrophication can be defined as the enrichment of water bodies leading to an excessive production of organic materials by algae and/or aquatic plants. This process has several direct and indirect impacts on reservoir water quality and beneficial uses. Common measures of eutrophication include total nutrient concentrations (phosphorus and nitrogen), chlorophyll *a* (a measure of algal density), Secchi depth (a measure of transparency), organic nutrient forms (nitrogen and carbon), and hypolimnetic dissolved oxygen depletion.

The basis of the modeling approach described below is to relate eutrophication symptoms to external nutrient loadings, hydrology, and reservoir morphometry using statistical models derived from a representative cross section of reservoirs. When applied to existing reservoirs, the models provide a framework for interpreting water quality monitoring data and predicting

1 Introduction

Background

This report describes simplified procedures for eutrophication assessment and prediction. These techniques, initially developed for use at U.S. Army Corps of Engineer (CE) reservoirs, are based upon research previously described in a series of technical reports. These reports describe database development (Report 1; Walker 1981); model testing (Report 2; Walker 1982); model refinement (Report 3; Walker 1985); and applications procedures (Report 4; Walker 1987). Reported here is detailed information concerning application of the latest versions of these techniques using a DOS-based personal computer and also reported is an update of the original applications manual (i.e., Report 4).

Three computer programs facilitate data reduction and model implementation. While the assessment procedures and programs can be "run" based upon the information contained in this report, their intelligent "use" requires an understanding of basic modeling concepts and familiarity with the supporting research. Review of the above research reports and related references on this topic (see References and Bibliography) will facilitate proper use of the techniques described below.

Eutrophication can be defined as the enrichment of water bodies leading to an excessive production of organic materials by algae and/or aquatic plants. This process has several direct and indirect impacts on reservoir water quality and beneficial uses. Common measures of eutrophication include total nutrient concentrations (phosphorus and nitrogen), chlorophyll *a* (a measure of algal density), Secchi depth (a measure of transparency), organic nutrient forms (nitrogen and carbon), and hypolimnetic dissolved oxygen depletion.

The basis of the modeling approach described below is to relate eutrophication symptoms to external nutrient loadings, hydrology, and reservoir morphometry using statistical models derived from a representative cross section of reservoirs. When applied to existing reservoirs, the models provide a framework for interpreting water quality monitoring data and predicting

2 FLUX

FLUX Overview

FLUX is an interactive program designed for use in estimating the loadings of nutrients or other water quality components passing a tributary sampling station over a given period of time. These estimates can be used in formulating reservoir nutrient balances over annual or seasonal averaging periods appropriate for application of empirical eutrophication models. Data requirements include (a) grab-sample nutrient concentrations, typically measured at a weekly to monthly frequency for a period of at least 1 year, (b) corresponding flow measurements (instantaneous or daily mean values), and (c) a complete flow record (mean daily flows) for the period of interest.

Using six calculation techniques, FLUX maps the flow/concentration relationship developed from the sample record onto the entire flow record to calculate total mass discharge and associated error statistics. An option to stratify the data into groups based upon flow, date, and/or season is also included. In many cases, stratifying the data increases the accuracy and precision of loading estimates. Uncertainty is characterized by error variances of the loading estimates. A variety of graphic and tabular output formats are available to assist the user in evaluating data adequacy and in selecting the most appropriate calculation method and stratification scheme for each application. FLUX provides information which can be used to improve the efficiencies of future monitoring programs designed to provide data for calculating loadings and reservoir mass balances.

The succeeding sections of this chapter contain descriptions of the following topics:

a. Input data requirements.

b. Theory.

c. Program operation.

d. Typical application sequence.

APPENDIX III – GRAND RIVER WATER QUALITY DATA

SITE	FORK	DATE	FLOW cfs	TIME	FECAL col./100ml	WT oC	FPH su	DO mg/L	NO32 mg/L	NH3 mg/L	UNA mg/L	TKN mg/L	ON mg/L	TN mg/L	T mg/
Big Nasty Creek	South	03/28/2000		1145		8.00	8.51	10.40	0.10	0.08	0.0039	1.41	1.33	1.51	0.12
Big Nasty Creek	South	03/30/2000			10										
Big Nasty Creek	South	04/04/2000	1.10	1230		7.00		11.60	0.10	0.02	0.0000	1.30	1.28	1.40	0.08
Big Nasty Creek	South	04/11/2000		1100		7.00	8.56	10.20	0.10	0.02	0.0010	1.35	1.33	1.45	0.09
Big Nasty Creek	South	04/13/2000			60										
Big Nasty Creek	South	04/20/2000			80										
Big Nasty Creek	South	04/25/2000	1.50	1150		15.00	8.18	8.20	0.10	0.02	0.0008	1.68	1.66	1.78	0.12
Big Nasty Creek	South	04/27/2000			1000										
Big Nasty Creek	South	05/09/2000	2.87	1300		16.00	8.43	11.40	0.10	0.02	0.0015	2.57	2.55	2.67	0.23
Big Nasty Creek	South	05/11/2000			580										
Big Nasty Creek	South	05/23/2000		1145		20.00	8.22	8.40	0.10	0.02	0.0012	1.97	1.95	2.07	0.08
Big Nasty Creek	South	05/25/2000			1800										
Big Nasty Creek	South	06/08/2000			240										
Big Nasty Creek	South	06/22/2000			6800										
Bull Creek	South	03/23/2000		900	10										
Bull Creek	South	03/27/2000		1330		3.60	8.61		0.10	0.02	0.0009	0.73	0.71	0.83	0.17
Bull Creek	South	03/30/2000			20										
Bull Creek	South	04/03/2000	2.29	1400		6.00		12.00	0.10	0.02	0.0000	0.82	0.80	0.92	0.11
Bull Creek	South	04/13/2000			10										
Bull Creek	South	04/20/2000			10										
Bull Creek	South	04/24/2000	2.40	1040		13.00	8.75	7.60	0.10	0.02	0.0023	0.56	0.54	0.66	0.17
Bull Creek	South	04/27/2000			760										
Bull Creek	South	05/08/2000	4.39	1330		13.00	8.52	9.20	0.10	0.02	0.0014	0.95	0.93	1.05	0.31
Bull Creek	South	05/11/2000			9700										
Bull Creek	South	05/22/2000	1.04	1045		19.00	8.44	6.80	0.10	0.02	0.0018	1.36	1.34	1.46	0.21
Bull Creek	South			1030		7.00	8.77	10.60							
Butcher Creek	South	03/23/2000		1330	10										
Butcher Creek	South	03/29/2000		1320		5.00	8	10.60	0.10	0.02	0.0002	1.49	1.47	1.59	0.04
Butcher Creek	South	03/30/2000			10										
Butcher Creek	South	04/05/2000	1.35	1230		9.00		10.80	0.10	0.02	0.0000	1.20	1.18	1.30	0.06
Butcher Creek	South	04/10/2000		1410		18.00	8.24	10.80	0.10	0.02	0.0011	1.56	1.54	1.66	0.09
Butcher Creek	South	04/12/2000		1315		8.00	8.22	10.00	0.10	0.02	0.0005	1.23	1.21	1.33	0.06
Butcher Creek	South	04/13/2000			10										
Butcher Creek	South	04/20/2000			10										
Butcher Creek	South	04/26/2000	2.75	30		18.00	8.17	7.40	0.10	0.02	0.0010	1.37	1.35	1.47	0.08
Butcher Creek	South	04/27/2000			370										
Butcher Creek	South	05/11/2000			190										
Butcher Creek	South	05/24/2000		1400		19.00	8.24	9.40	0.10	0.02	0.0012	1.65	1.63	1.75	0.10
Clarks Fork Creek	South	03/23/2000		815	50										

SITE	FORK	DATE	FLOW	TIME	FECAL	WT	FPH	DO	NO32	NH3	UNA	TKN	ON	TN	T
			cfs		col./100ml	oC	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/
Clarks Fork Creek	South	03/27/2000		1100		9.00	8.94	11.00	0.10	0.02	0.0026	1.11	1.09	1.21	0.15
Clarks Fork Creek	South	03/30/2000			460										
Clarks Fork Creek	South	04/03/2000	2.64	1150		4.00		12.60	0.10	0.02	0.0000	0.66	0.64	0.76	0.13
Clarks Fork Creek	South	04/10/2000	2.81	840		5.00	9	11.20	0.10	0.02	0.0022	0.63	0.61	0.73	0.14
Clarks Fork Creek	South	04/13/2000			4900										
Clarks Fork Creek	South	04/20/2000			560										
Clarks Fork Creek	South	04/24/2000	5.68	845		13.00	9.01	9.00	0.10	0.02	0.0039	0.63	0.61	0.73	0.36
Clarks Fork Creek	South	04/27/2000			2500										
Clarks Fork Creek	South	05/08/2000	105.93	945		8.00	9.43	10.20	0.20	0.02	0.0060	5.86	5.84	6.06	2.04
Clarks Fork Creek	South	05/11/2000			6300										
Clarks Fork Creek	South	05/22/2000	2.47	900		17.00	8.69	9.00	0.10	0.02	0.0027	0.96	0.94	1.06	0.23
Clarks Fork Creek	South	05/25/2000			900										
Clarks Fork Creek	South	06/08/2000			410										
Clarks Fork Creek	South	06/22/2000			700										
Crooked Creek	North	03/23/2000		920	10										
Crooked Creek	North	03/27/2000		1400		4.00	8.76	14.60	0.10	0.02	0.0012	1.33	1.31	1.43	0.15
Crooked Creek	North	03/30/2000			50										
Crooked Creek	North	04/03/2000	0.81	1448		6.00		11.40	0.10	0.02	0.0000	1.46	1.44	1.56	0.11
Crooked Creek	North	04/11/2000	0.79	1130		9.00	8.72	10.20	0.10	0.02	0.0017	1.25	1.23	1.35	0.13
Crooked Creek	North	04/13/2000			10										
Crooked Creek	North	04/20/2000			10										
Crooked Creek	North	05/08/2000	17.34	1415		15.00	8.53	9.80	0.10	0.02	0.0017	1.51	1.49	1.61	0.20
Crooked Creek	North	05/11/2000			3500										
Crooked Creek	North	05/22/2000	2.03	1135		18.00	8.36	8.20	0.10	0.02	0.0015	2.02	2.00	2.12	0.18
Crooked Creek	North	06/22/2000			610										
Horse Creek	South	03/23/2000		1145	10										
Horse Creek	South	03/23/2000		1210	20										
Horse Creek	South	03/28/2000		1000		5.00	8.94	11.20	0.10	0.02	0.0020	0.60			0.20
Horse Creek	South	03/30/2000			90										
Jones Creek	South	03/23/2000		850	10										
Jones Creek	South	03/27/2000		1300		9.00	8.34	13.20	0.10	0.02	0.0007	0.66			0.14
Jones Creek	South	03/30/2000			10										
Jones Creek	South	04/03/2000	1.64	1315		6.00		12.80	0.10	0.02	0.0000	0.89			0.10
Jones Creek	South	04/11/2000	0.66	1000		5.00	8.77	10.60	0.10	0.02	0.0014	0.69			0.13
Jones Creek	South	04/13/2000			10										
Jones Creek	South	04/24/2000	3.52	1010		12.00	8.86	8.60	0.30	0.02	0.0027	0.32			0.36
Jones Creek	South	04/27/2000			40										
Jones Creek	South	05/08/2000	3.76	1300		16.00	8.3	7.80	0.10	0.02	0.0011	1.18			0.35
Jones Creek	South	05/11/2000			180										

SITE	FORK	DATE	FLOW	TIME	FECAL	WT	FPH	DO	NO32	NH3	UNA	TKN	ON	TN	T
			cfs		col./100ml	oC	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/
Jones Creek	South	05/22/2000	0.43	1015		18.00		8.60	0.10	0.02	0.0000	1.04			0.03
Jones Creek	South	05/25/2000			1000										
Jones Creek	South	06/08/2000			480										
LodgePole Creek	Shadehil	03/22/2000		1230	260	9.00	8.64	10.40	0.10	0.02	0.0014	0.83			0.14
LodgePole Creek	Shadehil	03/29/2000		900		5.00	8.16	5.20	0.10	0.02	0.0004	0.73			0.04
LodgePole Creek	Shadehil	03/30/2000			320										
LodgePole Creek	Shadehil	04/05/2000		905		8.00		8.80	0.10	0.02	0.0000	0.68			0.05
LodgePole Creek	Shadehil	04/12/2000		915		5.00	8.22	7.00	0.10	0.02	0.0004	0.58			0.05
LodgePole Creek	Shadehil	04/13/2000			290										
LodgePole Creek	Shadehil	04/20/2000			110										
NFG1	North	05/19/1999	138.46	1112		16.50	8.4	7.40	0.39	0.01	0.0007	1.60	1.59	1.99	0.06
NFG1	North	06/03/1999	40.16		100										
NFG1	North	06/16/1999	35.10	1045		25.10	8.25	9.20	0.27	0.38	0.0351	2.00	1.62	2.27	0.10
NFG1	North	06/23/1999	20.79		40										
NFG1	North	07/07/1999	17.13		90										
NFG1	North	07/09/1999	15.69	1124		20.90	8.87	7.35	1.12	0.00	0.0000	1.60	1.60	2.72	0.04
NFG1	North	07/20/1999	13.40	1030		22.50	8.55	11.60	0.10	0.15	0.0217	1.60	1.45	1.70	0.11
NFG1	North	07/21/1999	12.87		60										
NFG1	North	08/02/1999	9.64		60										
NFG1	North	08/04/1999	9.21	1026		23.00	8.64	12.00	0.42	0.03	0.0053	0.90	0.87	1.32	0.09
NFG1	North	08/09/1999	8.22	1015		22.00	8.59	12.70	0.21	0.07	0.0106	1.60	1.53	1.81	0.00
NFG1	North	08/11/1999	7.14		40										
NFG1	North	08/16/1999	30.03	1108		21.00	8.54	10.60	0.23	0.00	0.0000	1.90	1.90	2.13	0.10
NFG1	North	08/18/1999	31.73		80										
NFG1	North	08/24/1999	31.58	1040		21.00	8.37	6.80	0.91	0.24	0.0218	1.40	1.16	2.31	0.13
NFG1	North	08/25/1999	31.45		30										
NFG1	North	08/30/1999	12.05	1100		19.00	8.17	7.90	0.22	0.28	0.0145	1.40	1.12	1.62	0.09
NFG1	North	09/08/1999	8.30	1150		14.70	8.44	9.62	0.21	0.21	0.0144	1.10	0.89	1.31	0.06
NFG1	North	09/14/1999	8.75	1040		11.00	8.58	8.10	0.05	0.14	0.0100	1.60	1.46	1.65	0.06
NFG1	North	09/15/1999	8.75		20										
NFG1	North	09/21/1999	9.87	1030		13.00	8.23	7.50	0.01	0.15	0.0058	1.00	0.85	1.01	0.06
NFG1	North	09/22/1999	9.92		10										
NFG1	North	09/27/1999	9.33	1110		10.00	8.19	9.60	0.01	0.13	0.0036	1.10	0.97	1.11	0.10
NFG1	North	09/28/1999	9.74		40										
NFG1	North	10/05/1999	9.50	1056		8.00	8.22	9.30	0.05	0.24	0.0062	1.10	0.86	1.15	0.09
NFG1	North	10/06/1999	10.50		10										
NFG1	North	10/13/1999	10.59		30										
NFG1	North	10/14/1999	10.90	1025		11.00	8.21	10.00	0.09	0.15	0.0047	1.00	0.85	1.09	0.07
NFG1	North	11/02/1999	7.95	1225		4.00	8.26	11.80	0.03	0.03	0.0006	0.90	0.87	0.93	0.11

SITE	FORK	DATE	FLOW	TIME	FECAL	WT	FPH	DO	NO32	NH3	UNA	TKN	ON	TN	T
			cfs		col./100ml	oC	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/
NFG1	North	11/03/1999	7.95		90										
NFG1	North	03/23/2000			10										
NFG1	North	03/28/2000		900		6.00	8.6	11.00	0.10	0.02	0.0010	1.08	1.06	1.18	0.04
NFG1	North	03/30/2000			10										
NFG1	North	04/04/2000	11.62	1020		6.00		10.20	0.10	0.02	0.0000	0.94	0.92	1.04	0.03
NFG1	North	04/11/2000	6.96	900		5.00	8.66	11.00	0.10	0.02	0.0011	0.90	0.88	1.00	0.03
NFG1	North	04/13/2000			10										
NFG1	North	04/20/2000			80										
NFG1	North	04/25/2000	3.76	945		13.00	8.35	8.20	0.10	0.02	0.0010	1.01	0.99	1.11	0.05
NFG1	North	04/27/2000			260										
NFG1	North	05/09/2000	6.24	1100		15.00	8.53	9.00	0.10	0.02	0.0017	1.18	1.16	1.28	0.09
NFG1	North	05/11/2000			7500										
NFG1	North	05/23/2000	1.58	950		17.00	8.6	7.60	0.10	0.02	0.0022	1.21	1.19	1.31	0.09
NFG1	North	06/08/2000			190										
NFG1	North	06/22/2000			200										
NFG2	North	05/11/1999	41.37	1330		19.00	8.47	9.20	0.20	0.12	0.0118	1.40	1.28	1.60	0.05
NFG2	North	06/03/1999	15.28		100										
NFG2	North	06/15/1999	11.19	1140		20.50	8.1	8.50	0.16	0.25	0.0123	1.80	1.55	1.96	0.02
NFG2	North	06/23/1999	13.28		290										
NFG2	North	07/06/1999	23.45	1045		21.00	8.23	7.40	0.20	0.00	0.0000	1.40	1.40	1.60	0.04
NFG2	North	07/07/1999	20.50		70										
NFG2	North	07/19/1999	29.87	1315		22.50	8.52	10.00	0.09	0.05	0.0068	1.40	1.35	1.49	0.11
NFG2	North	07/21/1999	22.10		140										
NFG2	North	07/21/1999	22.10		1200										
NFG2	North	08/02/1999	11.82		450										
NFG2	North	08/03/1999	11.73	1030		25.00	8.6	6.00	0.30	0.00	0.0000	2.00	2.00	2.30	0.09
NFG2	North	08/10/1999	11.58	1040		22.00	8.62	9.40	0.22	0.04	0.0064	1.80	1.76	2.02	0.04
NFG2	North	08/11/1999	12.18		130										
NFG2	North	08/17/1999	20.63	1313		24.00	8.62	7.90	0.20	0.00	0.0000	1.70	1.70	1.90	1.00
NFG2	North	08/18/1999	21.65		170										
NFG2	North	08/23/1999	32.63	1108		21.00	8.43	7.40	0.24	0.25	0.0258	1.30	1.05	1.54	0.10
NFG2	North	08/25/1999	33.89		90										
NFG2	North	08/31/1999	18.09	1127		23.50	8.36	7.20	0.26	0.22	0.0231	1.20	0.98	1.46	0.06
NFG2	North	09/01/1999	16.97		120										
NFG2	North	09/07/1999	16.85	1045		17.00	8.16	6.30	0.36	0.22	0.0097	1.40	1.18	1.76	0.06
NFG2	North	09/13/1999	13.04	1120		11.00	8.31	10.60	0.07	0.15	0.0059	1.20	1.05	1.27	0.04
NFG2	North	09/15/1999	13.70		10										
NFG2	North	09/20/1999	13.64	1037		11.50	8.18	8.30	0.01	0.11	0.0034	1.10	0.99	1.11	0.05
NFG2	North	09/22/1999	13.76		40										

SITE	FORK	DATE	FLOW cfs	TIME	FECAL col./100ml	WT oC	FPH su	DO mg/L	NO32 mg/L	NH3 mg/L	UNA mg/L	TKN mg/L	ON mg/L	TN mg/L	T mg/
NFG2	North	09/28/1999	14.76		10										
NFG2	North	09/29/1999	15.14	1114		9.00	8.14	8.40	0.01	0.12	0.0028	0.90	0.78	0.91	0.05
NFG2	North	10/04/1999	13.86	1123		8.00	7.92	9.20	0.03	0.13	0.0017	0.80	0.67	0.83	0.06
NFG2	North	10/06/1999	14.14		20										
NFG2	North	10/12/1999	14.25	1115		12.00	8.09	8.20	0.07	0.14	0.0037	0.80	0.66	0.87	0.05
NFG2	North	10/13/1999	14.40		20										
NFG2	North	11/01/1999	15.63	1145		4.50	8.27	14.70	0.05	0.02	0.0004	1.00	0.98	1.05	0.05
NFG2	North	11/03/1999	15.63		10										
NFG2	North	03/28/2000		50		8.00	8.66	10.20	0.10	0.02	0.0014	1.14	1.12	1.24	0.05
NFG2	North	03/30/2000			10										
NFG2	North	04/04/2000	15.78	1330		8.00		12.00	0.10	0.02	0.0000	1.02	1.00	1.12	0.04
NFG2	North	04/11/2000	15.09	30		6.00	8.71	11.20	0.10	0.02	0.0013	0.94	0.92	1.04	0.05
NFG2	North	04/13/2000			10										
NFG2	North	04/20/2000			10										
NFG2	North	04/25/2000	8.46	1300		14.00	8.36	9.60	0.10	0.02	0.0011	0.91	0.89	1.01	0.06
NFG2	North	04/27/2000			40										
NFG2	North	05/09/2000	11.53	1415		17.00	8.55	10.00	0.10	0.02	0.0020	1.25	1.23	1.35	0.08
NFG2	North	05/11/2000			200										
NFG2	North	05/23/2000	6.67	1310		20.00	8.36	8.00	0.10	0.02	0.0017	1.13	1.11	1.23	0.11
NFG2	North	06/08/2000			120										
NFG2	North	06/22/2000			140										
NFG3	North	05/11/1999	28.30	1240		19.00	8.33	8.90	0.24	0.00	0.0000	1.80	1.80	2.04	0.02
NFG3	North	06/03/1999	28.67		610										
NFG3	North	06/15/1999	18.90	1008		21.00	8.67	7.95	0.22	0.25	0.0416	1.50	1.25	1.72	0.05
NFG3	North	06/23/1999	18.96		1200										
NFG3	North	07/06/1999	10.49	915		22.00	8.82	6.50	0.36	0.00	0.0000	1.50	1.50	1.86	0.10
NFG3	North	07/07/1999	11.95		17000										
NFG3	North	07/19/1999	10.35	1030		20.00	8.37	7.10	0.07	0.03	0.0026	1.00	0.97	1.07	0.09
NFG3	North	07/21/1999	13.30		1200										
NFG3	North	08/02/1999	10.08		120										
NFG3	North	08/03/1999	9.14	910		24.50	8.5	10.40	0.27	0.09	0.0133	1.90	1.81	2.17	0.02
NFG3	North	08/10/1999	9.31	907		22.50	8.68	10.60	0.21	0.04	0.0074	2.00	1.96	2.21	0.01
NFG3	North	08/11/1999	9.18		150										
NFG3	North	08/17/1999	19.24	1204		24.50	8.68	7.40	0.22	0.00	0.0000	1.60	1.60	1.82	0.05
NFG3	North	08/18/1999	22.31		240										
NFG3	North	08/23/1999	38.31	945		22.00	8.49	6.20	0.23	0.24	0.0298	1.40	1.16	1.63	0.07
NFG3	North	08/25/1999	32.81		40										
NFG3	North	08/31/1999	21.12	920		22.50	8.31	6.60	0.23	0.34	0.0301	1.30	0.96	1.53	0.06
NFG3	North	09/01/1999	17.61		130										

SITE	FORK	DATE	FLOW	TIME	FECAL	WT	FPH	DO	NO32	NH3	UNA	TKN	ON	TN	T
			cfs		col./100ml	oC	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/
NFG3	North	09/07/1999	15.81	922		17.00	8.14	6.60	0.24	0.23	0.0097	1.50	1.27	1.74	0.07
NFG3	North	09/13/1999	11.63	930		11.00	8.41	9.80	0.06	0.13	0.0064	1.50	1.37	1.56	0.12
NFG3	North	09/15/1999	11.47		60										
NFG3	North	09/20/1999	9.93	918		11.50	8.19	8.50	0.01	0.12	0.0038	1.20	1.08	1.21	0.00
NFG3	North	09/22/1999	10.05		20										
NFG3	North	09/28/1999	14.59		30										
NFG3	North	09/29/1999	13.88	952		9.00	8.07	9.20	0.01	0.12	0.0024	0.90	0.78	0.91	0.12
NFG3	North	10/04/1999	22.08	922		6.00	8.04	10.20	0.04	0.13	0.0019	0.80	0.67	0.84	0.06
NFG3	North	10/06/1999	19.99		20										
NFG3	North	10/12/1999	14.30	915		11.00	8.15	8.40	0.07	0.14	0.0039	0.80	0.66	0.87	0.07
NFG3	North	10/13/1999	10.21		60										
NFG3	North	11/01/1999	9.16	1030		4.50	8.19	14.00	0.04	0.01	0.0002	0.90	0.89	0.94	0.11
NFG3	North	11/03/1999	9.16		10										
NFG3	North	03/29/2000		1005		5.00	8.8	10.80	0.10	0.02	0.0015	0.88	0.86	0.98	0.05
NFG3	North	03/30/2000			160										
NFG3	North	04/05/2000	14.75	1030		9.00		11.00	0.10	0.02	0.0000	0.91	0.89	1.01	0.06
NFG3	North	04/12/2000	17.29	1010		6.00	8.8	11.20	0.10	0.02	0.0016	0.90	0.88	1.00	0.05
NFG3	North	04/20/2000			180										
NFG3	North	04/26/2000	15.97	1020		14.00	8.63	8.80	0.10	0.02	0.0020	0.77	0.75	0.87	0.08
NFG3	North	04/27/2000			460										
NFG3	North	05/10/2000	17.91	1035		17.00	8.46	9.20	0.10	0.02	0.0017	1.43	1.41	1.53	0.10
NFG3	North	05/11/2000			410										
NFG3	North	05/24/2000	10.41	1105		18.00	8.57	8.00	0.10	0.02	0.0023	1.35	1.33	1.45	0.11
NFG3	North	06/07/2000	78.46			24.00	8.61	6.80	0.10	0.02	0.0036	1.27	1.25	1.37	0.05
NFG3	North	06/08/2000			390										
NFG3	North	06/22/2000			830										
SFG4	South	05/19/1999	24.49	920		14.90	8.67	7.00	0.49	0.01	0.0011	4.00	3.99	4.49	1.19
SFG4	South	06/03/1999	3.19		2200										
SFG4	South	06/16/1999	39.00	845		21.90	9.18	8.50	0.32	0.17	0.0694	0.80	0.63	1.12	0.07
SFG4	South	06/23/1999	1.71		620										
SFG4	South	07/07/1999	0.14		490										
SFG4	South	07/09/1999	0.72	920		17.90	9.09	7.40	0.25	0.00	0.0000	0.90	0.90	1.15	0.24
SFG4	South	07/20/1999	2.41	845		19.00	8.92	11.30	0.05	0.06	0.0141	0.80	0.74	0.85	0.15
SFG4	South	07/21/1999	2.15		670										
SFG4	South	08/02/1999	1.43		680										
SFG4	South	08/04/1999	1.34	847		19.00	8.98	11.20	0.35	0.00	0.0000	1.90	1.90	2.25	0.00
SFG4	South	08/09/1999	1.25	835		20.00	8.97	11.40	0.19	0.05	0.0135	1.00	0.95	1.19	0.10
SFG4	South	08/11/1999	1.95		1400										
SFG4	South	08/16/1999	7.95	846		18.00	8.9	11.20	0.35	0.11	0.0235	6.90	6.79	7.25	0.99

SITE	FORK	DATE	FLOW	TIME	FECAL	WT	FPH	DO	NO32	NH3	UNA	TKN	ON	TN	T
			cfs		col./100ml	oC	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/
SFG4	South	08/18/1999	11.93		1700										
SFG4	South	08/24/1999	1.86	848		18.00	8.75	7.30	0.37	0.23	0.0372	2.10	1.87	2.47	0.48
SFG4	South	08/25/1999	1.82		350										
SFG4	South	08/30/1999	2.09	925		18.00	8.76	7.90	1.66	0.18	0.0297	0.90	0.72	2.56	0.11
SFG4	South	09/01/1999	1.97		250										
SFG4	South	09/08/1999	2.11	800		12.00	8.74	10.90	0.28	0.15	0.0160	1.10	0.95	1.38	0.09
SFG4	South	09/14/1999	2.18	840		8.50	8.84	8.40	0.08	0.13	0.0134	0.60	0.47	0.68	0.10
SFG4	South	09/15/1999	2.20		220										
SFG4	South	09/21/1999	2.32	845		10.50	8.81	7.80	0.01	0.00	0.0000	0.70	0.70	0.71	0.12
SFG4	South	09/22/1999	2.34		1500										
SFG4	South	09/27/1999	2.61	930		8.00	8.66	9.70	0.01	0.00	0.0000	0.60	0.60	0.61	0.11
SFG4	South	09/28/1999	2.74		260										
SFG4	South	10/05/1999	12.58	900		6.00	8.87	9.60	0.90	0.21	0.0192	1.10	0.89	2.00	0.40
SFG4	South	10/06/1999	3.71		990										
SFG4	South	10/13/1999	1.97		250										
SFG4	South	10/14/1999	1.97	840		8.00	8.87	10.60	0.07	0.01	0.0011	0.70	0.69	0.77	0.11
SFG4	South	11/02/1999	2.36	900		0.20	8.69	14.70	0.03	0.01	0.0004	0.70	0.69	0.73	0.10
SFG4	South	11/03/1999	2.36		100										
SFG4	South	03/23/2000			10										
SFG4	South	03/27/2000		1200		4.00	8.6	12.40	0.10	0.02	0.0009	0.33	0.31	0.43	0.17
SFG4	South	03/30/2000			10										
SFG4	South	04/03/2000	4.59	1230		5.00		12.40	0.10	0.02	0.0000	0.48	0.46	0.58	0.12
SFG4	South	04/10/2000	3.77	920		4.00	9	11.20	0.10	0.02	0.0021	0.40	0.38	0.50	0.09
SFG4	South	04/13/2000			10										
SFG4	South	04/20/2000			150										
SFG4	South	04/24/2000	39.01	945		12.00	9.65	9.00	0.30	0.04	0.0197	0.30	0.26	0.60	1.49
SFG4	South	04/27/2000			900										
SFG4	South	05/08/2000		1045		10.00	9.1	8.80	0.70	0.03	0.0057	7.39	7.36	8.09	3.26
SFG4	South	05/11/2000			3100										
SFG4	South	05/22/2000	2.36	940		16.00	8.5	9.00	0.10	0.02	0.0017	0.96	0.94	1.06	0.20
SFG4	South	06/08/2000			5400										
SFG4	South	06/22/2000			2200										
SFG6	South	05/19/1999	120.79	1530		19.50	8.29	8.20	0.37	0.00	0.0000	2.80	2.80	3.17	0.49
SFG6	South	06/04/1999	39.86		2300										
SFG6	South	06/16/1999	86.58	1230		22.50	8.21	8.45	0.34	0.23	0.0165	2.60	2.37	2.94	1.11
SFG6	South	06/23/1999	17.75		5900										
SFG6	South	07/07/1999	16.95		570										
SFG6	South	07/09/1999	15.25	1255		20.50	9.21	8.25	0.19	0.00	0.0000	1.90	1.90	2.09	0.19
SFG6	South	07/20/1999	15.14	1210		25.00	8.95	12.60	0.06	0.07	0.0236	0.80	0.73	0.86	0.14

SITE	FORK	DATE	FLOW	TIME	FECAL	WT	FPH	DO	NO32	NH3	UNA	TKN	ON	TN	T
			cfs		col./100ml	oC	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/
SFG6	South	07/21/1999	14.73		170										
SFG6	South	08/02/1999	14.26		100										
SFG6	South	08/04/1999	14.39	1210		25.20	9.03	8.65	0.24	0.00	0.0000	2.20	2.20	2.44	0.04
SFG6	South	08/09/1999	14.23	1205		24.00	9	13.00	0.21	0.04	0.0139	1.20	1.16	1.41	0.05
SFG6	South	08/11/1999	14.35		160										
SFG6	South	08/16/1999	80.09	1300		22.00	8.68	10.80	0.28	0.05	0.0090	3.60	3.55	3.88	0.91
SFG6	South	08/18/1999	60.87		4500										
SFG6	South	08/24/1999	15.58	1235		23.00	8.71	7.80	0.21	0.16	0.0323	1.70	1.54	1.91	0.14
SFG6	South	08/25/1999	15.17		980										
SFG6	South	08/30/1999	15.59	1220		22.50	8.75	8.80	0.23	0.17	0.0359	1.30	1.13	1.53	0.12
SFG6	South	09/01/1999	14.68		660										
SFG6	South	09/08/1999	15.07	248		15.50	8.89	11.10	0.24	0.15	0.0271	1.30	1.15	1.54	0.11
SFG6	South	09/14/1999	14.62	1220		13.00	8.92	7.80	0.06	0.01	0.0016	0.90	0.89	0.96	0.13
SFG6	South	09/15/1999	14.66		440										
SFG6	South	09/21/1999	14.70	1215		16.00	8.8	7.40	0.01	0.00	0.0000	0.60	0.60	0.61	0.04
SFG6	South	09/22/1999	14.67		330										
SFG6	South	09/27/1999	14.57	1245		9.50	8.67	9.50	0.01	0.00	0.0000	0.50	0.50	0.51	0.09
SFG6	South	09/28/1999	14.82		190										
SFG6	South	10/05/1999	22.25	1230		10.00	8.7	9.20	0.08	0.07	0.0060	0.80	0.73	0.88	0.14
SFG6	South	10/06/1999	23.10		1100										
SFG6	South	10/13/1999	15.46		110										
SFG6	South	10/14/1999	15.50	1120		12.00	8.63	10.50	0.06	0.01	0.0008	0.80	0.79	0.86	0.07
SFG6	South	11/01/1999	15.50	1440		4.20	8.7	15.50	0.08	0.01	0.0006	0.90	0.89	0.98	0.17
SFG6	South	11/03/1999	15.50		120										
SFG6	South	03/28/2000		1050		7.00	8.91	10.80	0.10	0.02	0.0021	0.68	0.66	0.78	0.22
SFG6	South	03/30/2000			10										
SFG6	South	04/04/2000	13.87	1120		6.00		11.60	0.10	0.02	0.0000	0.41	0.39	0.51	0.10
SFG6	South	04/11/2000	17.30	1000		5.00	9.12	12.00	0.10	0.02	0.0028	0.74	0.72	0.84	0.13
SFG6	South	04/13/2000			10										
SFG6	South	04/20/2000			10										
SFG6	South	04/25/2000	23.93	1050		14.00	8.73	9.80	0.10	0.03	0.0036	0.67	0.64	0.77	0.18
SFG6	South	04/27/2000			500										
SFG6	South	05/23/2000	15.37	1050		17.00	8.82	9.00	0.10	0.02	0.0035	0.58	0.56	0.68	0.17
SFG6	South	06/08/2000			1760										
SFG6	South	06/22/2000			1300										
SFG7	South	05/11/1999	147.83	1440		19.00	8.35	7.90	0.40	0.00	0.0000	2.70	2.70	3.10	0.50
SFG7	South	06/04/1999	51.25		210										
SFG7	South	06/15/1999	81.08	1335		21.50	8.39	8.00	0.22	0.23	0.0226	2.20	1.97	2.42	0.18
SFG7	South	06/23/1999	41.19		1400										

SITE	FORK	DATE	FLOW cfs	TIME	FECAL col./100ml	WT oC	FPH su	DO mg/L	NO32 mg/L	NH3 mg/L	UNA mg/L	TKN mg/L	ON mg/L	TN mg/L	T mg/
SFG7	South	07/06/1999	31.16	1240		24.00	9.2	8.00	0.23	0.00	0.0000	1.00	1.00	1.23	0.14
SFG7	South	07/07/1999	30.74		330										
SFG7	South	07/20/1999	18.55	1335		26.50	8.96	14.20	0.06	0.06	0.0219	0.80	0.74	0.86	0.09
SFG7	South	07/21/1999	17.21		270										
SFG7	South	08/02/1999	7.55		170										
SFG7	South	08/03/1999	8.20	1230		27.50	9.04	7.60	0.22	0.00	0.0000	2.00	2.00	2.22	0.00
SFG7	South	08/10/1999	9.59	1230		25.00	8.99	13.60	0.19	0.05	0.0179	1.70	1.65	1.89	0.05
SFG7	South	08/11/1999	10.22		270										
SFG7	South	08/17/1999	97.31	1418		24.00	8.08	7.00	0.32	0.13	0.0078	4.10	3.97	4.42	0.84
SFG7	South	08/18/1999	69.59		6500										
SFG7	South	08/23/1999	25.02	1301		22.00	8.66	9.10	0.22	0.19	0.0330	1.70	1.51	1.92	0.17
SFG7	South	08/25/1999	21.89		320										
SFG7	South	08/31/1999	22.74	1315		25.50	8.71	8.60	0.26	0.22	0.0511	1.20	0.98	1.46	0.08
SFG7	South	09/01/1999	19.25		230										
SFG7	South	09/07/1999	24.62	1230		17.00	8.64	6.80	0.27	0.18	0.0220	1.20	1.02	1.47	0.11
SFG7	South	09/13/1999	19.60	1300		11.00	8.82	12.00	0.14	0.01	0.0012	1.20	1.19	1.34	0.12
SFG7	South	09/15/1999	19.78		30										
SFG7	South	09/20/1999	19.72	1245		15.00	8.83	9.20	0.01	0.00	0.0000	1.20	1.20	1.21	0.15
SFG7	South	09/22/1999	17.87		140										
SFG7	South	09/28/1999	20.94		90										
SFG7	South	09/29/1999	19.12	1255		10.00	8.71	9.60	0.01	0.00	0.0000	0.50	0.50	0.51	0.06
SFG7	South	10/04/1999	29.17	1303		9.00	8.69	10.40	0.04	0.04	0.0031	0.60	0.56	0.64	0.09
SFG7	South	10/06/1999	37.93		300										
SFG7	South	10/12/1999	25.07	1250		12.00	8.57	10.00	0.07	0.01	0.0007	0.70	0.69	0.77	0.05
SFG7	South	10/13/1999	23.95		160										
SFG7	South	11/01/1999	23.80	1325		4.50	8.63	15.00	0.16	0.02	0.0010	1.60	1.58	1.76	0.26
SFG7	South	11/03/1999	23.80		40										
SFG7	South	03/28/2000		1348		9.00	8.77	11.40	0.10	0.02	0.0018	0.84	0.82	0.94	0.24
SFG7	South	03/30/2000			50										
SFG7	South	04/04/2000	11.81	1500		9.00		9.20	0.10	0.02	0.0000	0.50	0.48	0.60	0.18
SFG7	South	04/11/2000	12.14	1400		7.00	9.05	12.00	0.10	0.02	0.0028	0.67	0.65	0.77	0.18
SFG7	South	04/13/2000			550										
SFG7	South	04/20/2000			280										
SFG7	South	04/25/2000	15.08	1450		16.00	8.62	10.20	0.10	0.02	0.0022	0.92	0.90	1.02	0.19
SFG7	South	04/27/2000			1800										
SFG7	South	05/23/2000	9.77	1430		21.00	8.69	8.00	0.10	0.02	0.0035	0.39	0.37	0.49	0.51
SFG7	South	06/08/2000			340										
SFG7	South	06/22/2000			560										
SFG8	South	05/11/1999	186.78	1130		17.50	8.61	8.80	0.50	0.04	0.0047	2.90	2.86	3.40	0.65

SITE	FORK	DATE	FLOW	TIME	FECAL	WT	FPH	DO	NO32	NH3	UNA	TKN	ON	TN	T
			cfs		col./100ml	oC	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/
SFG8	South	06/04/1999	32.06		700										
SFG8	South	06/15/1999	63.61	920		20.50	8.68	8.50	0.22	0.23	0.0379	1.70	1.47	1.92	0.06
SFG8	South	06/23/1999	30.16		1300										
SFG8	South	07/06/1999	19.60	815		17.50	8.83	7.20	0.36	0.00	0.0000	1.20	1.20	1.56	0.03
SFG8	South	07/07/1999	21.66		390										
SFG8	South	07/19/1999	16.58	925		23.00	8.73	7.30	0.12	0.07	0.0147	1.00	0.93	1.12	0.04
SFG8	South	07/21/1999	17.32		250										
SFG8	South	08/02/1999	12.54		40										
SFG8	South	08/03/1999	13.16	800		23.50	8.99	6.75	0.22	0.00	0.0000	3.80	3.80	4.02	0.00
SFG8	South	08/10/1999	14.96	810		20.00	9.02	11.00	0.20	0.01	0.0029	1.50	1.49	1.70	0.05
SFG8	South	08/11/1999	19.12		90										
SFG8	South	08/17/1999	106.08	930		20.50	8.37	7.20	0.29	0.13	0.0114	4.00	3.87	4.29	0.00
SFG8	South	08/18/1999	73.93		5900										
SFG8	South	08/23/1999	20.94	830		18.50	8.56	8.10	0.22	0.21	0.0240	1.70	1.49	1.92	0.15
SFG8	South	08/25/1999	19.17		280										
SFG8	South	08/31/1999	19.39	815		21.00	8.62	7.50	0.22	0.19	0.0287	1.20	1.01	1.42	0.12
SFG8	South	09/01/1999	17.00		320										
SFG8	South	09/07/1999	18.60	815		16.50	8.59	8.50	0.23	0.16	0.0171	1.20	1.04	1.43	0.13
SFG8	South	09/13/1999	19.21	832		7.50	8.71	11.50	0.06	0.01	0.0007	0.80	0.79	0.86	0.13
SFG8	South	09/15/1999	18.38		280										
SFG8	South	09/20/1999	16.55	813		9.00	8.71	10.40	0.01	0.00	0.0000	1.00	1.00	1.01	0.05
SFG8	South	09/22/1999	16.40		230										
SFG8	South	09/28/1999	19.13		140										
SFG8	South	09/29/1999	18.83	828		7.00	8.63	10.20	0.01	0.00	0.0000	0.60	0.60	0.61	0.07
SFG8	South	10/04/1999	21.38	814		5.00	8.51	10.90	0.04	0.04	0.0016	0.50	0.46	0.54	0.07
SFG8	South	10/06/1999	24.44		520										
SFG8	South	10/12/1999	19.97	815		10.00	8.74	9.60	0.08	0.05	0.0046	0.90	0.85	0.98	0.04
SFG8	South	10/13/1999	19.69		260										
SFG8	South	11/01/1999	19.99	930		4.00	9.24	13.40	0.08	0.01	0.0017	1.40	1.39	1.48	0.25
SFG8	South	11/03/1999	19.99		80										
SFG8	South	03/22/2000		1030		5.00	8.61	11.60	0.10	0.02	0.0010	0.61	0.59	0.71	0.17
SFG8	South	03/22/2000			10										
SFG8	South	03/29/2000		830		4.00	9.86	11.80	0.10	0.02	0.0091	0.87	0.85	0.97	0.20
SFG8	South	03/30/2000			40										
SFG8	South	04/05/2000	8.33	825		8.00		11.00	0.10	0.02	0.0000	0.57	0.55	0.67	0.24
SFG8	South	04/12/2000	15.17	835		4.00	9.08	11.60	0.10	0.02	0.0024	0.70	0.68	0.80	0.13
SFG8	South	04/13/2000			10										
SFG8	South	04/20/2000			10										
SFG8	South	04/26/2000	16.46	850		14.00	8.68	8.80	0.10	0.02	0.0022	0.97	0.95	1.07	0.19

SITE	FORK	DATE	FLOW	TIME	FECAL	WT	FPH	DO	NO32	NH3	UNA	TKN	ON	TN	T
			cfs		col./100ml	oC	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/
SFG8	South	04/27/2000			190										
SFG8	South	05/24/2000	11.50	900		14.00	8.84	9.00	0.10	0.02	0.0030	0.88	0.86	0.98	0.22
SFG8	South	06/07/2000	8.96			24.00	9.05	8.20	0.10	0.02	0.0075	0.66	0.64	0.76	0.09
SFG8	South	06/08/2000			720										
SFG8	South	06/22/2000			210										
SRO5	Below	05/27/1999	159.48	930		16.20	8.57	10.00	0.78	0.00	0.0000	1.50	1.50	2.28	0.00
SRO5	Below	06/04/1999	0.00		80										
SRO5	Below	06/23/1999	0.00		120										
SRO5	Below	06/30/1999	78.58	1000		20.80	8.84	7.80	0.28	0.00	0.0000	1.00	1.00	1.28	0.02
SRO5	Below	07/07/1999	79.14		740										
SRO5	Below	07/19/1999	79.06	1130		21.00	8.57	12.40	0.19	0.12	0.0164	0.70	0.58	0.89	0.02
SRO5	Below	07/21/1999	78.72		50										
SRO5	Below	08/02/1999	112.16		250										
SRO5	Below	08/04/1999	111.91	1400		21.00	8.57	12.40	0.29	0.00	0.0000	0.30	0.30	0.59	0.00
SRO5	Below	08/11/1999	111.10		30										
SRO5	Below	08/17/1999	109.98	1125		25.00	8.74	7.40	0.30	0.00	0.0000	0.50	0.50	0.80	0.83
SRO5	Below	08/18/1999	109.87		40										
SRO5	Below	08/25/1999	108.95		80										
SRO5	Below	08/31/1999	107.79	1030		22.50	8.4	8.60	0.32	0.25	0.0267	0.80	0.55	1.12	0.00
SRO5	Below	09/01/1999	107.67		60										
SRO5	Below	09/13/1999	105.30	1018		16.00	8.4	9.10	0.18	0.11	0.0076	1.00	0.89	1.18	0.03
SRO5	Below	09/15/1999	105.01		10										
SRO5	Below	09/22/1999	63.20		80										
SRO5	Below	09/28/1999	62.67		10										
SRO5	Below	10/04/1999	62.60	1017		12.00	8.06	9.60	0.11	0.13	0.0032	0.70	0.57	0.81	0.06
SRO5	Below	10/06/1999	58.86		40										
SRO5	Below	10/12/1999	50.91	1005		12.00	8.27	9.20	0.10	0.08	0.0031	0.70	0.62	0.80	0.03
SRO5	Below	10/13/1999	50.86		90										
SRO5	Below	11/03/1999	50.90		10										
SRO5	Below	03/23/2000			10										
SRO5	Below	03/29/2000		1145		5.00	8.87	11.80	0.10	0.02	0.0017	0.63	0.61	0.73	0.01
SRO5	Below	03/30/2000			10										
SRO5	Below	04/12/2000		15		9.00	8.35	11.60	0.10	0.02	0.0007	0.78	0.76	0.88	0.01
SRO5	Below	04/13/2000			10										
SRO5	Below	05/10/2000		1300		18.00	8.64	11.00	0.10	0.02	0.0026	1.05	1.03	1.15	0.06
SRO5	Below	05/11/2000			320										
SRO5	Below	06/07/2000				23.00	8.89	11.20	0.10	0.02	0.0055	0.59	0.57	0.69	0.02
Teeter Creek	North	03/23/2000		1050	10										
Teeter Creek	North	03/27/2000		1500		4.40	9.01	12.20	0.10	0.02	0.0022	4.58			0.27

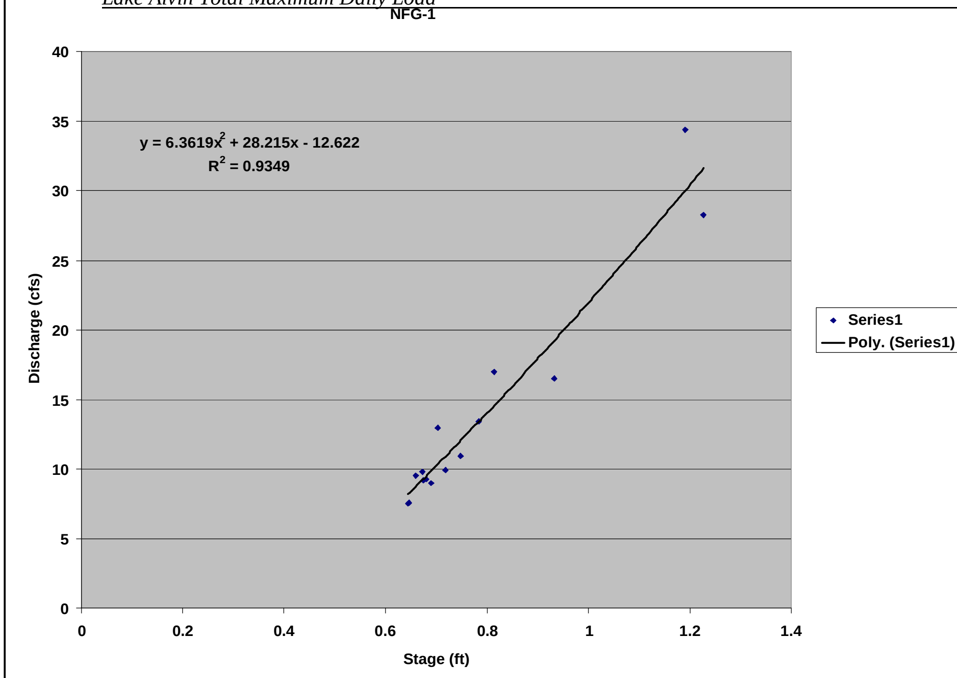
APPENIDX IV - Quality Assurance and Quality Control Data

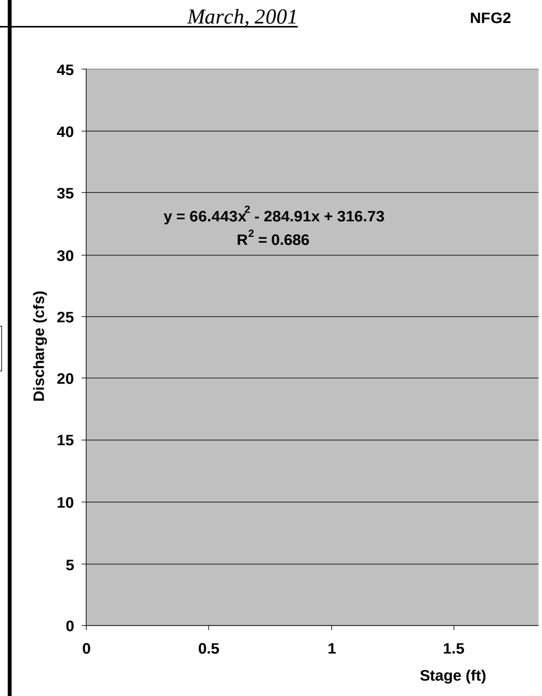
LOCATION	SITE	QAQC	DATE	FECAL	TALK	TS	TSS	AMM	NIT	TKN	TP	TDP	SOD
Grand River	SFG4	DUPLICATE	05/08/00		294.00	11698.00	5900.00	0.02	0.60	0.78	3.49	0.21	
Grand River	SFG4		05/08/00		297.00	11635.00	5900.00	0.03	0.70	7.39	3.26	0.17	
Grand River	**SFG4**	**%Difference**	**05/08/00**		**1.01**	**0.54**	**0.00**	**33.33**	**14.29**	**89.45**	**7.06**	**22.94**	
Grand River	NFG1	DUPLICATE	05/09/00		470.00	2066.00	28.00	0.02	0.10	1.30	0.10	0.02	
Grand River	NFG1		05/09/00		474.00	2070.00	27.00	0.02	0.10	1.18	0.09	0.02	
Grand River	**NFG1**	**%Difference**	**05/09/00**		**0.84**	**0.19**	**3.70**	**0.00**	**0.00**	**10.17**	**8.79**	**12.50**	
Grand River	SRO5	DUPLICATE	05/10/00		360.00	1450.00	53.00	0.02	0.10	0.84	0.07	0.03	
Grand River	SRO5		05/10/00		359.00	1459.00	54.00	0.02	0.10	1.05	0.06	0.03	
Grand River	**SRO5**	**%Difference**	**05/10/00**		**0.28**	**0.62**	**1.85**	**0.00**	**0.00**	**20.00**	**6.35**	**12.00**	
Grand River	NFG3	DUPLICATE	05/11/00	560.00									
Grand River	NFG3		05/11/00	410.00									
Grand River	**NFG3**	**%Difference**	**05/11/00**	**36.59**									
Grand River	SFG4	DUPLICATE	05/11/00	3300.00									
Grand River	SFG4		05/11/00	3100.00									
Grand River	**SFG4**	**%Difference**	**05/11/00**	**6.45**									
Grand River	SRO5	DUPLICATE	05/11/00	330.00									
Grand River	SRO5		05/11/00	320.00									
Grand River	**SRO5**	**%Difference**	**05/11/00**	**3.13**									
Grand River	SRO5	DUPLICATE	06/07/00		356.00	1456.00	7.00	0.02	0.10	0.65	0.02	0.02	
Grand River	SRO5		06/07/00		359.00	1460.00	7.00	0.02	0.10	0.59	0.03	0.02	
Grand River	**SRO5**	**%Difference**	**06/07/00**		**0.84**	**0.27**	**0.00**	**0.00**	**0.00**	**10.17**	**15.38**	**6.25**	
Grand River	NFG1	DUPLICATE	06/08/00	180.00									
Grand River	NFG1		06/08/00	190.00									
Grand River	**NFG1**	**%Difference**	**06/08/00**	**5.26**									
Grand River	SFG6	DUPLICATE	06/08/00	1710.00									
Grand River	SFG6		06/08/00	1760.00									
Grand River	**SFG6**	**%Difference**	**06/08/00**	**2.84**									
Grand River	SRO5	DUPLICATE	06/08/00	210.00									
Grand River	SRO5		06/08/00	180.00									
Grand River	**SRO5**	**%Difference**	**06/08/00**	**16.67**									
Grand River	SFG7	DUPLICATE	06/15/99			2287.00	407.00	0.25	0.20	2.50	0.19	0.01	464.00
Grand River	SFG7		06/15/99			2249.00	397.00	0.23	0.22	2.20	0.18	0.01	464.00
Grand River	**SFG7**	**%Difference**	**06/15/99**			**1.69**	**2.52**	**8.70**	**9.09**	**13.64**	**5.56**	**0.00**	**0.00**
Grand River	NFG2	DUPLICATE	07/06/99			1968.00	40.00	0.00	0.41	2.20	0.05	0.02	443.00
Grand River	NFG2		07/06/99			2034.00	30.00	0.00	0.20	1.40	0.04	0.03	464.00
Grand River	**NFG2**	**%Difference**	**07/06/99**			**3.24**	**33.33**	**0.00**	**105.00**	**57.14**	**25.00**	**33.33**	**4.53**
Grand River	SFG4	DUPLICATE	07/20/99			1403.00	99.00	0.06	0.05	1.00	0.07	0.01	5.70
Grand River	SFG4		07/20/99			1555.00	87.00	0.06	0.05	0.80	0.15	0.01	402.20
Grand River	**SFG4**	**%Difference**	**07/20/99**			**9.77**	**13.79**	**0.00**	**0.00**	**25.00**	**53.33**	**0.00**	**98.58**
Grand River	NFG1	DUPLICATE	08/09/99			1968.00	76.00	0.00	0.20	1.90	0.01	0.01	463.00
Grand River	NFG1		08/09/99			2010.00	106.00	0.07	0.21	1.60	0.00	0.06	500.00
Grand River	**NFG1**	**%Difference**	**08/09/99**			**2.09**	**28.30**	**100.00**	**4.76**	**18.75**	**0.00**	**83.33**	**7.40**
Grand River	NFG3	DUPLICATE	08/31/99			2034.00	50.00	0.46	0.24	1.20	0.06	0.01	569.00
Grand River	NFG3		08/31/99			2051.00	51.00	0.34	0.23	1.30	0.06	0.01	549.00
Grand River	**NFG3**	**%Difference**	**08/31/99**			**0.83**	**1.96**	**35.29**	**4.35**	**7.69**	**0.00**	**0.00**	**3.64**
Grand River	SFG6	DUPLICATE	08/16/99			3578.00	2390.00	0.02	0.27	3.40	0.13	0.01	472.00
Grand River	SFG6		08/16/99			3447.00	1987.00	0.05	0.28	3.60	0.91	0.01	447.00
Grand River	**SFG6**	**%Difference**	**08/16/99**			**3.80**	**20.28**	**60.00**	**3.57**	**5.56**	**85.71**	**0.00**	**5.59**
Grand River	NFG2	DUPLICATE	08/23/99			2014.00	58.00	0.24	0.23	1.50	0.09	0.01	559.00
Grand River	NFG2		08/23/99			1992.00	56.00	0.25	0.24	1.30	0.10	0.01	544.00
Grand River	**NFG2**	**%Difference**	**08/23/99**			**1.10**	**3.57**	**4.00**	**4.17**	**15.38**	**10.00**	**0.00**	**2.76**
Grand River	SFG8	DUPLICATE	09/07/99			1602.00	174.00	0.14	0.22		0.15	0.01	440.00
Grand River	SFG8		09/07/99			1583.00	163.00	0.16	0.23	1.20	0.13	0.01	436.00
Grand River	**SFG8**	**%Difference**	**09/07/99**			**1.20**	**6.75**	**12.50**	**4.35**	**100.00**	**15.38**	**0.00**	**0.92**
Grand River	SFG8	DUPLICATE	10/04/99			1603.00	63.00	0.04	0.04	0.50	0.09	0.06	456.30
Grand River	SFG8		10/04/99			1604.00	64.00	0.04	0.04	0.50	0.07	0.05	453.90
Grand River	**SFG8**	**%Difference**	**10/04/99**			**0.06**	**1.56**	**0.00**	**0.00**	**0.00**	**28.57**	**20.00**	**0.53**
Grand River	SFG4	DUPLICATE	09/14/99			1306.00	70.00	0.10	0.08	0.60	0.09	0.01	423.00
Grand River	SFG4		09/14/99			1331.00	63.00	0.13	0.08	0.60	0.10	0.03	414.00
Grand River	**SFG4**	**%Difference**	**09/14/99**			**1.88**	**11.11**	**23.08**	**0.00**	**0.00**	**10.00**	**66.67**	**2.17**
Grand River	NFG3	DUPLICATE	09/20/99			2000.00	28.00	0.12	0.01	1.20	0.02	0.05	449.50
Grand River	NFG3		09/20/99			1976.00	28.00	0.12	0.01	1.20	0.00	0.01	478.20
Grand River	**NFG3**	**%Difference**	**09/20/99**			**1.21**	**0.00**	**0.00**	**0.00**	**0.00**	**#DIV/0!**	**400.00**	**6.00**
Grand River	SFG6	DUPLICATE	09/27/99			1591.00	59.00	0.00	0.01	0.60	0.07	0.01	518.50
Grand River	SFG6		09/27/99			1620.00	60.00	0.00	0.01	0.50	0.09	0.03	513.30
Grand River	**SFG6**	**%Difference**	**09/27/99**			**1.79**	**1.67**	**0.00**	**0.00**	**20.00**	**22.22**	**66.67**	**1.01**

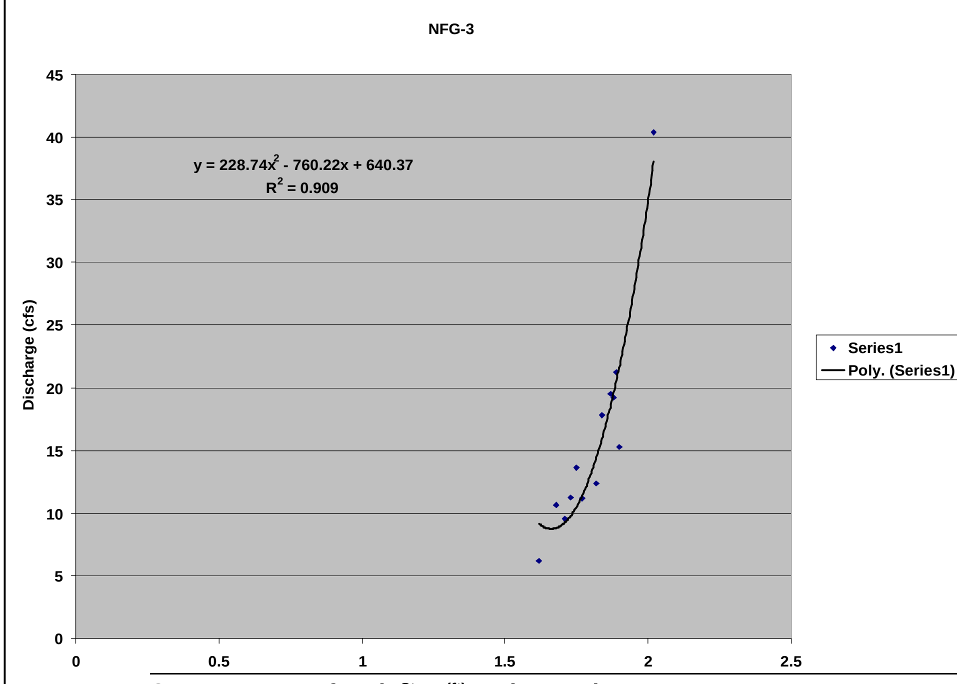
Grand River	SRO5	DUPLICATE	10/12/99			1264.00	12.00	0.10	0.10	0.60	0.00	0.07	313.30
Grand River	SRO5		10/12/99			1291.00	11.00	0.08	0.10	0.70	0.03	0.08	316.30
Grand River	**SRO5**	**%Difference**	**10/12/99**			**2.09**	**9.09**	**25.00**	**0.00**	**14.29**	**100.00**	**12.50**	**0.95**
Grand River	NFG1	DUPLICATE	11/02/99			1968.00	24.00	0.02	0.02	1.20	0.04	0.01	469.00
Grand River	NFG1		11/02/99			1932.00	20.00	0.03	0.03	0.90	0.11	0.02	484.00
Grand River	**NFG1**	**%Difference**	**11/02/99**			**1.86**	**20.00**	**33.33**	**33.33**	**33.33**	**63.64**	**50.00**	**3.10**

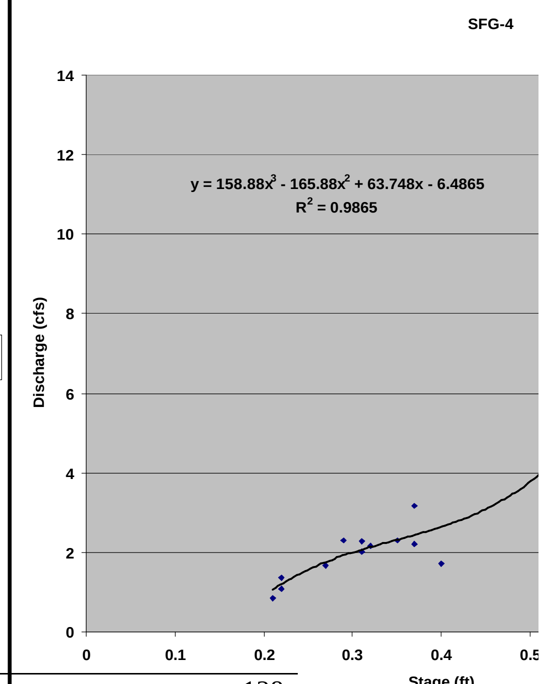
LOCATION	**SITE**	**QAQC**	**DATE**	**FECAL**	**TALK**	**TS**	**TSS**	**AMM**	**NIT**	**TKN**	**TP**	**TDP**	**SOD**
Grand River	BLANK	BLANK	05/09/00		15.00	17.00	1.00	0.02	0.10	0.21	0.00	0.00	
Grand River	BLANK	BLANK	05/11/00	10.00									
Grand River	BLANK	BLANK	06/08/00	10.00									
Grand River	BLANK	BLANK	05/08/00		10.00	30.00	1.00	0.02	0.10	0.21	0.00	0.00	
Grand River	BLANK	BLANK	06/08/00	10.00									
Grand River	BLANK	BLANK	05/11/00	10.00									
Grand River	BLANK	BLANK	05/10/00		13.00	21.00	1.00	0.02	0.10	0.21	0.00	0.00	
Grand River	BLANK	BLANK	05/11/00	10.00									
Grand River	BLANK	BLANK	06/07/00		11.00	23.00	1.00	0.02	0.10	0.21	0.00	0.00	
Grand River	BLANK	BLANK	06/08/00	10.00									
Grand River	BLANK	BLANK	05/19/99			23.00	3.00	0.01	0.33	0.20	0.00	0.04	2.90
Grand River	BLANK	BLANK	06/16/99			24.00	4.00	0.12	0.21	0.20	0.01	0.01	8.00
Grand River	BLANK	BLANK	07/09/99			52.00	2.00	0.00	0.22	0.00	0.04	0.02	2.00
Grand River	BLANK	BLANK	07/20/99			52.00	2.00	0.06	0.11	1.00	0.01	0.01	400.80
Grand River	BLANK	BLANK	08/04/99			82.00	2.00	0.00	0.35	1.60	0.00	0.01	1.10
Grand River	BLANK	BLANK	08/10/99			52.00	2.00	0.07	0.21	0.20	0.00	0.01	1.20
Grand River	BLANK	BLANK	08/31/99			52.00	2.00	0.18	0.20	0.20	0.00	0.01	1.20
Grand River	BLANK	BLANK	08/17/99			58.00	6.00	0.00	0.20	0.10	0.00	0.01	0.90
Grand River	BLANK	BLANK	08/24/99			52.00	2.00	0.19	0.20	0.00	0.01	0.01	1.20
Grand River	BLANK	BLANK	09/08/99			52.00	2.00	0.17	0.20	0.00	0.02	0.01	0.90
Grand River	BLANK	BLANK	10/05/99			52.00	2.00	0.04	0.03	0.00	0.03	0.01	6.40
Grand River	BLANK	BLANK	09/14/99			52.00	2.00	0.04	0.05	0.20	0.01	0.01	0.80
Grand River	BLANK	BLANK	09/21/99			52.00	2.00	0.00	0.01	0.30	0.00	0.01	7.10
Grand River	BLANK	BLANK	09/29/99			53.00	3.00	0.00	0.02	0.00	-0.04	0.01	7.00
Grand River	BLANK	BLANK	10/14/99			52.00	2.00	0.01	0.02	0.00	-0.02	0.04	6.10
Grand River	BLANK	BLANK	11/02/99			52.00	2.00	0.01	0.03	0.40	0.00	0.01	6.00

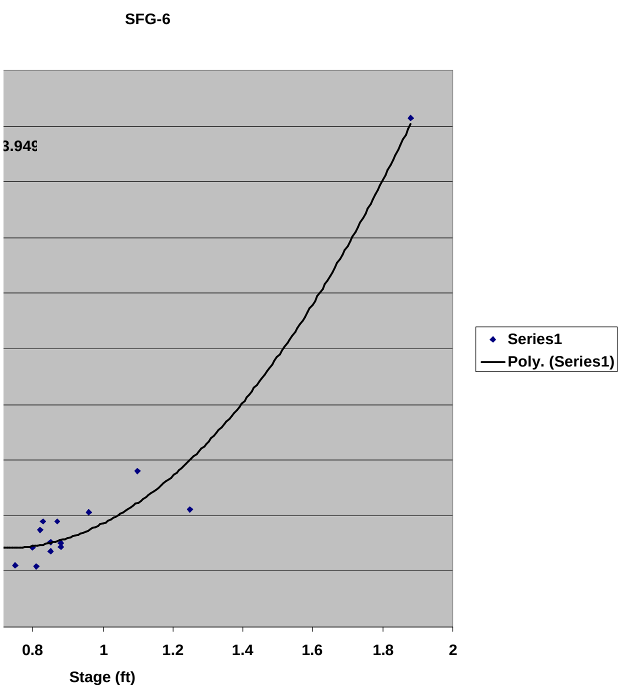
APPENDIX V – Discharge Data for All Sites

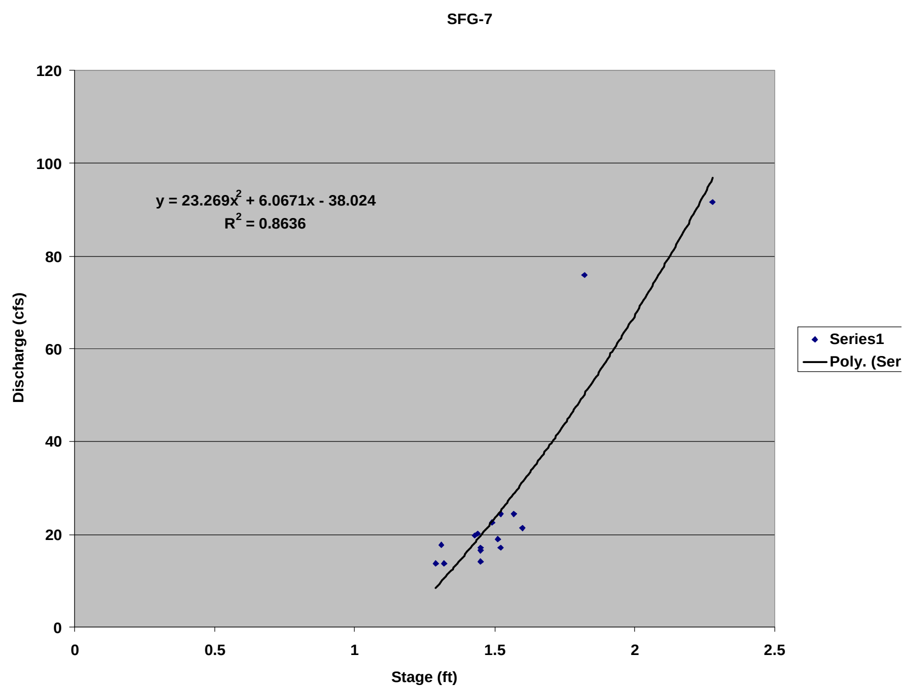

NFG-1
y = 6.3619x² + 28.215x - 12.622
R² = 0.9349
Discharge (cfs)
Stage (ft)
Series1
Poly. (Series1)

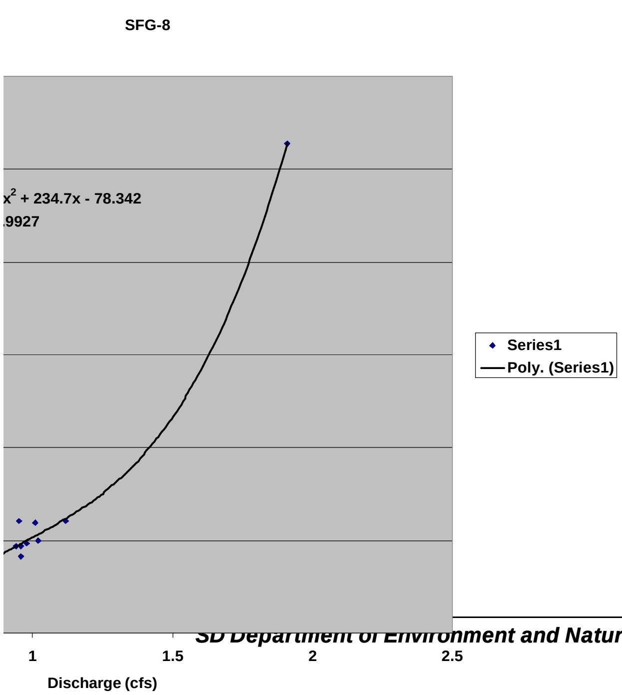

NFG2
y = 66.443x² - 284.91x + 316.73
R² = 0.686
Discharge (cfs)
Stage (ft)


NFG-3
y = 228.74x² - 760.22x + 640.37
R² = 0.909
Discharge (cfs)
Stage (ft)
Series1
Poly. (Series1)


SFG-4
y = 158.88x³ - 165.88x² + 63.748x - 6.4865
R² = 0.9865
Discharge (cfs)
Stage (ft)

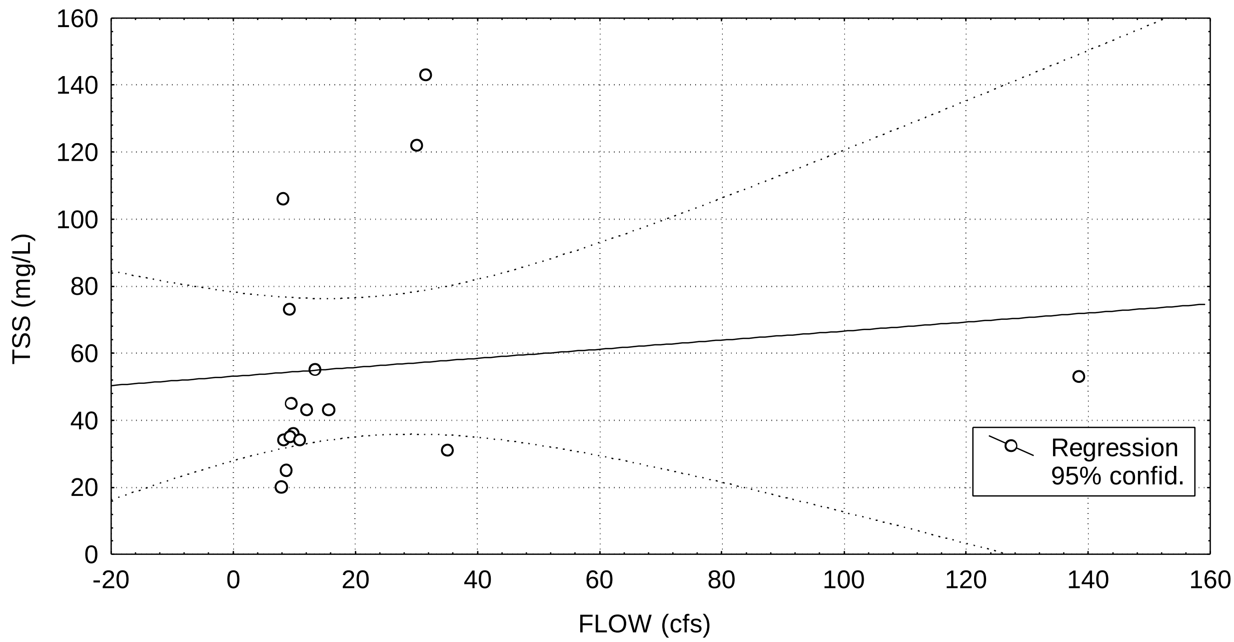

SFG-6
3.949
Series1
Poly. (Series1)
0.8
1
1.2
1.4
1.6
1.8
2
Stage (ft)


SFG-7
y = 23.269x2 + 6.0671x - 38.024
R2 = 0.8636
120
100
80
60
40
20
0
Discharge (cfs)
0
0.5
1
1.5
2
2.5
Stage (ft)
Series1
Poly. (Ser

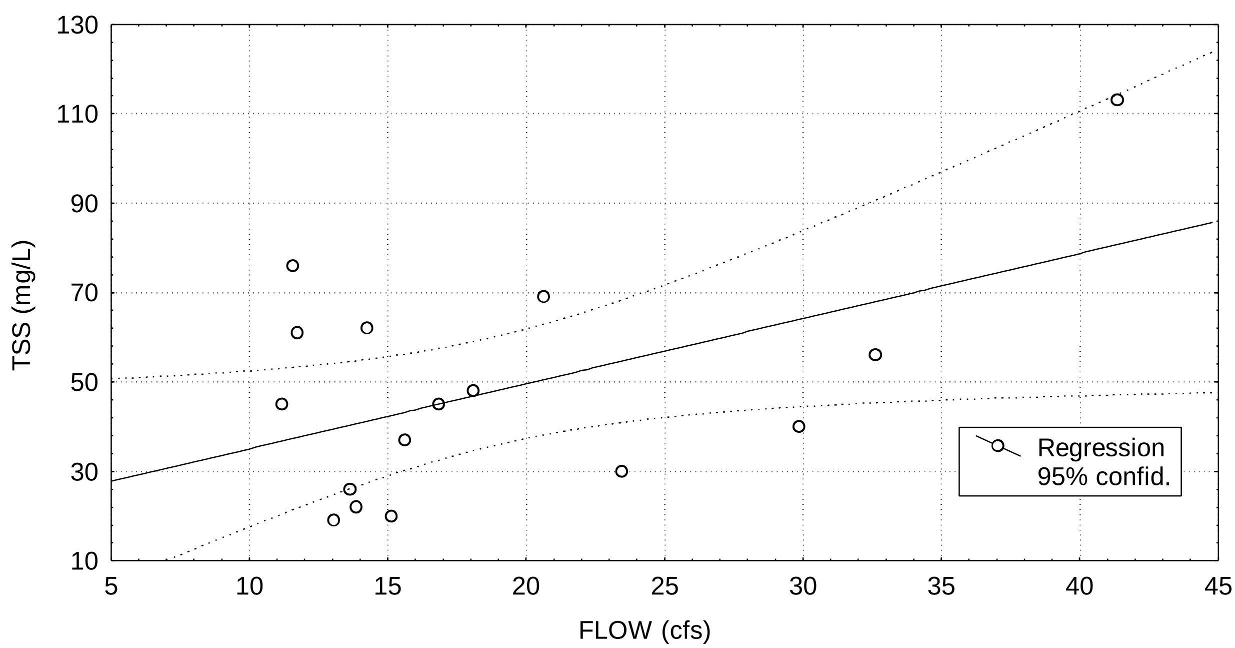

SFG-8
x2 + 234.7x - 78.342
.9927
Series1
Poly. (Series1)
1
1.5
2
2.5
Discharge (cfs)

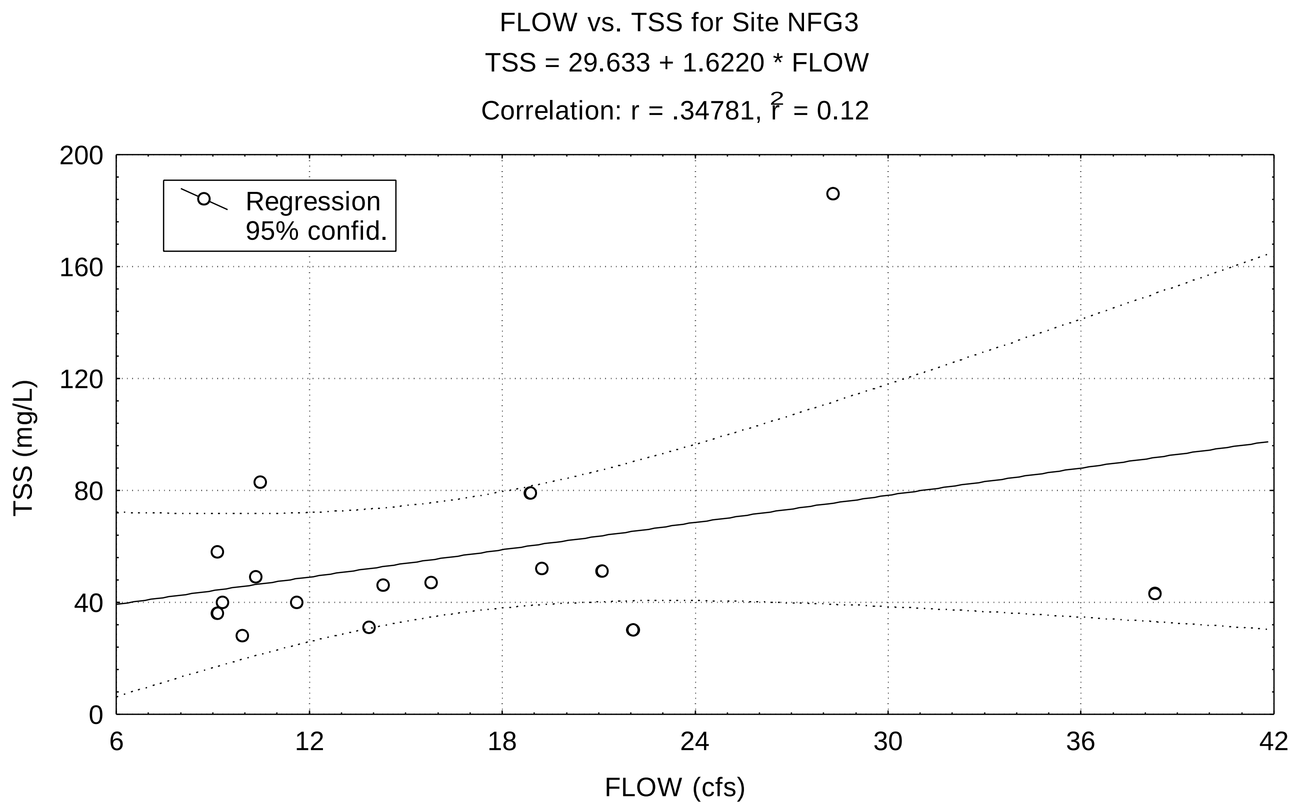
APPENDIX VI – FLOW versus Suspended Solids Data

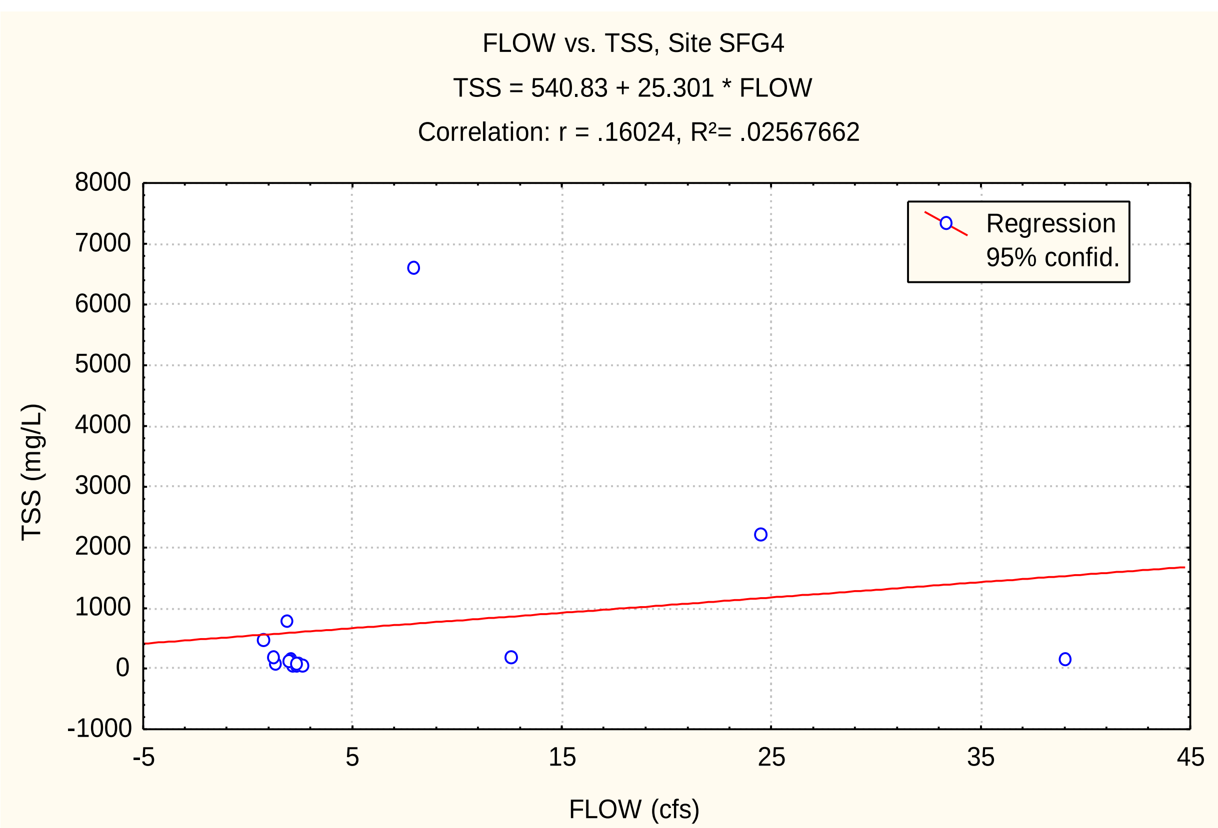
FLOW vs. TSS for Site NFG1
TSS = 53.100 + .13509 * FLOW
Correlation: r = .11969, r^2 = 0.01

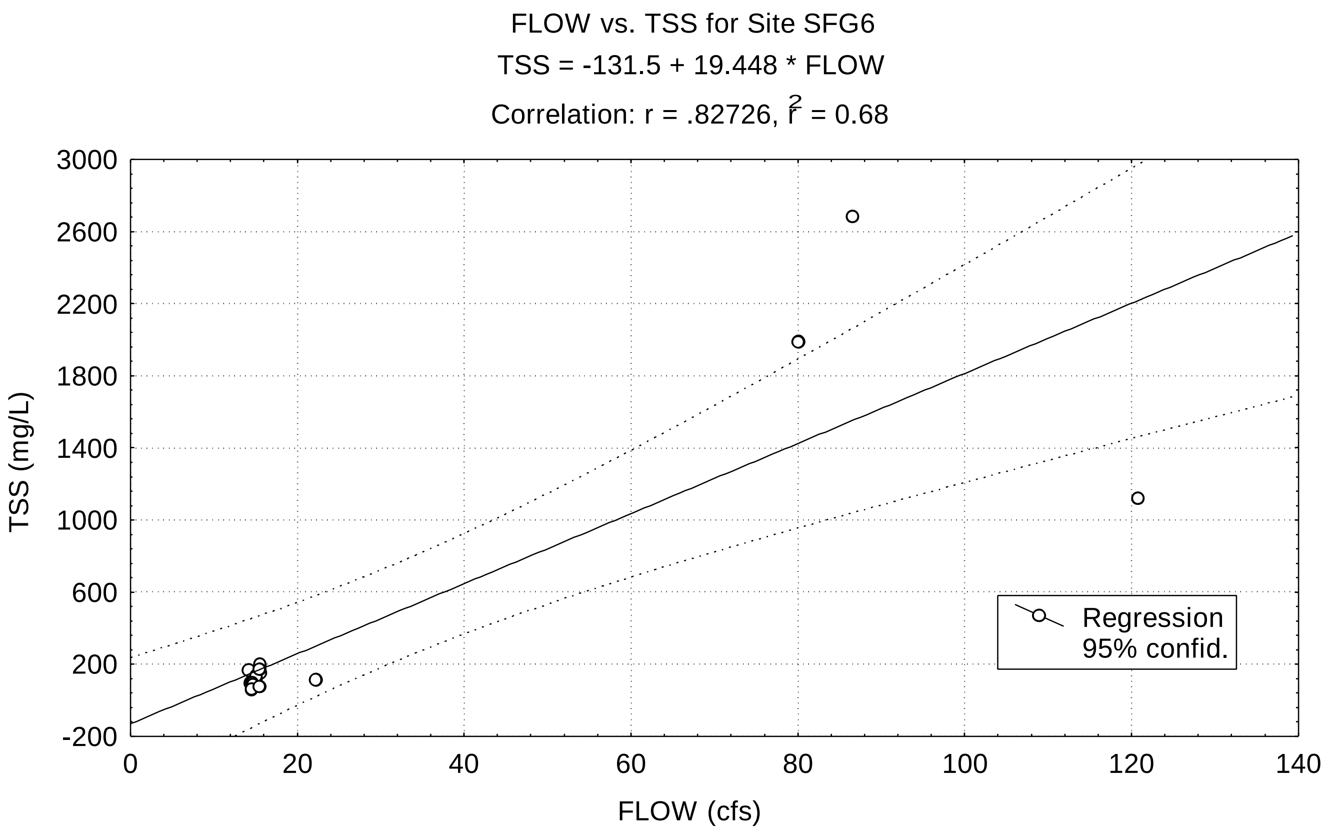


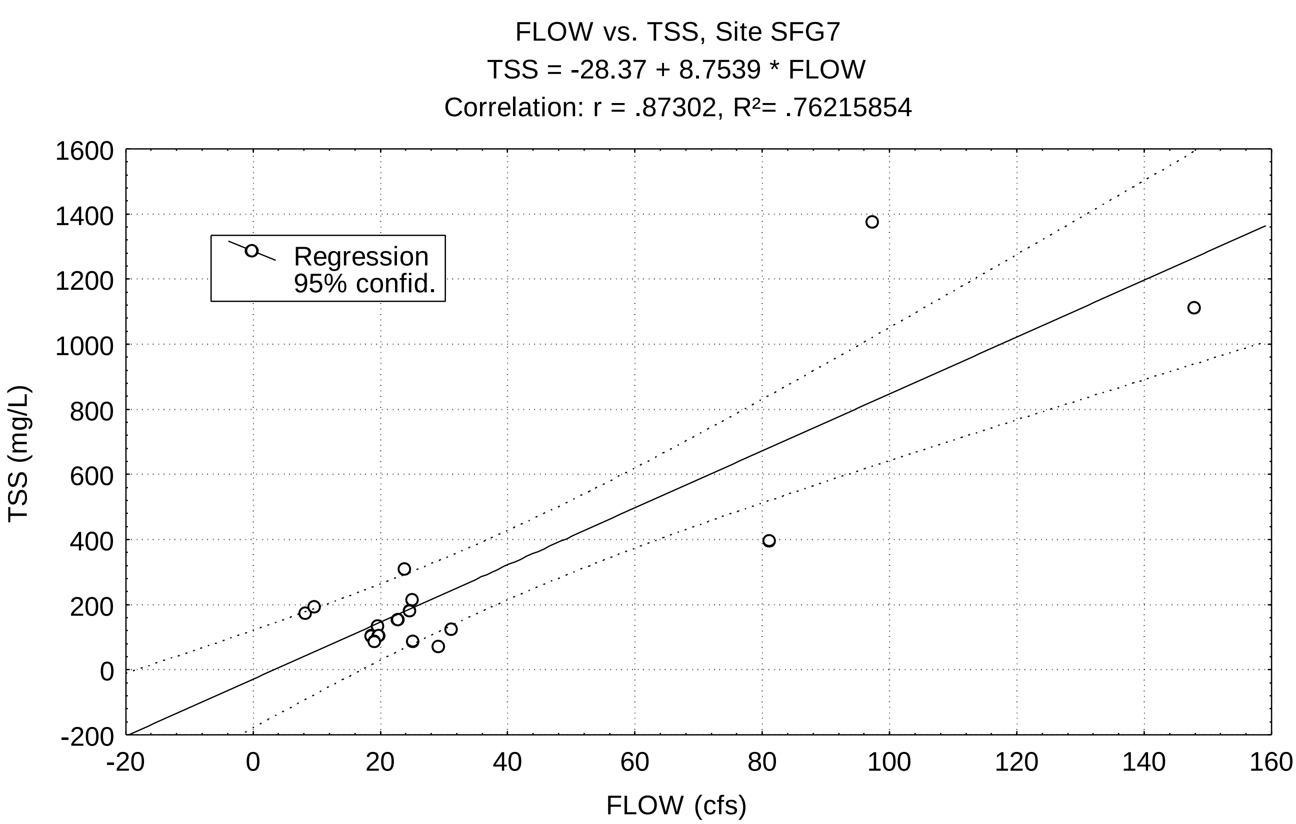
FLOW vs. TSS for Site NFG2
TSS = 20.487 + 1.4564 * FLOW
Correlation: r = .51297, r^2 = 0.26

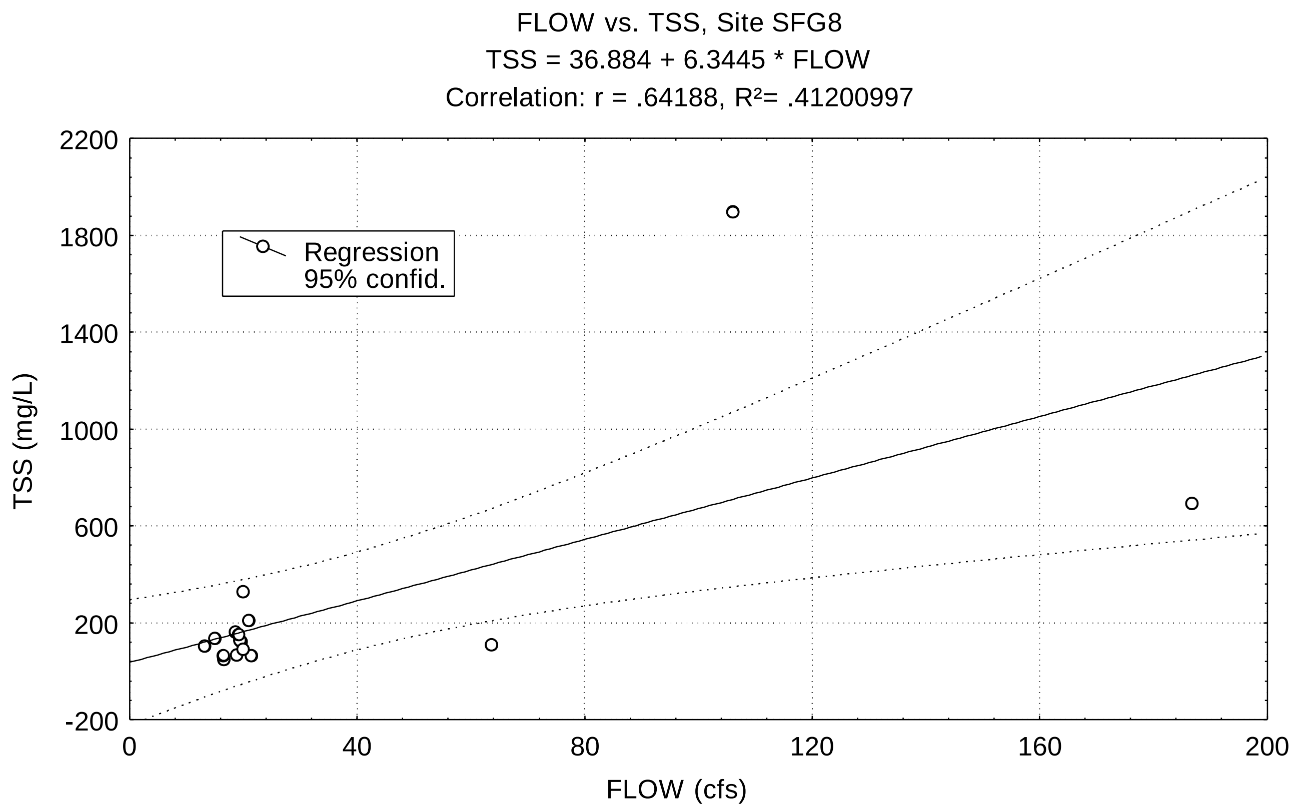



FLOW vs. TSS for Site NFG3
TSS = 29.633 + 1.6220 * FLOW
Correlation: r = .34781, r2 = 0.12
Regression
95% confid.
TSS (mg/L)
200
160
120
80
40
0
6
12
18
24
30
36
42
FLOW (cfs)


FLOW vs. TSS, Site SFG4
TSS = 540.83 + 25.301 * FLOW
Correlation: r = .16024, R²= .02567662
Regression
95% confid.
TSS (mg/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-5
5
15
25
35
45
FLOW (cfs)


FLOW vs. TSS for Site SFG6
TSS = -131.5 + 19.448 * FLOW
Correlation: r = .82726, r2 = 0.68
TSS (mg/L)
3000
2600
2200
1800
1400
1000
600
200
-200
0
20
40
60
80
100
120
140
FLOW (cfs)
Regression
95% confid.


FLOW vs. TSS, Site SFG7
TSS = -28.37 + 8.7539 * FLOW
Correlation: r = .87302, R²= .76215854
TSS (mg/L)
1600
1400
1200
1000
800
600
400
200
0
-200
-20
0
20
40
60
80
100
120
140
160
FLOW (cfs)
Regression
95% confid.



FLOW vs. TSS, Site SFG8
TSS = 36.884 + 6.3445 * FLOW
Correlation: r = .64188, R²= .41200997
Regression
95% confid.
TSS (mg/L)
2200
1800
1400
1000
600
200
-200
0
40
80
120
160
200
FLOW (cfs)

APPENIDIX VII – FLUX LOADING CALCULATIONS

NFG1 TDP VAR=TDP METHOD= 2 Q WTD C COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	247	23	23	100.0	34.663	29.355	0.086	0.663
***	247	23	23	100.0	34.663	29.355		

FLOW STATISTICS
FLOW DURATION = 247.0 DAYS = .676 YEARS
MEAN FLOW RATE = 34.663 HM3/YR
TOTAL FLOW VOLUME = 23.44 HM3
FLOW DATE RANGE = 19990301 TO 19991102
SAMPLE DATE RANGE = 19990328 TO 19991102

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	572.6	846.8	3.34E+04	24.43	0.216
2 Q WTD C	676.2	999.9	4.51E+04	28.85	0.212
3 IJC	664.2	982.2	4.68E+04	28.34	0.22
4 REG-1	685.9	1014.3	7.10E+04	29.26	0.263
5 REG-2	685.8	1014.2	8.83E+04	29.26	0.293
6 REG-3	802.4	1186.5	1.05E+05	34.23	0.273

NFG1TP VAR=TP METHOD = 2 Q WTD C COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	247	22	22	100.0	34.663	30.356	-0.151	0.138
***	247	22	22	100.0	34.663	30.356		

FLOW STATISTICS
FLOW DURATION = 247.0 DAYS = .676 YEARS
MEAN FLOW RATE = 34.663 HM3/YR
TOTAL FLOW RANGE VOLUME = 23.44 HM3
FLOW DATE RANGE = 19990301 TO 19991102
SAMPLE DATE RANGE = 19990328 TO 19991102

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1407.6	2081.5	2.02E+05	60.05	0.216
2 Q WTD C	1607.3	2376.8	6.78E+04	68.57	0.11
3 IJC	1601.2	2367.7	6.84E+04	68.31	0.11
4 REG-1	1575.4	2329.6	7.95E+04	67.21	0.121
5 REG-2	1570.6	2322.4	8.53E+04	67	0.126
6 REG-3	1563.7	2312.3	9.58E+04	66.71	0.134

NFG1TN VAR=TN METHOD = 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	247	23	23	100.0	34.663	29.355	0.02	0.797
***	247	23	23	100.0	34.663	29.355		

FLOW STATISTICS
FLOW DURATION = 247.0 DAYS = .676 YEARS
MEAN FLOW RATE 34.663 HM3/YR
TOTAL FLOW VOLUME = 23.44 HM3
FLOW DATE RANGE = 19990301 TO 19991102
SAMPLE DATE RANGE = 19990328 TO 19991102

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	29765.5	44015.6	1.17E+08	1269.81	0.246
2 Q WTD C	35147.6	51974.3	2.66E+07	1499.42	0.099
3 IJC	35289.4	52184	3.00E+07	1505.46	0.105
4 REG-1	35261.7	52143.1	3.42E+07	1504.28	0.112
5 REG-2	35261	52142.1	3.42E+07	1504.25	0.112
6 REG-3	35390.7	52333.9	3.27E+07	1509.79	0.109

NFG1TSS VAR=TSS METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	247	23	23	100.0	34.663	29.355	-0.278	0.149
***	247	23	23	100.0	34.663	29.355		

FLOW STATISTICS
FLOW DURATION = 247.0 DAYS = .676 YEARS
MEAN FLOW RATE 34.663 HM3/YR
TOTAL FLOW VOLUME = 23.44 HM3
FLOW DATE RANGE 19990301 TO 19991102
SAMPLE DATE RANGE = 19990328 TO 19991102

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	787334	1164266	1.09E+11	33588.08	0.283
2 Q WTD C	929697.8	1374786	7.56E+10	39661.4	0.2
3 IJC	929148.8	1373974	7.47E+10	39637.98	0.199
4 REG-1	887763.1	1312775	1.04E+11	37872.44	0.245
5 REG-2	887962.1	1313070	1.25E+11	37880.93	0.269
6 REG-3	846756.6	1252137	1.25E+11	36123.08	0.282

NFG2TDP VAR=TDP METHOD = 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	23	23	100.0	27.041	23.602	0.049	0.864
***	246	23	23	100.0	27.041	23.602		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 27.041 HM3/YR
TOTAL FLOW VOLUME = 18.21 HM3
FLOW DATE RANGE 1999030 1 TO 19991101
SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	404.8	601.1	8.01E+03	22.23	0.149
2 Q WTD C	463.8	688.7	7.03E+03	25.47	0.122
3 IJC	462.3	686.4	6.86E+03	25.38	0.121
4 REG-1	466.9	693.3	7.50E+03	25.64	0.125
5 REG-2	470.8	699	8.94E+03	25.85	0.135
6 REG-3	516.1	766.3	1.32E+04	28.34	0.15

NFG2TP VAR=TP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	23	23	100.0	27.041	23.602	0.317	0.264
***	246	23	23	100.0	27.041	23.602		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 27.041 HM3/YR
TOTAL FLOW VOLUME = 18.21 HM3
FLOW DATE RANGE 1999030 1 TO 19991101
SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1597.5	2372	6.24E+05	87.72	0.333
2 Q WTD C	1830.3	2717.5	7.58E+05	100.5	0.32
3 IJC	1823.4	2707.3	7.23E+05	100.12	0.314
4 REG-1	1910.8	2837.1	8.58E+05	104.92	0.326
5 REG-2	2030.3	3014.5	9.72E+05	111.48	0.327
6 REG-3	1789.9	2657.6	5.32E+05	98.28	0.275

NFG2TN VAR=TN METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	23	23	100.0	27.041	23.602	-0.107	0.347
***	246	23	23	100.0	27.041	23.602		

FLOW STATISTICS

FLOW DURATION = 246.0 DAYS = .674 YEARS

MEAN FLOW RATE 27.041 HM3/YR

TOTAL FLOW VOLUME = 18.21 HM3

FLOW DATE RANGE 19990301 TO 19991101

SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	21072.7	31287.9	1.17E+07	1157.05	0.109
2 Q WTD C	24142.8	35846.1	2.93E+06	1325.62	0.048
3 IJC	24089.8	35767.5	2.88E+06	1322.71	0.047
4 REG-1	23792.5	35326	2.45E+06	1306.39	0.044
5 REG-2	23421	34774.5	2.68E+06	1285.99	0.047
6 REG-3	24134	35833.1	2.54E+06	1325.14	0.044

NFG2TSS VAR=TSS METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW S	AMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	23	23	100.0	27.041	23.602	-0.215	0.37
***	246	23	23	100.0	27.041	23.602		

FLOW STATISTICS

FLOW DURATION = 246.0 DAYS = .674 YEARS

MEAN FLOW RATE 27.041 HM3/YR

TOTAL FLOW VOLUME= 18.21 HM3

FLOW DATE RANGE 19990301 TO 19991101

SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	640928.5	951622.5	3.68E+10	35191.76	0.202
2 Q WTD C	734304.3	1090263	3.34E+10	40318.79	0.168
3 IJC	734243.1	1090172	3.43E+10	40315.43	0.17
4 REG-1	713125.4	1058817	4.62E+10	39155.91	0.203
5 REG-2	693286.3	1029361	5.41E+10	38066.59	0.226
6 REG-3	698895.8	1037690	4.20E+10	38374.6	0.197

NFG3TDP VAR=TDP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	26	25	100.0	31.331	21.953	0.248	0.231
***	246	26	25	100.0	31.331	21.953		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 31.331 HM3/YR
TOTAL FLOW VOLUME = 21.10 HM3
FLOW DATE RANGE 19990301 TO 19991101
SAMPLE DATE RANGE = 19990329 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	350.7	520.7	8.62E+03	16.62	0.178
2 Q WTD C	500.5	743.2	5.05E+03	23.72	0.096
3 IJC	502	745.4	4.97E+03	23.79	0.095
4 REG-1	546.6	811.6	7.40E+03	25.9	0.106
5 REG-2	631	937	2.46E+04	29.91	0.167
6 REG-3	566.1	840.5	1.17E+04	26.83	0.129

NFG3TP VAR=TP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	25	24	100.0	31.331	22.476	0.203	0.335
***	246	25	24	100.0	31.331	22.476		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 31.331 HM3/YR
TOTAL FLOW VOLUME = 21.10 HM3
FLOW DATE RANGE 19990301 TO 19991101
SAMPLE DATE RANGE = 19990329 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1098.2	1630.6	8.97E+04	52.05	0.184
2 Q WTD C	1530.9	2273	4.85E+04	72.55	0.097
3 IJC	1537	2282	5.23E+04	72.84	0.1
4 REG-1	1637.6	2431.4	1.04E+05	77.61	0.132
5 REG-2	1843.5	2737.1	4.99E+05	87.36	0.258
6 REG-3	1773.9	2633.9	1.71E+05	84.07	0.157

NFG3TN VAR=TN METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	26	25	100.0	31.331	21.953	-0.088	0.441
***	246	26	25	100.0	31.331	21.953		

FLOW STATISTICS

FLOW DURATION = 246.0 DAYS = .674 YEARS

MEAN FLOW RATE 31.331 HM3/YR

TOTAL FLOW VOLUME = 21.10 HM3

FLOW DATE RANGE 19990301 TO 19991101

SAMPLE DATE RANGE = 19990329 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	19376.9	28770	1.42E+07	918.26	0.131
2 Q WTD C	27653.9	41059.4	6.18E+06	1310.51	0.061
3 IJC	27624.1	41015.1	6.18E+06	1309.09	0.061
4 REG-1	26804.4	39797.9	9.71E+06	1270.25	0.078
5 REG-2	25646.3	38078.5	2.09E+07	1215.36	0.12
6 REG-3	27180.1	40355.8	1.00E+07	1288.05	0.078

NFG3TSS VAR=TSS METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	26	25	100.0	31.331	21.953	-0.07	0.674
***	246	26	25	100.0	31.331	21.953		

FLOW STATISTICS

FLOW DURATION = 246.0 DAYS = .674 YEARS

MEAN FLOW RATE 31.331 HM3/YR

TOTAL FLOW VOLUME = 21.10 HM3

FLOW DATE RANGE 19990301 TO 19991101

SAMPLE DATE RANGE = 19990329 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	697489.7	1035602	3.69E+10	33053.68	0.186
2 Q WTD C	995429.9	1477971	5.58E+10	47172.91	0.16
3 IJC	992994.6	1474355	5.55E+10	47057.5	0.16
4 REG-1	970955.3	1441632	8.14E+10	46013.07	0.198
5 REG-2	936941	1391129	1.33E+11	44401.15	0.262
6 REG-3	962345.1	1428848	6.76E+10	45605.04	0.182

SFG4TDP VAR=TDP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	25	25	100.0	7.458	6.971	0.506	0.023
***	246	25	25	100.0	7.458	6.971		

FLOW STATISTICS

FLOW DURATION = 246.0 DAYS = .674 YEARS

MEAN FLOW RATE 7.458 HM3/YR

TOTAL FLOW VOLUME = 5.02 HM3

FLOW DATE RANGE 19990301 TO 19991101

SAMPLE DATE RANGE = 19990327 TO 19991025

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	420	623.6	7.00E+04	83.61	0.424
2 Q WTD C	449.4	667.2	7.48E+04	89.46	0.41
3 IJC	447.1	663.9	8.61E+04	89.02	0.442
4 REG-1	465	690.4	1.38E+05	92.57	0.538
5 REG-2	502.1	745.5	2.94E+05	99.96	0.727
6 REG-3	571.9	849.1	2.11E+05	113.86	0.541

SFG4TP VAR=TP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	24	24	100.0	7.458	7.211	0.373	0.065
***	246	24	24	100.0	7.458	7.211		

FLOW STATISTICS

FLOW DURATION = 246.0 DAYS = .674 YEARS

MEAN FLOW RATE 7.458 HM3/YR

TOTAL FLOW VOLUME = 5.02 HM3

FLOW DATE RANGE 19990301 TO 19991101

SAMPLE DATE RANGE = 19990327 TO 19991025

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	3080.8	4574.3	3.80E+06	613.33	0.426
2 Q WTD C	3186.3	4730.9	3.45E+06	634.33	0.393
3 IJC	3180.5	4722.3	3.82E+06	633.18	0.414
4 REG-1	3226.6	4790.7	5.21E+06	642.35	0.476
5 REG-2	3464.4	5143.7	1.08E+07	689.69	0.64
6 REG-3	2674.8	3971.4	4.95E+06	532.5	0.56

SFG4TN VAR=TN METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	25	25	100.0	7.458	6.971	0.093	0.598
***	246	25	25	100.0	7.458	6.971		

FLOW STATISTICS

FLOW DURATION = 246.0 DAYS = .674 YEARS

MEAN FLOW RATE 7.458 HM3/YR

TOTAL FLOW VOLUME = 5.02 HM3

FLOW DATE RANGE 19990301 TO 19991101

SAMPLE DATE RANGE = 19990327 TO 19991025

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	9322.8	13842.1	2.42E+07	1855.99	0.355
2 Q WTD C	9974.5	14809.7	2.08E+07	1985.74	0.308
3 IJC	9908.2	14711.3	2.14E+07	1972.54	0.315
4 REG-1	10037.6	14903.4	2.42E+07	1998.29	0.33
5 REG-2	10191.4	15131.8	2.86E+07	2028.92	0.354
6 REG-3	9209.3	13673.5	2.52E+07	1833.39	0.367

SFG4TSS VAR=TSS METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	25	25	100.0	7.458	6.971	0.485	0.114
***	246	25	25	100.0	7.458	6.971		

FLOW STATISTICS

FLOW DURATION = 246.0 DAYS = .674 YEARS

MEAN FLOW RATE 7.458 HM3/YR

TOTAL FLOW VOLUME = 5.02 HM3

FLOW DATE RANGE 19990301 TO 19991101

SAMPLE DATE RANGE = 19990327 TO 19991025

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	7144511	10607860	2.61E+13	1422337	0.482
2 Q WTD C	7643978	11349440	2.65E+13	1521771	0.454
3 IJC	7654674	11365320	2.92E+13	1523900	0.476
4 REG-1	7898577	11727460	4.11E+13	1572457	0.546
5 REG-2	8506506	12630090	7.71E+13	1693484	0.695
6 REG-3	5773243	8571858	4.98E+13	1149343	0.823

SFG6TDP VAR=TDP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	22	22	100.0	39.125	32.374	0.294	0.346
***	246	22	22	100.0	39.125	32.374		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 39.125 HM3/YR
TOTAL FLOW VOLUME = 26.35 HM3
FLOW DATE RANGE 19990301 TO 19991101
SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1093.8	1624.1	2.21E+05	41.51	0.29
2 Q WTD C	1321.9	1962.8	3.08E+05	50.17	0.283
3 IJC	1308.6	1943	3.25E+05	49.66	0.294
4 REG-1	1397.7	2075.2	7.30E+05	53.04	0.412
5 REG-2	1441.9	2140.9	1.09E+06	54.72	0.489
6 REG-3	1583.8	2351.6	1.46E+06	60.11	0.515

SFG6TP VAR=TP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	22	22	100.0	39.125	32.374	0.822	0
***	246	22	22	100.0	39.125	32.374		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 39.125 HM3/YR
TOTAL FLOW VOLUME = 26.35 HM3
FLOW DATE RANGE 19990301 TO 19991101
SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	8211	12191.3	2.50E+07	311.6	0.41
2 Q WTD C	9923.3	14733.7	2.02E+07	376.58	0.305
3 IJC	10176.4	15109.4	2.08E+07	386.19	0.301
4 REG-1	11594.3	17214.7	3.00E+07	440	0.318
5 REG-2	12656.5	18791.7	3.96E+07	480.3	0.335
6 REG-3	10062.8	14940.8	2.15E+07	381.88	0.311

SFG6TN VAR=TN METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	22	22	100.0	39.125	32.374	0.182	0.332
***	246	22	22	100.0	39.125	32.374		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 39.125 HM3/YR
TOTAL FLOW VOLUME = 26.35 HM3
FLOW DATE RANGE 19990301 TO 19991101
SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	38850.8	57684	4.01E+08	1474.36	0.347
2 Q WTD C	46952.8	69713.4	2.56E+08	1781.83	0.23
3 IJC	47893.8	71110.6	2.70E+08	1817.54	0.231
4 REG-1	48601.8	72161.8	3.63E+08	1844.4	0.264
5 REG-2	49521.6	73527.5	4.14E+08	1879.31	0.277
6 REG-3	42425.8	62991.9	3.13E+08	1610.03	0.281

SFG6TSS VAR=TSS METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	22	22	100.0	39.125	32.374	0.813	0.006
***	246	22	22	100.0	39.125	32.374		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE = 39.125 HM3/YR
TOTAL FLOW VOLUME = 26.35 HM3
FLOW DATE RANGE = 19990301 TO 19991101
SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	16107220	23915290	1.42E+14	611258.1	0.498
2 Q WTD C	19466210	28902570	1.39E+14	738729.6	0.408
3 IJC	20110810	29859640	1.43E+14	763191.7	0.401
4 REG-1	22705160	33711630	2.30E+14	861645.8	0.45
5 REG-2	24763670	36768020	2.82E+14	939764.9	0.457
6 REG-3	14075530	20898730	1.37E+14	534157	0.56

SFG7TDP VAR=TDP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	22	22	100.0	46.026	38.941	0.97	0.001
***	246	22	22	100.0	46.026	38.941		

FLOW STATISTICS
FLOW DURATION = 246.0 D AYS = .674 YEARS
MEAN FLOW RATE 46.026 HM3/YR
TOTAL FLOW VOLU ME = 31 .00 HM3
FLOW DATE RANGE 1999030 1 TO 19991101
SAMPLE DATE RAN GE = 1999032 8 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2087	3098.7	8.22E+05	67.33	0.293
2 Q WTD C	2466.7	3662.5	3.83E+05	79.57	0.169
3 IJC	2503.4	3716.9	3.88E+05	80.76	0.168
4 REG-1	2900.7	4306.9	7.33E+05	93.58	0.199
5 REG-2	3001.6	4456.6	1.07E+06	96.83	0.232
6 REG-3	3449.3	5121.3	2.08E+06	111.27	0.282

SFG7TP VAR=TP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	21	21	100.0	46.026	40.446	0.816	0
***	246	21	21	100.0	46.026	40.446		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 46.026 HM3/YR
TOTAL FLOW VOLUME = 31.00 HM3
FLOW DATE RANGE 19990301 TO 19991101
SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	8271.5	12281.2	1.91E+07	266.83	0.356
2 Q WTD C	9412.5	13975.3	1.20E+07	303.64	0.248
3 IJC	9615.6	14276.8	1.26E+07	310.19	0.248
4 REG-1	10459.4	15529.6	1.31E+07	337.41	0.233
5 REG-2	11040.2	16392.1	1.45E+07	356.15	0.232
6 REG-3	10473.2	15550.2	1.17E+07	337.86	0.22

SFG7TN VAR=TN METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	22	22	100.0	46.026	38.941	0.077	0.682
***	246	22	22	100.0	46.026	38.941		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 46.026 HM3/YR
TOTAL FLOW VOLUME = 31.00 HM3
FLOW DATE RANGE 19990301 TO 19991101
SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	46558.1	69127.4	5.68E+08	1501.93	0.345
2 Q WTD C	55028.5	81704	3.71E+08	1775.18	0.236
3 IJC	56136.3	83348.8	3.94E+08	1810.92	0.238
4 REG-1	55738.1	82757.5	5.07E+08	1798.07	0.272
5 REG-2	55869.6	82952.7	5.31E+08	1802.31	0.278
6 REG-3	47426.9	70417.4	3.57E+08	1529.96	0.268

SFG7TSS VAR=TSS METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	22	22	100.0	46.026	38.941	0.585	0.006
***	246	22	22	100.0	46.026	38.941		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE = 46.026 HM3/YR
TOTAL FLOW VOLUME = 31.00 HM3
FLOW DATE RANGE = 19990301 TO 19991101
SAMPLE DATE RANGE = 19990328 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	12095730	17959210	6.63E+13	390199	0.453
2 Q WTD C	14296350	21226590	5.68E+13	461189.2	0.355
3 IJC	14783400	21949750	6.18E+13	476901.2	0.358
4 REG-1	15765570	23408030	7.10E+13	508585.3	0.36
5 REG-2	16096460	23899320	6.45E+13	519259.4	0.336
6 REG-3	11710700	17387530	3.50E+13	377778.2	0.34

SFG8TDP VAR=TDP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	26	25	100.0	49.51	40.722	0.327	0.205
***	246	26	25	100.0	49.51	40.722		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 49.51HM3/YR
TOTAL FLOW VOLUME = 33.35 HM3
FLOW DATE RANGE 19990301 TO 19991101
SAMPLE DATE RANGE = 19990322 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1065	1581.3	1.61E+05	31.94	0.253
2 Q WTD C	1294.9	1922.5	1.80E+05	38.83	0.22
3 IJC	1288.3	1912.8	1.88E+05	38.63	0.227
4 REG-1	1380.4	2049.5	3.72E+05	41.4	0.298
5 REG-2	1447.9	2149.8	6.69E+05	43.42	0.38
6 REG-3	1580.1	2346.1	6.84E+05	47.39	0.352

SFG8TP VAR=TP METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	24	23	100.0	49.51	39.675	0.63	0.002
***	246	24	23	100.0	49.51	39.675		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 49.51HM3/YR
TOTAL FLOW VOLUME = 33.35 HM3
FLOW DATE RANGE 19990301 TO 19991101
SAMPLE DATE RANGE = 19990322 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	6177.6	9172.3	1.94E+07	185.26	0.48
2 Q WTD C	7709.1	11446.1	1.98E+07	231.19	0.389
3 IJC	8018.3	11905.3	2.42E+07	240.46	0.413
4 REG-1	8862.6	13158.8	2.65E+07	265.78	0.391
5 REG-2	9675.2	14365.3	2.29E+07	290.15	0.333
6 REG-3	8577.1	12735	1.24E+07	257.22	0.276

SFG8TN VAR=TN METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	26	25	100.0	49.51	40.722	0.1	0.56
***	246	26	25	100.0	49.51	40.722		

FLOW STATISTICS
FLOW DURATION 246 DAYS = .674 YEARS
MEAN FLOW RATE 49.51 HM3/YR
TOTAL FLOW VOLME = 33.35 HM3
FLOW DATE RANGE = 19990301 TO 19991101
SAMPLE DATE RANGE = 19990322 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	46707	69348.5	6.29E+08	1400.69	0.362
2 Q WTD C	56787.4	84315.4	4.64E+08	1702.99	0.256
3 IJC	58028.9	86158.8	5.14E+08	1740.22	0.263
4 REG-1	57903	85971.8	6.39E+08	1736.45	0.294
5 REG-2	58706	87164	7.63E+08	1760.53	0.317
6 REG-3	49946.4	74158.3	4.01E+08	1497.84	0.27

SFG8TSS VAR=TSS METHOD = 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	246	26	25	100.0	49.51	40.722	0.625	0.003
***	246	26	25	100.0	49.51	40.722		

FLOW STATISTICS
FLOW DURATION = 246.0 DAYS = .674 YEARS
MEAN FLOW RATE 49.51 HM3/YR
TOTAL FLOW VOLME = 33.35 HM3
FLOW DATE RANGE = 19990301 TO 19991101
SAMPLE DATE RANGE = 19990322 TO 19991101

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	11154710	16562020	6.21E+13	334517.7	0.476
2 Q WTD C	13562140	20136470	6.46E+13	406714	0.399
3 IJC	13917480	20664060	6.74E+13	417370.2	0.397
4 REG-1	15323820	22752140	9.13E+13	459545.1	0.42
5 REG-2	16787460	24925280	1.10E+14	503438	0.42
6 REG-3	12229480	18157790	4.88E+13	366748.9	0.385

APPENDIX VII – FISHERIES DATA

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Jones Creek County: Harding

Two sites on Jones Creek were selected to conduct stream surveys during the summer of 1995. Site 1 is located at Sec. 01, R6E, T19N and Site 2 is located at Sec. 15, R5E, T20N (Figure 1).

Table 1. Results of water chemistry collected at Jones, Site 1 and Site 2 on 25 July 1995 and 28 June 1995, respectively.

Site #	pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)
1	8.9	1,071	23.3	9.0	0.15
2	8.6	2,464	19.8	8.4	na

A stream survey was conducted on Jones Creek, Site 1 on 25 July 1995. The length of stream sampled was 109 m. with an average width of 3.1 m.

Downstream seining (100 m) and cross stream seining (16 m) were used to sample fish populations. Although only 49 total fish were captured nine species were represented (Table 2 and 3). Black spot was noted on one sand shiner.

Table 2. Species sampled by downstream seining 100 meters with a 4'x15'x1/4" mesh seine at Site 1, Jones Creek, on 25 July 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 meters
Creek chub	3	26.1	3.2	3.0
Flathead chub	3	94.7	10.5	3.0
Fathead minnow	2	43.5	na	2.0
Green sunfish	1	80.0	8.0	1.0
Sand shiner	30	52.8	1.3	30.0
Stone cat	1	120.0	14.0	1.0
White crappie	2	99.5	10.5	2.0
White sucker	1	127.0	22.0	1.0
Total	33			

Table 3. Species sampled by 16 meters of cross stream seining at Site 1, Jones Creek on 25 July 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Black bullhead	1	108.0	17.0	6.2
Creek chub	1	85.0	4.0	6.2
Sand shiner	4	62.0	na	25.0
Total	6			

g:\common\fish\streams\95survey\prairi95\95report\jones April 2, 1996

A stream survey was conducted on Jones Creek, Site 2 on 28 June 1995. The length of stream sampled was 100 m. with an average width of 2.6 m.

Downstream seining (95 m) and dip netting (10 min) were methods used to sample fish populations. Four species were sampled: Fathead minnow, green sunfish, Iowa darter and sand shiner (Table 4 and 5).

Table 4. Species sampled by downstream seining 95 meters with a 4'x15'x1/4" mesh seine at Site 1 2 Jones Creek, on 28 June 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Fathead minnow	31	49.3	-	32.6
Fathead minnow*	34	-	1.9	35.8
Green sunfish	13	62.9	4.2	13.7
Iowa darter	1	62.0	1.0	1.0
Sand shiner	12	67.1	1.9	12.6
Total	91			

* Individual fish were counted and a total weight recorded - no lengths were recorded.

Black spot was observed on three sand shiner.

Table 5. Species sampled by 10 minutes of dip netting at Site 1 2 Jones Creek on 28 June 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Minute
Fathead minnow*	1	na	1.0	0.9

* Individual fish were counted and a total weight recorded - no lengths were recorded.

No fisheries management options are recommended for Jones Creek. The present survey was designed for collection of baseline data.

g:\common\fish\streams\95survey\prairi95\95report\jones April 2, 1996

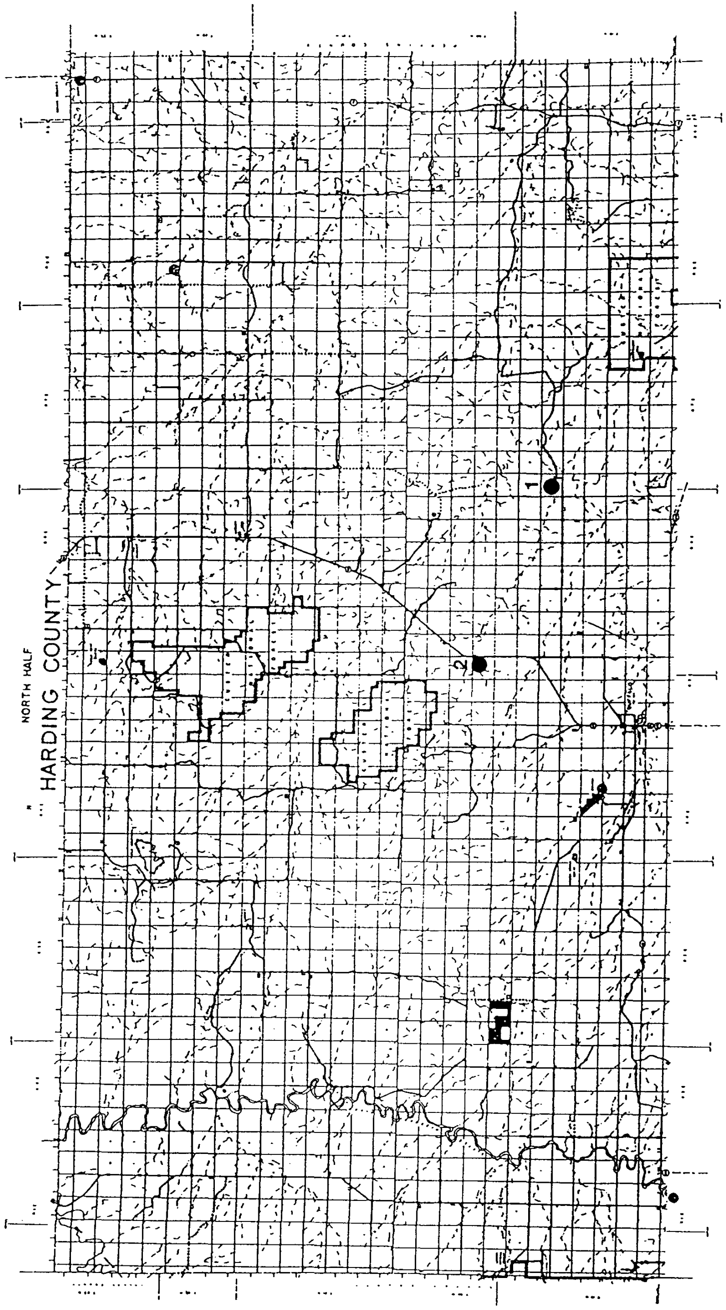


Figure 1. Stream survey Sites 1 and 2 on Jones Creek.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Grand River, South Fork Counties: Perkins and Harding

Five sites on Grand River, South Fork, in Perkins and Harding Counties were selected for fisheries surveys in 1995. Site 6, located in Sec. 03, R9E, T19N in Harding County, was not surveyed due to access denial by the landowner (Figure 2). Downstream seining, cross seining and trap netting were used to assess the fish communities within those reaches. Water quality parameters sampled are shown in Table 1.

Table 1. Results of water chemistry collected at Grand River, South Fork at Sites 3, 7, 8 and 9, 1995.

Site #	Date Day/Month	pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)
3	22/Aug	9.4	1,764	22.3	12.4	0.15
7	25/Jul	9.2	1,748	27.9	10.8	0.14
8	24/Jul	9.1	1,847	28.4	11.0	0.15
9	04/Jul	8.9	1,599	17.9	7.0	

Grand River, South Fork at Site 3, T20N, R12E, S33, Perkins County, was surveyed on 22 August 1995 (Figure 1). Site length was 416 m and average stream width was 11.9 m.

Downstream seining and kick seining were used to sample the fish population at this location. The fish community was comprised of 14 species. Black bullhead, channel catfish and green sunfish represented the sportfish species within this reach. Flathead chub was the most abundant species at 215 and comprised approximately 36% of the total fish population, followed by sand shiner with 26.7% and 160 individuals. Species composition and CPUE by gear type for Site 1 are compiled in Tables 2 and 3.

Table 2. Species composition and CPUE (catch per 100 m) by 34 m of kick seining for Grand River, South Fork at Site 3, Perkins County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Emerald Shiner	2	68.5		5.9
Flathead Chub	8	111.0		23.5
Longnose Dace	8	65.3		23.5
Silvery Minnow	2	87.0	6.0	5.9
Sand Shiner*	8	-	1.3	23.5
Sand Shiner	21	54.4		61.8
Stonecat	1	32.0		2.9
Total	50			

* Mean weight was calculated by weighing all fish listed.

g:\common\fish\streams\95survey\prairi95\95report\grand-sf April 2, 1996

Table 3. Species composition and CPUE (catch per 100 m) with a 6'x25'x1/4" seine (390 m downstream seine haul) for Grand River, South Fork at Site 3, Perkins County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Black Bullhead	2	166.5	67.0	0.5
Common Carp	4	240.5	189.8	1.0
Channel Catfish	18	54.6		4.6
River Carpsucker	2	202.0	128.5	0.5
River Carpsucker	1	56.0		0.3
Emerald Shiner*	39	-	2.2	10.0
Emerald Shiner	41	72.8		10.5
Flathead Chub*	136	-	5.7	34.9
Flathead Chub	71	91.2		18.2
Fathead Minnow*	24		1.5	6.2
Fathead Minnow	42	53.5		10.8
Green Sunfish	3	83.0	8.3	0.8
Longnose Dace	8	66.6	1.8	2.1
Shorthead Redhorse	4	51.3		1.0
Shorthead Redhorse	1	176.0	55.0	0.3
Silvery Minnow	19	93.3	7.4	4.9
Spottail Shiner	1	72.0		0.3
Sand Shiner*	89		1.0	22.8
Sand Shiner	42	51.7		10.8
Stonecat	3	53.3		0.8
Total	550			

* Mean weight was calculated by weighing all fish listed.

Grand River, South Fork at Site 7, T20N, R7E, S26, Harding County, was surveyed on 25 July 1995 (Figure 2). Site length was 192 m and average stream width was 5.5 m.

Downstream seining, cross seining, kick seining and trap netting were used to sample the fish population. Seven fish species were collected at Site 7. Flathead chub was the most abundant species with 54 individuals and 62.8% of the total fish captured, followed by sand shiner at 17 fish and 19.8% (Tables 4-7). Five channel catfish with a mean total length and weight of 408.8 mm and 498.8 g, indicate the existence of a sportfishery within this reach. Anchor worms were observed on >48 per cent of the flathead chubs and one sand shiner.

Table 4. Species composition and catch per 24 hr trap net for Grand River, South Fork at Site 7, Harding County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Common Carp	2	313.0	408.0	2.0
Channel Catfish	5	408.8	498.8	5.0
Total	7			

g:\common\fish\streams\95survey\prairi95\95report\grand-sf April 2, 1996

Table 5. Species composition and CPUE (catch per 100 m) with a 6'x25'x1/4" seine (15 m cross stream seine haul) for Grand River South Fork at Site 7, Harding County, 1995.

Species	(N)	Mean Ln. (mm)	Mean Wt. (g)	CPUE
Common Carp	1	381.0	680.0	6.7
Flathead Chub	24	83.6		160.0
Longnose Dace	1	64.0	2.0	6.7
Sand Shiner	4	47.5		26.7
Total	30			

Table 6. Species composition and CPUE (catch per 100 m) with a 6'x25'x1/4" seine (185 m downstream seine haul) for Grand River South Fork at Site 7, Harding County, 1995.

Species	(N)	Mean Ln. (mm)	Mean Wt. (g)	CPUE
Flathead Chub	27	93.6		14.6
Fathead Minnow	3	51.7	1.3	1.6
Sand Shiner	13	51.2		7.0
Stonecat	1	74.0	4.0	0.5
Total	44			

Table 7. Species composition and CPUE (catch per 100 m) by 7 m of kick seining for Grand River, South Fork at Site 7, Perkins County, 1995.

Species	(N)	Mean Ln. (mm)	Mean Wt. (g)	CPUE
Flathead Chub	3	109.7	10.7	42.9
Sand Shiner	1	50.0		14.3
Stonecat	1	67.0	3.0	14.3
Total	5			

Grand River, South Fork at Site 8, T19N, R6E, S12, Harding County, was surveyed on 24 July 1995 (Figure 2). Site length was 147 m and average stream width was 4.2 m.

Downstream seining, cross seining, and kick seining were used to sample the fish population. Five fish species were collected at Site 8 (Tables 8-10). Flathead chub were most numerous at 20 fish, comprising 80% of the total fish population. Four flathead chub were infected with anchor worms equalling a 20% incidence rate for the flathead chub population at Site 8.

Table 8. Species composition and CPUE (catch per 100 m) with a 4'x15'x1/4" seine (15 m cross stream seine haul) for Grand River South Fork at Site 8, Harding County, 1995.

Species	(N)	Mean Ln. (mm)	Mean Wt. (g)	CPUE
Flathead Chub	7	74.4		46.7
Fathead Minnow	1	49.0		6.7
Total	8			

g:\common\fish\streams\95survey\prairi95\95report\grand-sf April 2, 1996

Table 9. Species composition and CPUE (catch per 100 m) with a 4'x15'x1/4" seine (85 m downstream seine haul) for Grand River South Fork at Site 8, Harding County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Flathead Chub	7	133.4	17.4	8.2
Fathead Minnow	1	50.0		1.2
Golden Shiner	1	403.0	522.0	1.2
Green Sunfish	1	61.0	3.0	1.2
Total	10			

Table 10. Species composition and CPUE (catch per 100 m) by 13 m of kick seining for Grand River, South Fork, Site 8, Perkins County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Flathead Chub	6	72.8		46.2
Stonecat	1	68.0	2.0	7.7
Total	7			

Grand River, South Fork at Site 9, T19N, R5E, S29, Harding County, was surveyed on 04 July 1995 (Figure 1). Site length was 105 m and average stream width was 3.0 m.

Downstream seining and cross stream seining were used to sample the fish population. Four fish species were collected at Site 9 (Tables 11 and 12). Flathead chub were most numerous at 14 fish, comprising 56% of the total fish population. Three flathead chubs and one sand shiner were infected with anchor worms equalling a 21.4% and 11.1% incidence rate, respectively.

Table 11. Species composition and CPUE (catch per 100 m) with a 4'x15'x1/4" seine (9 m cross stream seine haul) for Grand River South Fork at Site 9, Harding County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Flathead Chub	1	172.0	37.0	11.1
Sand Shiner	2	41.0		22.2
Total	3			

Table 12. Species composition and CPUE (catch per 100 m) with a 4'x15'x1/4" seine (105 m downstream seine haul) for Grand River South Fork at Site 9, Harding County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Flathead Chub	13	98.3		12.4
Fathead Minnow	1	49.0		1.0
Golden Shiner	1	421.0	687.0	1.0
Sand Shiner	7	43.1		6.7
Total	22			

No fisheries management options are recommended. Surveys were designed to collect baseline data.

g:\common\fish\streams\95survey\prairi95\95report\grand-sf April 2, 1996

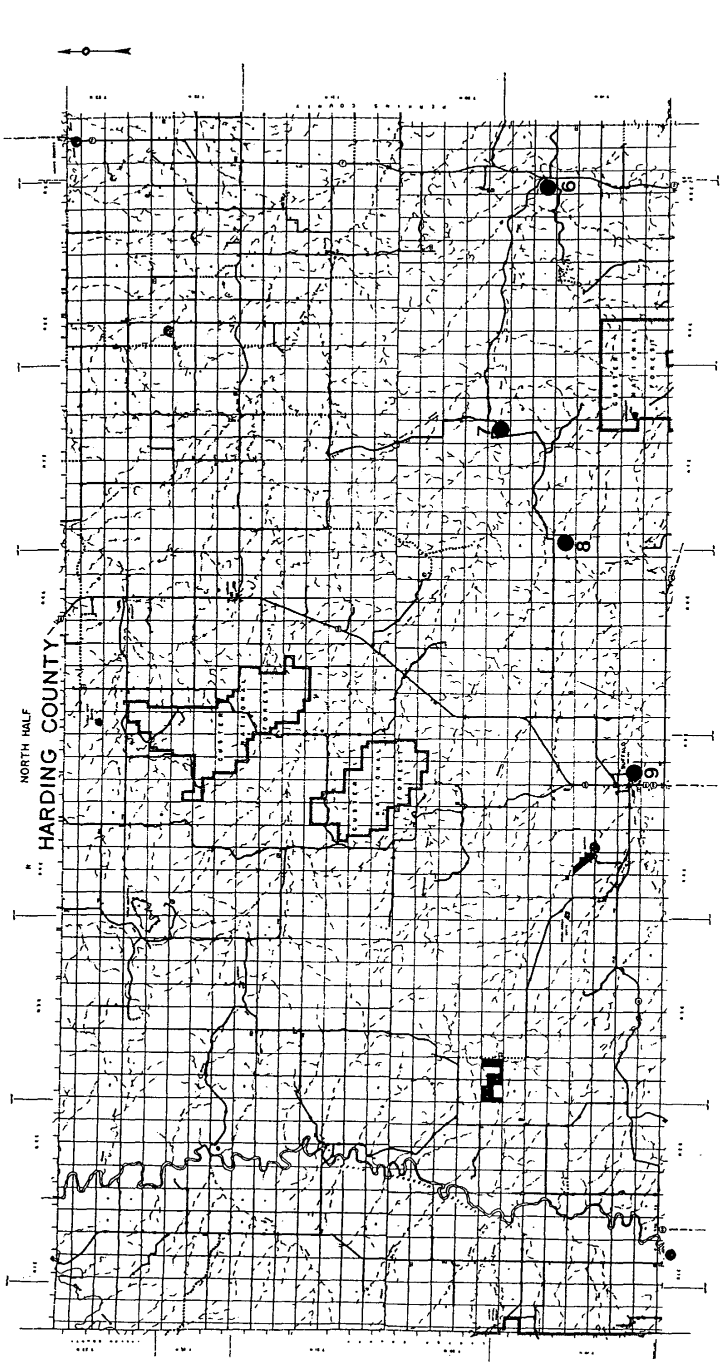


Figure 2. Stream survey Sites 6 through 9 on Grand River, South Fork.

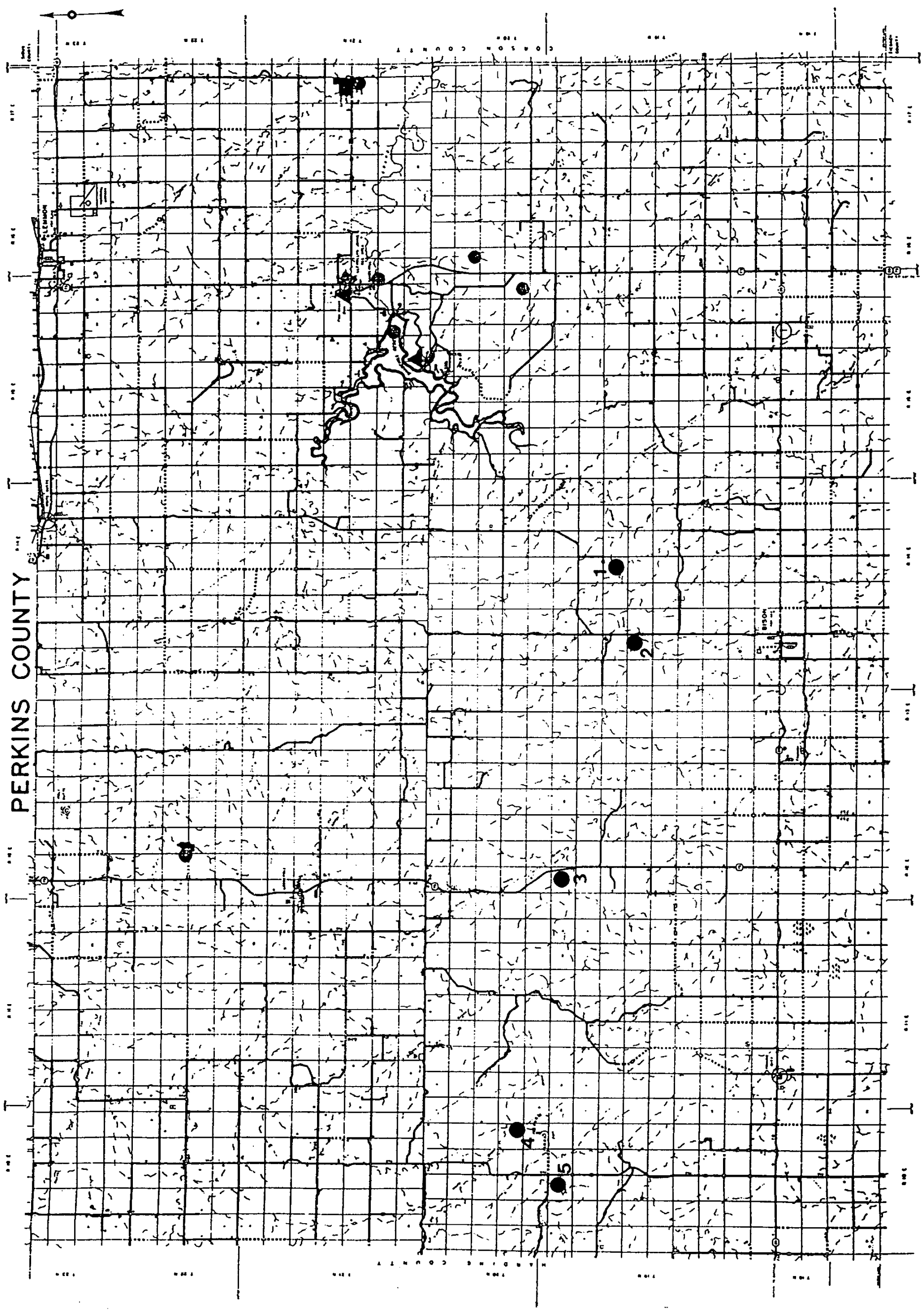


Figure 1. Stream survey Sites 1 through 5 on Grand River, South Fork.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Grand River, North Fork County: Perkins

Four sites on Grand River, North Fork were selected for conducting stream surveys during the summer of 1995. Sites are shown on Perkins County map (Figures 1).

Locations of Sites 1 through 4 and dates surveyed are as follows:

Site 1 - Sec. 09, R14E, T21N - 21 August 1995
Site 2 - Sec. 32, R13E, T22N - Rescheduled for 1996.
Site 3 - Sec. 25, R10E, T23N - 16 July 1995
Site 4 - Sec. 19, R10E, T23N - 16 August 1995

Table 1. Results of water chemistry collected on the Grand River, North Fork during the summer of 1995.

Site #	pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)
1	9.0	3,100	25.4	13.0	0.35
3	8.8	2,155	21.5	9.6	0.30
4	8.8	2,381	26.4	13.6	0.45

A stream survey was conducted on Grand River, North Fork at Site 1 on 21 August 1995. The length of stream sampled was 235 m. with an average width of 6.7 m.

Downstream seining (100 m) and kick seining (50 m) were methods used to sample fish populations. A total 123 fish were collected with ten species represented (Table 2 and 3).

Table 2. Species sampled by downstream seining 20 meters with a 6'x25'x1/4" mesh seine and 80 meters with a 4'x15'x1/4" mesh seine at Site 1, Grand River, N. Fork on 21 August 1995. (Field data sheets did not record the results of each seine type separately.)

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Bluegill	1	94.0	14.0	1.0
Emerald shiner	27	68.4	-	27.0
Fathead minnow	11	59.7	-	11.0
Green sunfish	1	85.0	10.0	1.0
Shorthead redhorse	2	89.0	-	2.0
Spottail shiner	10	56.2	-	10.0
Sand shiner	61	59.8	-	61.0
Stonecat	1	68.0	-	1.0
White bass	1	76.0	4.0	1.0
White sucker	6	139.7	30.0	6.0
Total	121			

g:\common\fish\streams\95survey\prairi95\95report\grand-nf April 2, 1996

Table 5. Species sampled by one overnight, 1/4" mesh, trap net set at Site 3, Grand River, N. Fork on 16 August 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Black bullhead	2	97.0	-	2.0
Northern pike	1	176.0	29.0	1.0
Shorhead redhorse	1	51.0	1.0	1.0
White sucker	1	274.0	202.0	1.0
Total	5			

A stream survey was conducted on Grand River, N. Fork at Site 4 on 16 August 1995. The length of stream sampled was 192 m. with an average width of 5.6 m.

Downstream seining (150 m) and kick seining (32 m) were methods used to sample fish populations. A total of 63 fish were captured with seven species represented (Table 6 and 7).

Table 6. Species sampled by downstream seining 150 meters with a 4'x15'x1/4" mesh seine at Site 4, Grand River, N. Fork on 16 August 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Common carp	2	151.0	50.5	1.3
Fathead minnow	28	31.5	-	18.7
Green sunfish	1	94.0	15.0	0.7
River carpsucker	1	47.0	-	0.7
Sand shiner	23	36.9	-	15.3
White sucker	2	151.0	37.5	1.3
Total	57			

Table 7. Species sampled by 32 meters of kick seining with a 4'x15'x1/4" mesh seine at Site 4, Grand River, N. Fork on 16 August 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Black bullhead	1	95.0	11.0	3.1
Sand shiner	5	44.4	-	15.6
Total	6			

No fisheries management options are recommended for Grand River, N. Fork. The present survey was designed for collection of baseline data.

g:\common\fish\streams\95survey\prairi95\95report\grand-nf April 2, 1996

Table 3. Species sampled by kick seining 50 meters with a 4'x15'x1/4" mesh seine at Site 1, Grand River, N. Fork on 21 August 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Unit Effort
Emerald shiner	2	71.5	-	4.0

A stream survey was conducted on Grand River, N. Fork at Site 3 on 16 August 1995. The length of stream sampled was 389 m. with an average width of 11.1 m.

Downstream seining (420 m) and trap netting (1 overnight set) were methods used to sample fish populations. A total of 748 fish were captured with twelve species represented (Table 4 and 5).

Table 4. Species sampled by downstream seining 420 meters with a 6'x25'x1/4" mesh seine at Site 3, Grand River, N. Fork on 16 August 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Black bullhead	37	43.9	-	8.8
Black bullhead*	306	-	4.8	72.9
Black bullhead**	13	145.7	61.1	3.1
Carp	9	161.9	58.1	2.1
Carp**	1	44.0	-	0.2
Channel catfish	3	426.0	647.3	0.7
Emerald shiner	5	57.4	-	1.2
Fathead minnow	10	53.1	-	2.4
Green sunfish	4	79.3	7.8	1.0
Northern pike	14	186.0	41.2	3.3
Shorthead redhorse	32	56.6	-	7.6
Shorthead redhorse*	162	-	2.8	38.6
Shorthead redhorse**	15	148.4	31.1	3.6
Sand shiner	41	47.5	-	9.8
Sand shiner*	8	-	1.3	1.9
Stonecat	1	52.0	-	0.2
White sucker	75	145.9	36.3	17.9
White sucker*	6	-	23.3	1.4
Yellow perch	1	116.0	16.0	0.2
Total	743			

* Individual fish were counted and a total weight recorded - no lengths were recorded.

** An additional line for the same species was used due to obvious age/size difference.

g:\common\fish\streams\95survey\prairi95\95report\grand-nf April 2, 1996

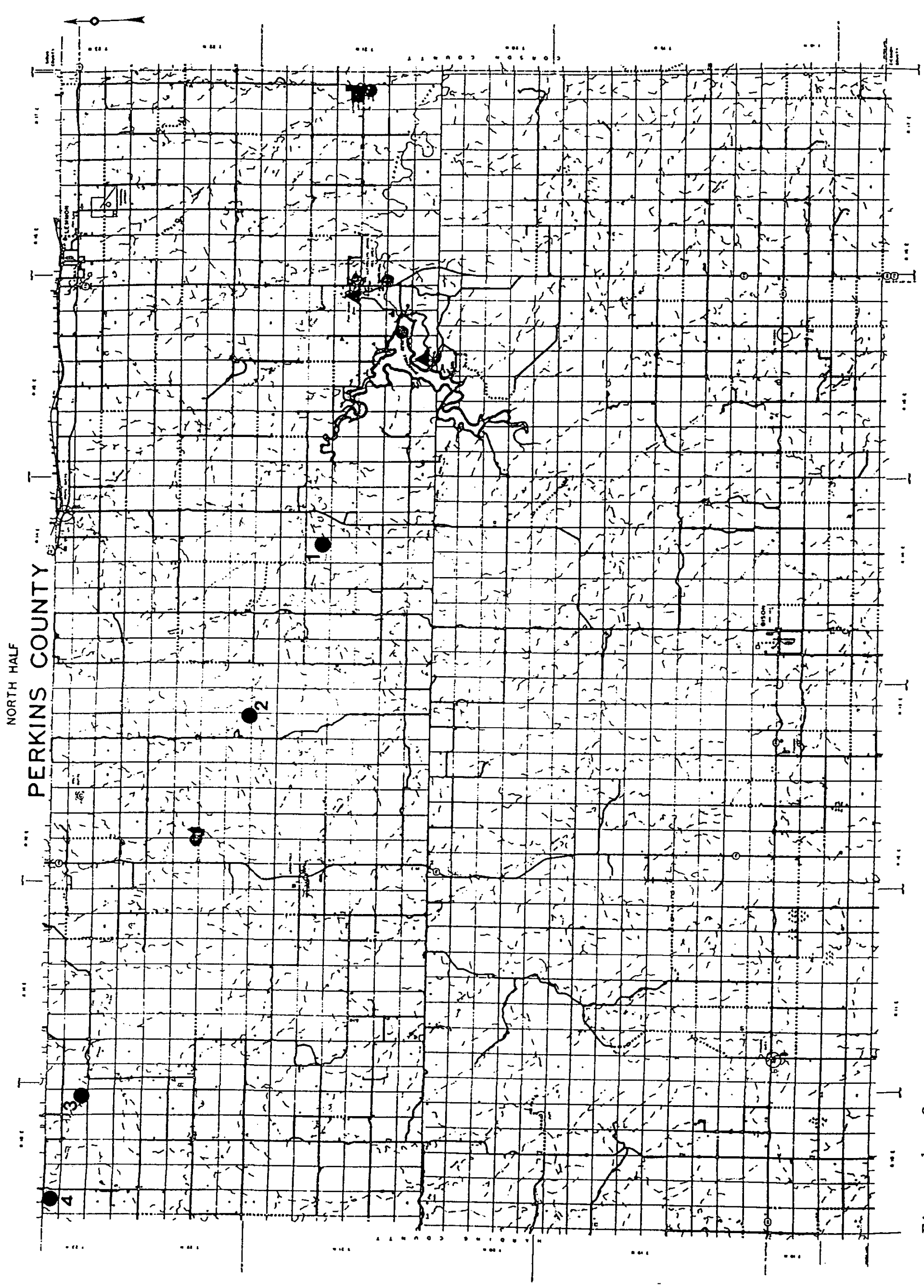


Figure 1. Stream survey Sites 1 through 4 on Grand River, North Fork.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Flat Creek County: Perkins

Two sites were selected on Flat Creek in Perkins County. Site 1, located in T21N, R16E, S18, approximately 1.0 km upstream of Flat Creek Dam, was surveyed on 29 August 1995 (Figure 1). Site length was 231 m and average stream width was 6.6 m. Water quality parameters sampled are shown in Table 1.

Table 1. Results of water chemistry collected at Flat Creek, Sites 1 and 2, 1995.

Site #	Date Day/Month	pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)
1	29/Aug	8.6	2,937	24.2	7.0	0.45
2	23/Aug	8.4	3,503	21.2	6.6	0.47

Downstream and cross stream seining were used to sample the fish population at this location. The fish community was comprised of 10 species. Bluegill, black bullhead, green sunfish and yellow perch made up the sport fish component, some of which may have migrated from Flat Creek Dam. Brassy minnow, common carp, creek chub, golden shiner, Iowa darter and white sucker represented the nongame fish at Site 1 (Table 2). Brassy minnow were most abundant, representing 58.8% of the total fish population within this reach.

Table 2. Species composition and CPUE (catch per 100 m) with a 6'x25'x1/4" seine (221 m downstream seine haul) for Flat Creek, Site 1, Perkins County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Blue Gill*	4		2.0	0.9
Blue Gill	14	55.5		6.3
Black Bullhead*	53		13.7	24.0
Black Bullhead	41	115.7	29.9	18.6
Brassy Minnow*	518		2.4	234.4
Brassy Minnow	21	83.2	4.9	9.6
Common Carp	3	168.7	66.0	1.4
Creek Chub	5	131.0	22.8	2.3
Golden Shiner*	9		4.9	4.1
Golden Shiner	31	74.9	3.2	14.0
Green Sunfish	6	71.0		2.7
Iowa Darter	1	57.0		0.5
White Sucker*	94		18.7	42.5
White Sucker	34	108.0	14.3	15.4
Yellow Perch*	55		2.4	24.9

g:\common\fish\streams\95survey\prairi95\95report\flat April 2, 1996

Table 2 (continued)

Yellow Perch	39	60.5		17.7
Yellow Perch	6	162.0	52.3	2.7
Total	934			

* Mean weight was calculated by weighing all fish listed.

Table 3. Species composition and CPUE (catch per 100 m) with a 4'x15'x1/4" seine (17 m cross stream seine haul) for Flat Creek, Site 1, Perkins County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Brassy Minnow	46	59.3	2.1	270.6
Golden Shiner	13	80.4	4.6	76.5
Green Sunfish	1	39.0	1.0	5.9
White Sucker	1	148.0	30.0	5.9
Total	61			

Site 2, located in T21N, R15E, S2, approximately 4.0 km upstream of Site 1, was surveyed on 23 August 1995 (Figure 1). Site length was 100 m. Water quality parameters sampled are shown in Table 1.

Downstream and cross stream seining were used at Site 2 to sample the fish community. Nine species were collected within this reach. Species composition differed from Site 1, in that bluegill, common carp and yellow perch did not inhabit this section of stream. One species, brook stickleback, was not found at Site 1. Fathead minnow were most abundant at 260 fish, comprising over 70 per cent of the total fish captured (Tables 4 and 5).

Table 4. Species composition and CPUE (catch per 100 m) with a 4'x15'x1/4" seine (90 m downstream seine haul) for Flat Creek, Site 2, Perkins County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Black Bullhead	6	106.2	17.0	6.7
Brassy Minnow	12	63.0		13.3
Brook Stickleback	9	39.2		100.0
Creek Chub	3	163.0	47.3	3.3
Fathead Minnow*	109		2.4	121.1
Fathead Minnow	63	59.3		70.0
Green Sunfish	2	92.0	13.0	2.2
Iowa Darter	3	61.0		3.3
White Sucker	6	93.3		6.7
Total	213			

* Mean weight was calculated by weighing all fish listed.

g:\common\fish\streams\95survey\prairi95\95report\flat April 2, 1996

Table 5. Species composition and CPUE (catch per 100 m) with a 4'x15'x1/4" seine (9 m cross stream seine haul) for Flat Creek, Site 2, Perkins County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Brassy Minnow	5	71.2		55.6
Brook Stickleback	36	41.2		400.0
Creek Chub	14	55.3		155.6
Fathead Minnow*	85		2.5	944.4
Fathead Minnow	3	61.7		33.3
Golden Shiner	2	90.0	4.0	22.2
Iowa Darter	5	62.0		55.6
White Sucker	3	105.7		33.3
Total	153			

* Mean weight was calculated by weighing all fish listed.

No fisheries management options are recommended. Survey was designed to collect baseline data.

g:\common\fish\streams\95survey\prairi95\95report\flat April 2, 1996

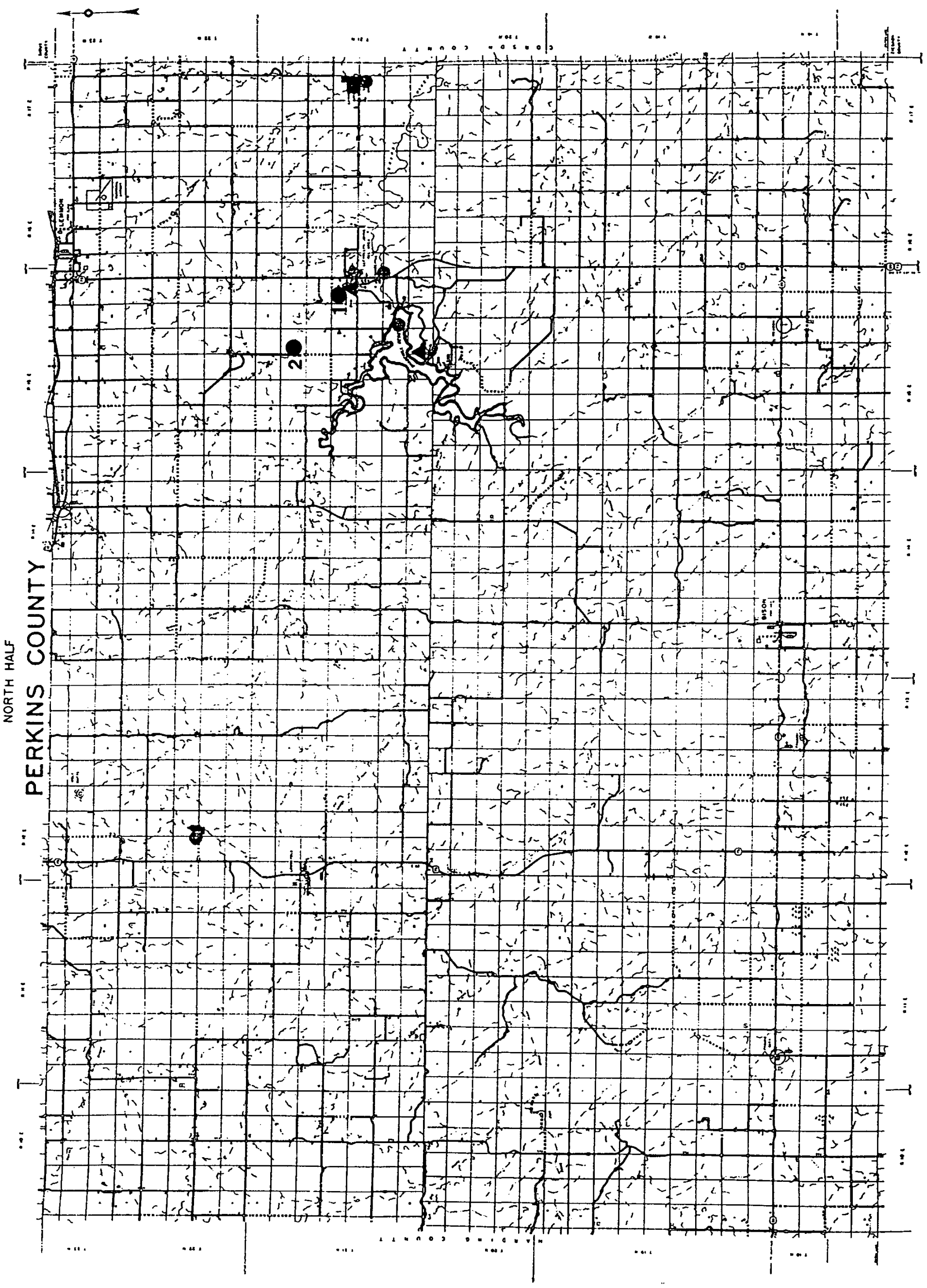


Figure 1. Stream survey Sites 1 and 2 on Flat Creek.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Crooked Creek County: Harding

A stream survey was conducted on Crooked Creek at Site 1 on 17 July 1995. Site location was Sec. 25, R6E, T23N (Figure 1). The length of stream sampled was 100 m. with an average width of 2.8 m.

Table 1. Results of water chemistry collected at Crooked Creek, Site 1 on 17 July 1995.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)
9.1	3,040	24.4	10.8	na

Downstream seining (90 m) and cross stream seining (11 m) were methods used to sample fish populations. Five species were sampled: Creek chub, fathead minnow, green sunfish, sand shiner and white sucker (Table 2 and 3).

Table 2. Species sampled by downstream seining 90 meters with a 4'x15'x1/4" mesh seine at Site 1, Crooked Creek, on 17 July 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Creek chub	7	155.7	40.7	7.8
Fathead minnow	50	49.2	2.0	55.6
Green sunfish	2	71.5	6.0	2.2
Sand shiner	50	59.6	2.2	55.6
White sucker	7	147.9	35.7	7.8
Total	116			

Table 3. Species sampled by cross stream seining a distance of 11 meters at Site 1, Crooked Creek on 17 July 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Creek chub	3	138.7	28.0	27.2
Fathead minnow	17	51.9	na	154.5
Sand shiner	6	64.2	2.0	54.5
White sucker	11	140.5	32.2	100.0
Total	37			

Anchors worms were noted on 3 white sucker, 1 sand shiner and 1 fathead minnow.

No fisheries management options are recommended. Survey was designed for collection of baseline data.

g:\common\fish\streams\95survey\prairi95\95report\crooked April 2, 1996

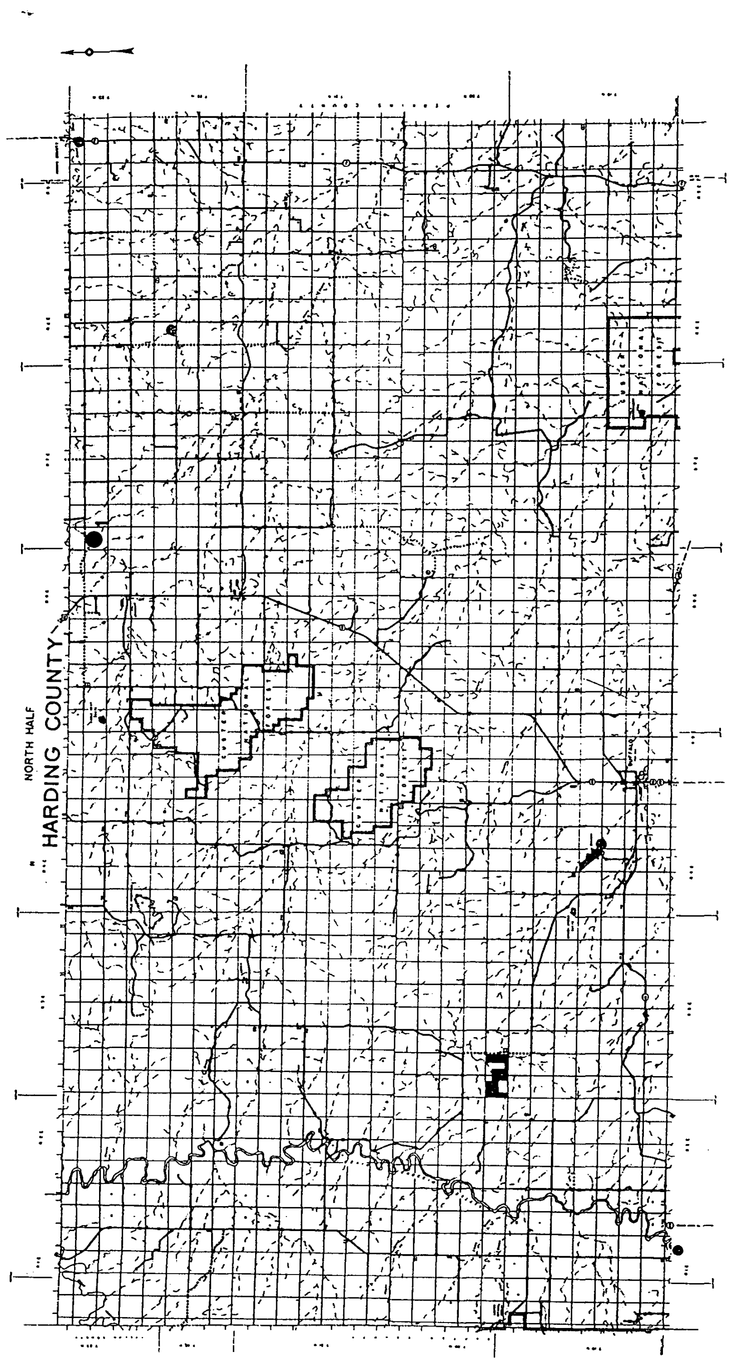


Figure 1. Stream survey Site 1 on Crooked Creek.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Clarks Fork Creek County: Harding

A stream survey was conducted on Clarks Fork Creek at Site 1 on 3 July 1995. Site location was Sec. 03, R6E, T18N (Figure 1). The length of stream sampled was 147 m. with an average width of 4.2 m.

Table 1. Results of water chemistry collected at Clarks Fork Creek, Site 1 on 5 July 1995.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)
8.8	1,556	16.3	7.4	na

Downstream seining (140 m) and cross stream seining (9 m) were methods used to sample fish populations. Four species were sampled: Fathead minnow, longnose dace, sand shiner and silvery minnow (Table 2 and 3).

Table 2. Species sampled by downstream seining 140 meters with a 4'x15'x1/4" mesh seine at Site 1, Clarks Fork Creek, on 5 July 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Fathead minnow	21	46.1	-	15.0
Longnose dace	24	67.7	2.5	17.1
Sand shiner	11	62.4	-	7.9
Sand shiner*	28	-	1.1	20.0
Silvery minnow	39	55.7	1.1	27.8
Total	123			

* Individual fish were counted and a total weight recorded - no lengths were recorded.

Table 3. Species sampled by cross stream seining a distance of 9 meters at Site 1, Clarks Fork Creek on 5 July 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Fathead minnow	6	37.8	na	66.7

One sand shiner was observed with anchor worms.

No fisheries management options are recommended. Survey was designed for collection of baseline data.

g:\common\fish\streams\95survey\prairi95\95report\clarkfk April 2, 1996

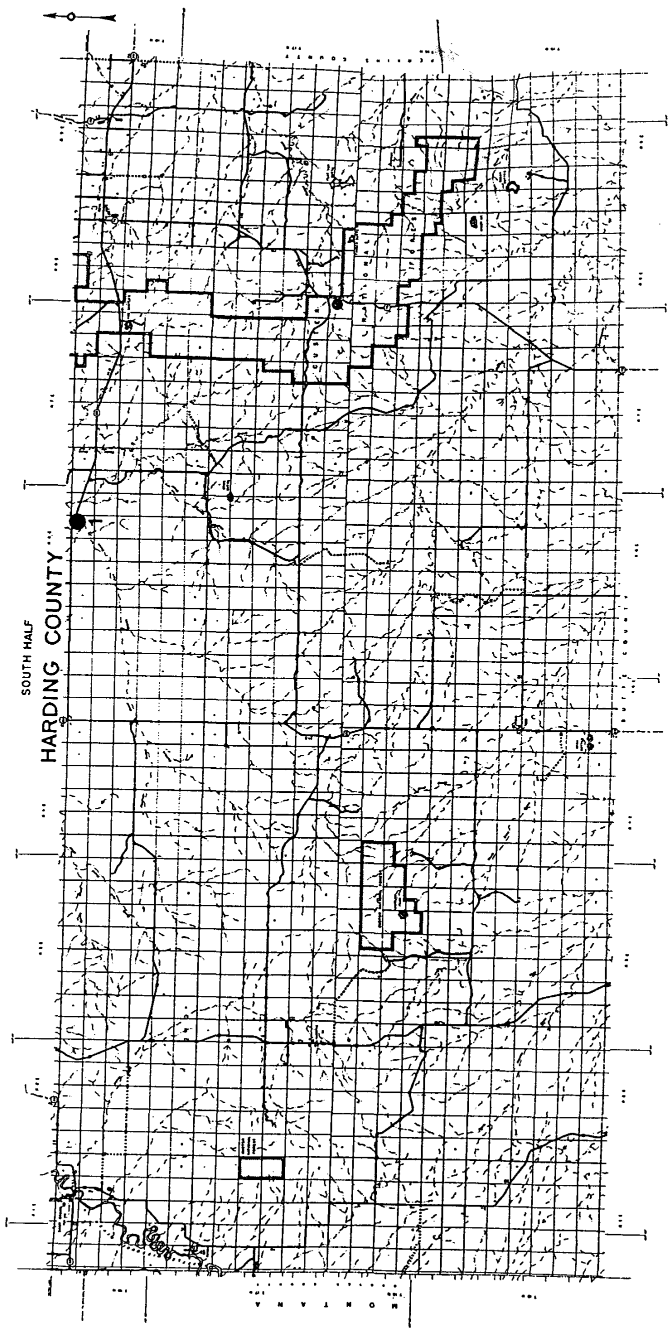


Figure 1. Stream survey Site 1 on Clarks Fork Creek.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Campbell Creek County: Harding

A stream survey was conducted on Campbell Creek at Site 1 on 27 June 1995. Site location was Sec. 03, R5E, T21N (Figure 1). The length of stream sampled was 100 m. with an average width of 5.6 m.

Table 1. Results of water chemistry collected at Big Nasty Creek, Site 1 on 27 June 1995.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)
8.6	2,906	18.3	6.6	na

Downstream seining (23 m) and dip netting (10 min) were methods used to sample fish populations. Two species were sampled: Brook stickleback and fathead minnow (Table 2).

Table 2. Species sampled by downstream seining 18 meters with a 6'x25'x1/4" mesh seine at Site 1, Campbell Creek, on 27 June 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Brook stickleback	27	64.37	1.7	150.0
Fathead minnow	30	53.8	-	166.7
Fathead minnow*	118	-	2.2	655.6
Total	175			

* Individual fish were counted and a total weight recorded - no lengths were recorded.

Downstream seining was conducted for 5 meters with a 4'x15'x1/4" mesh at this site. No fish were captured. Ten minutes of dip netting was completed with no fish being netted.

No fisheries management options are recommended. Survey was designed for collection of baseline data.

g:\common\fish\streams\95survey\prairi95\95report\campbell April 2, 1996

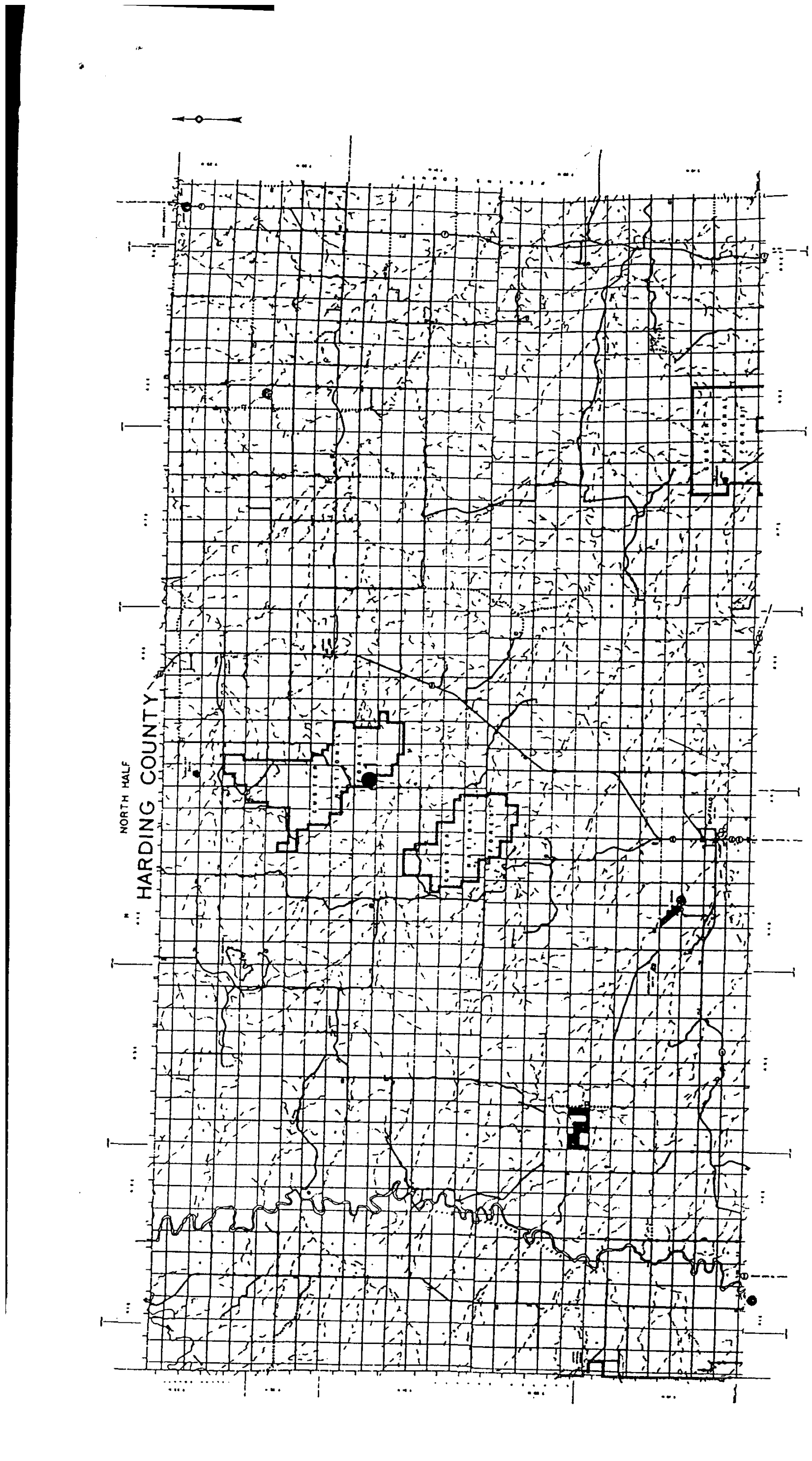


Figure 1. Stream survey Site 1 on Campbell Creek.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Bull Creek County: Harding

Results and Discussion:

Two sites on Bull Creek in Harding County were selected for fisheries surveys in 1995. Downstream seining, cross seining, dip netting and trap netting were used to assess the fish communities within those reaches. Water quality parameters sampled were pH, conductivity, water temperature, dissolved oxygen and Secchi disc transparency (Table 1).

Table 1. Results of water chemistry collected at Bull Creek, Sites 1 and 2 on 26 July and 28 June 1995, respectively.

Site #	pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)
1	9.1	1,692	22.7	10.4	0.12
2	8.9	2,276	16.5	10.0	

Bull Creek Site 1, T20N, R6E, S25, located in Harding County approximately 12 miles northeast of Buffalo, was surveyed on 26 July 1995 (Figure 1). Site length was 222 m and average stream width was 6.4 m.

Downstream seining, cross seining and trap netting were used to sample the fish population at this location. The fish community was comprised of 12 species. Black bullhead, green sunfish, white crappie and yellow perch represented the sportfish species within this reach. Fathead minnow was the most abundant species at 322, followed by flathead chub (54) and sand shiner (50) by all gear types combined. Species composition and CPUE by gear type for Site 1 are compiled in Tables 2-5. Four individuals, or 7.4 per cent of the total flathead chub catch at Site 1 were infected with anchor worms.

Table 2. Species composition and CPUE (catch per 100 m) with a 4'x15'x1/4" seine (20 m cross seine haul) for Bull Creek, Site 1, Harding County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Flathead Chub	6	113.5	10.0	30.0
Fathead Minnow	8	50.1		40.0
Green Sunfish	1	28.0		5.0
Sand Shiner	4	41.0		20.0
Total	19			

g:\common\fish\streams\95survey\prairi95\95report\bull April 2, 1996

Table 3. Species composition and catch per meter with a 6'x25'x1/4" seine (200 m downstream seine haul) for Bull Creek, Site 1, Harding County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Black Bullhead	4	157.5	52.5	2.0
Flathead Chub	31	100.8		15.5
Creek Chub	1	87.0	6.0	1.0
Fathead Minnow*	82		0.9	41.0
Fathead Minnow	32	45.5		16.0
Green Sunfish	3	70.0	5.3	1.5
Sand Shiner*	10		1.4	5.0
Sand Shiner	30	48.2		15.0
White Crappie	7	95.4		3.5
White Sucker	1	132.0	20.0	0.5
White Sucker	1	314.0	240.0	0.5
Yellow Perch	1	102.0	10.0	0.5
Total	203			

* Mean weight was calculated by weighing all fish listed.

Table 4. Species composition and catch per meter with a 4'x15'x1/4" seine (13 m downstream seine haul) for Bull Creek, Site 1, Harding County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Flathead Chub	3	95.0	6.7	23.1
Fathead Minnow	2	41.0		15.4
Longnose Dace	6	73.8		46.2
Sand Shiner*	6		1.3	46.2
Stonecat	1	106.0	10.0	7.7
White Sucker	1	233.0	18.0	7.7
Total	19			

* Mean weight was calculated by weighing all fish listed.

Table 5. Species composition and catch per 24 hour trap net for Bull Creek, Site 1, Harding County, 1995.

Species	(N)	Mean Ln.	Mean Wt.	CPUE
Black Bullhead	1	172.0	86.0	1.00
Flathead Chub	14	109.1	9.1	14.00
Green Sunfish	2	77.5	6.0	2.00
Stonecat	1	102.0	10.0	1.00
White Sucker	2	241.0	128.0	2.00
Total	20			

Bull Creek Site 2, T21N, R5E, S16, located in Harding County approximately midway between the North and South Cave Hills, was surveyed on 28 June 1995 (Figure 1). Site length was 135 m and average stream width was 3.9 m. Water quality parameters sampled included pH, conductivity, water temperature and dissolved oxygen (Table 1).

Downstream seining and dip netting were used to sample the fish population at this location. Green sunfish, creek chub and fathead minnow were the only species collected at Site 2. Fathead minnow comprised 94.7 per cent of the total fish population within this reach

g:\common\fish\streams\95survey\prairi95\95report\bull April 2, 1996

(Tables 6 and 7). One fathead minnow was noted to be infected with anchor worms.

Table 6. Species composition and catch per meter with a 4'x15'x1/4" seine (135 m downstream seine haul) for Bull Creek, Site 2, Harding County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Creek Chub	9	76.3	4.2	6.7
Fathead Minnow*	132	-	1.3	97.8
Fathead Minnow	62	54.1		45.9
Green Sunfish	1	71.0	5.0	0.7
Total	204			

* Mean weight was calculated by weighing all fish listed.

Table 7. Species composition and CPUE (catch per minute) on 10 minutes of dip netting for Bull Creek, Site 2, Harding County, 1995.

Species	(N)	Mean Ln.(mm)	Mean Wt.(g)	CPUE
Creek Chub	1	18.0		0.1
Fathead Minnow	2		2.0	0.2
Total	3			

No fisheries management options are recommended. Survey was designed to collect baseline data.

g:\common\fish\streams\95survey\prairi95\95report\bull April 2, 1996

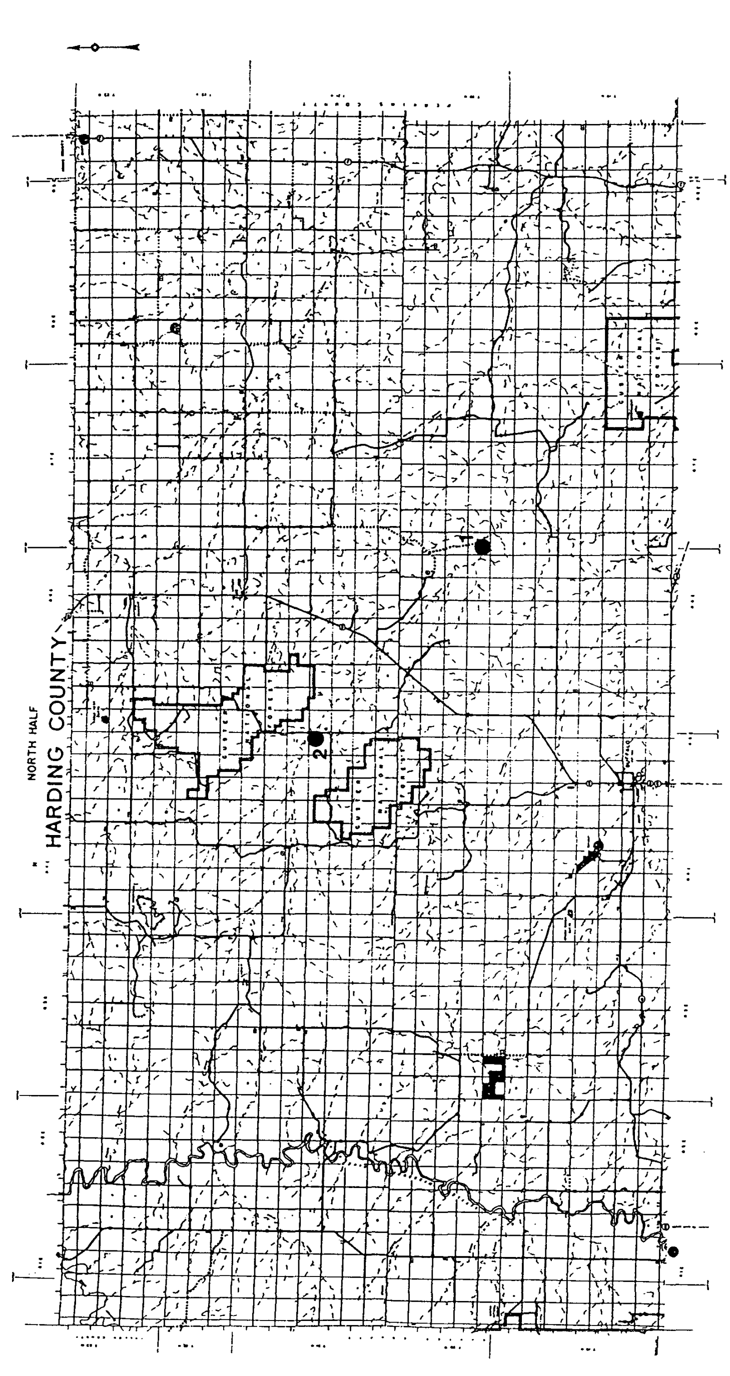


Figure 1. Stream survey Sites 1 and 2 on Bull Creek.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Big Nasty Creek **County:** Harding

A stream survey was conducted on Big Nasty Creek at Site 1 on 3 July 1995. Site location was Sec. 14, R8E, T21N (Figure 1). The length of stream sampled was 196 m. with an average width of 5.6 m.

Table 1. Results of water chemistry collected at Big Nasty Creek, Site 1 on 3 July 1995.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)
8.8	3,125	21.2	12.0	na

Downstream seining (176 m) and dip netting (10 min) were used to sample fish populations. Four species were sampled: brook stickleback, fathead minnow, golden shiner and sand shiner (Tables 2 and 3).

Table 2. Species sampled by downstream seining 176 meters with a 4'x15'x1/4" mesh seine at Site 1, Big Nasty Creek, on 3 July 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Brook stickleback	48	40.3	na	27.3
Fathead minnow	32	57.1	2.0	18.2
Fathead minnow*	800	-	2.2	454.5
Golden shiner	27	77.7	4.8	15.3
Sand shiner	32	74.2	4.1	18.2
Sand shiner*	38	-	3.9	21.6
Total	977			

* Individual fish were counted and a total weight recorded - no lengths were recorded.

Table 3. Species sampled by 10 minutes of dip netting at Site 1, Big Nasty Creek on 3 July 1995.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Minute
Brook stickleback	12	30.8	na	1.2
Fathead minnow	15	32.5	na	1.5

Anchors worms were noted on 5 golden shiners, 4 sand shiners and 1 fathead minnow. Black spot was observed on one fathead minnow and a lesion was noted on one fathead minnow.

No fisheries management options are recommended. Survey was designed for collection of baseline data.

g:\common\fish\streams\95survey\prairi95\95report\bignasty April 2, 1996

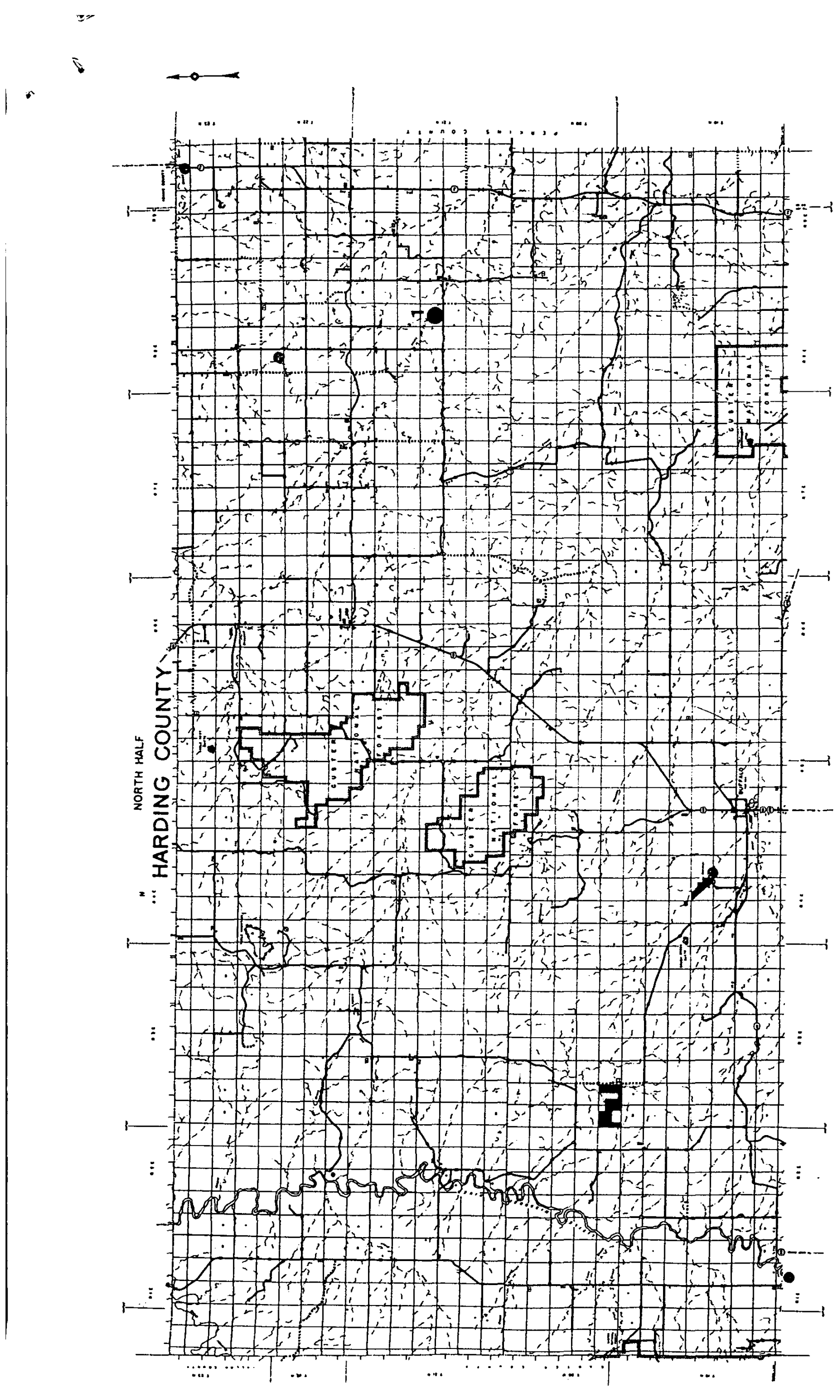


Figure 1. Stream survey Site 1 on Big Nasty Creek.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

Name: East Thunder Hawk Creek County: Perkins

One site was selected on East Thunder Hawk Creek, Perkins County, South Dakota to collect baseline fisheries data in 1996.

A stream survey was conducted on East Thunder Hawk Creek, Perkins County, Site 4 on 03 June 1996. Site location was T22N, R17E, Sec. 28 (Figure 1). Three downstream seine hauls equaling 65 m and four minnow traps, each set for five hours, were used to sample the resident fish community. Water quality measurements are given in Table 1.

Table 1. Results of water chemistry collected at East Thunder Hawk Creek, Site 1 on 3 June 1996.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)	Air Temp. (°C)
8.9	3,529	18.5	8.5	-	21.0

Five fish species were collected, of which fathead minnow were the most abundant (Tables 2 and 3).

Table 2. Fish species composition and CPUE by downstream seining at Site 1, East Thunder Hawk Creek, Perkins County, 3 June 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch per 100 m
Black bullhead	3	163.3	82.3	4.6
Brook stickleback	27	64.9	3.2	41.5
Fathead minnow	2,834	61.9	2.4	4,360.0
Iowa darter	1	58.0	1.0	1.5
White Sucker	69	113.4	17.0	106.2
Total	120			

N:\Common\Fish\Streams\96Report\Prairi96\ThnhkCr.Doc 10-Mar-97 12:22 PM

Table 3. Fish species composition and relative abundance by minnow trapping at Site 1, East Thunder Hawk Creek, Perkins County, 3 June 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)
Brook stickleback	52	50.5	0.7
Fathead minnow	224	-	3.5
Iowa darter	22	52.4	1.0
Total	298		

No fisheries management options are recommended for East Thunder Hawk Creek, Sites 1, Perkins County. Surveys were designed for collection of baseline data.

N:\Common\Fish\Streams\96Report\Prairi96\ThnhkCr.Doc 10-Mar-97 12:22 PM

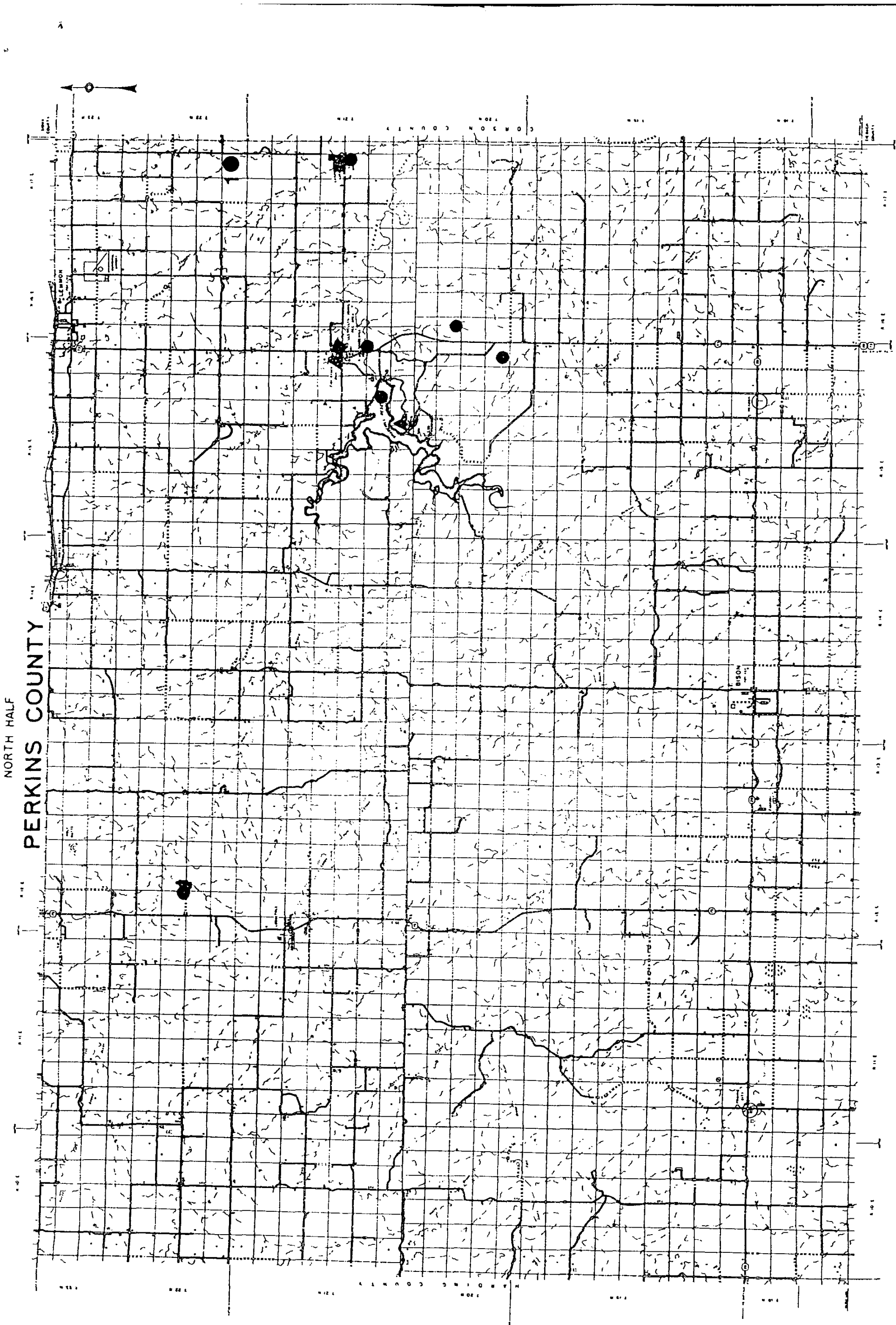


Figure 1. Stream survey Site 1, East Thunder Hawk Creek, Perkins County, South Dakota.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

Name: Thunder Hawk Creek County: Perkins

Two sites were selected on Thunder Hawk Creek, Perkins County, South Dakota to collect baseline fisheries data in 1996. The original sites, 1 and 2, were not surveyed due to access denial by landowners. Sites 3 and 4 were then established and Site 3 was completed. Site 4 was changed to Site 1 on East Thunder Hawk Creek by the survey crew and is reported under that filename.

A stream survey was conducted on Thunder Hawk Creek, Perkins County, Site 3 on 04 June 1996. Site location was T21N, R17E, Sec. 22 (Figure 1). Cross stream and downstream seining were used to sample the resident fish community. Average stream width was 7.2 m. Water quality measurements are given in Table 1.

Table 1. Results of water chemistry collected at Thunder Butte Creek, Site 3 on 4 June 1996.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)	Air Temp. (°C)
8.6	1,973	16.8	7.8	-	17.5

Three seine hauls, each equaling 42 m, were combined for a total downstream seine haul length of 126 m, while stream widths at the three cross seining locations were not recorded. Eleven species of fish were collected; of which, fathead minnow were most abundant, comprising 45.8 percent of the total catch by combined gear types (Tables 2&3).

Table 2. Fish species composition and relative abundance by cross seining at Site 3, Thunder Hawk Creek, Perkins County, 4 June 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)
Black Bullhead	17	-	13.4
Brassy Minnow	6	-	12.0
Brook Stickleback	2	56.5	1.5
Fathead Minnow	55	-	2.1
Golden Shiner	35	-	5.0
Green Sunfish	1	66.0	4.0
White Sucker	2	184.5	68.0
Yellow Perch	2	120.0	20.0
Total	120		

N:\Common\Fish\Streams\96Report\Prairi96\ThnhkCr.Doc 4/9/97 2:13 PM

Table 3. Fish species composition and CPUE by downstream seining at Site 3, Thunder Hawk Creek, Perkins County, 4 June 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch per 100 m
Black Bullhead	48	98.7	14.9	38.1
Brassy Minnow	169	72.5	4.6	134.1
Brook Stickleback	15	56.4	1.8	11.9
Common Carp	1	572.0	2,502.0	0.8
Emerald Shiner	1	41.0	1.0	0.8
Fathead Minnow	530	51.9	2.3	420.6
Golden Shiner	257	74.6	4.8	204.0
Green Sunfish	2	65.0	7.5	1.6
Western Silvery Minnow	6	58.7	1.8	4.8
White Sucker	40	177.3	70.5	31.7
Yellow Perch	87	106.8	15.5	69.0
Total	1,156			

No fisheries management options are recommended for Thunder Hawk Creek, Site 3, Perkins County. Survey was designed for collection of baseline data.

N:\Common\Fish\Streams\96Report\Prairi96\ThnhkCr.Doc 4/9/97 2:13 PM

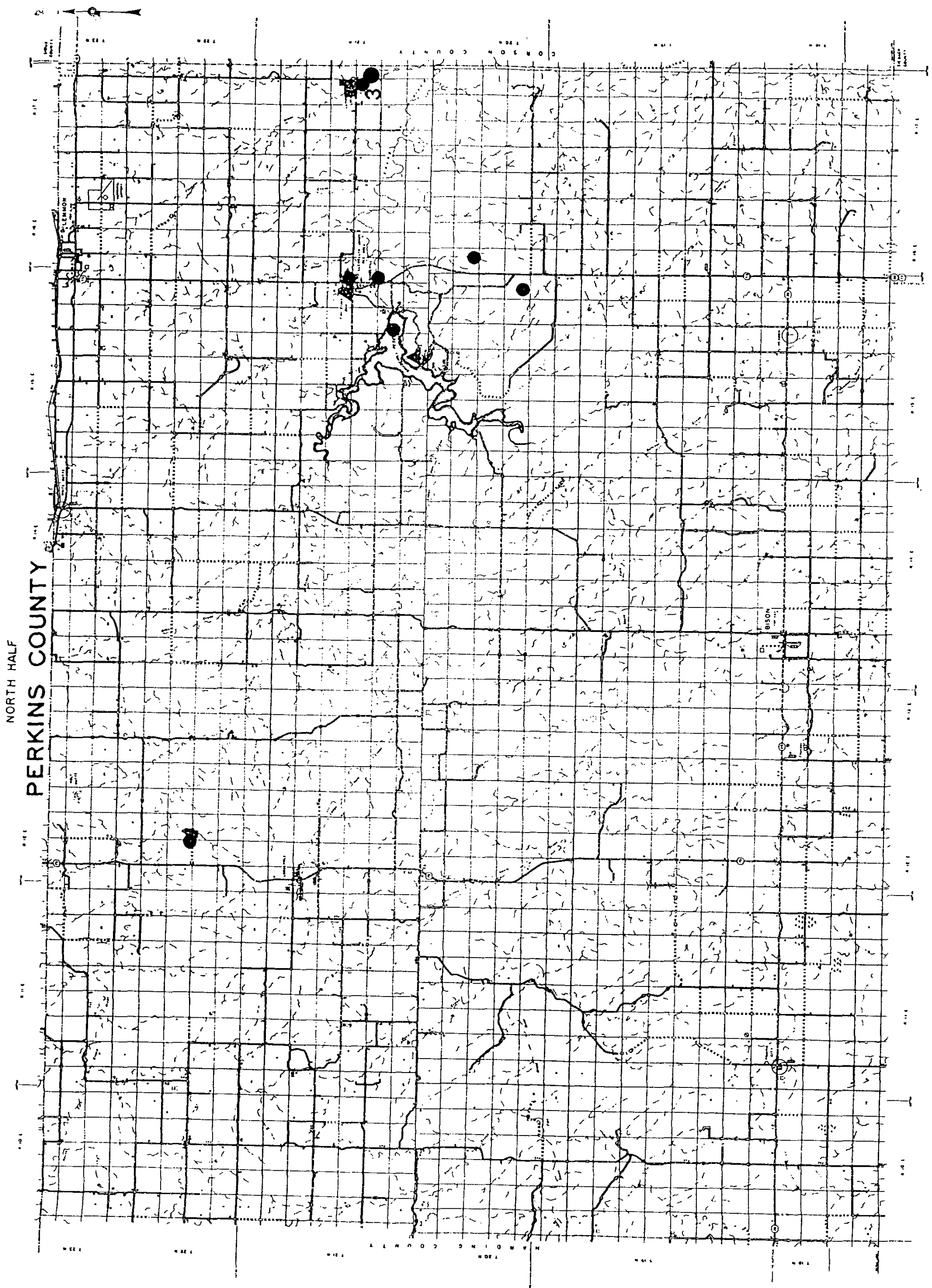


Figure 1. Stream survey Site 3, Thunder Hawk Creek, Perkins County, South Dakota.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

Name: North Fork Grand River County: Perkins

A stream survey was conducted on North Fork Grand River, Site 2 on 22 May 1996, 27 May 1996 and 17 June 1996. Site location was Sec. 28, R13E, T22N (Figure 1). The length of stream sampled was 227 m. with an average width of 12.6 m. Water quality is shown for parameters sampled in Table 1.

Table 1. Results of water chemistry collected at North Fork Grand River, Site 2 on 22 May 1996.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)	Air Temp. (°C)
7.8	2,532	20.5	7.5	-	25.3

On 22 May 1996, 1 trap net was run at North Fork Grand River, Site 2 (Table 2). Minnow traps (4) were run on 27 May 1996 (Table 3). Downstream seining 201.4 m., cross-stream seining (3 hauls), and kick seining (1 haul), were used to sample fish populations on 17 June 1996 (Tables 4 through 6). High water and rapid flows hampered fish sampling and only 7 species were collected by all methods.

Table 2. Species sampled by trap netting (1 trap net)at North Fork Grand River, Site 2 on 22 May 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Trap
Stonecat	4	133.5	21.0	4.0
White sucker	1	224.0	118.0	1.0
Total	5			

Table 3. Species sampled by minnow traps (4) at North Fork Grand River, Site 2 on 27 May 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Trap
Fathead minnow	5	81.6	3.6	1.3

Table 4. Species sampled by downstream seining 201.4 meters with a 6' x 50' x 3/16" mesh seine at North Fork Grand River, Site 2 on 17 June 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Fathead minnow	151	43.5	1.2	75.0
Green sunfish	2	54.0	2.0	1.0
Northern pike	1	600.0	1,347.0	0.5
Sand shiner	196	42.6	1.2	97.3
Shorthead redhorse	5	149.8	39.8	2.5
White sucker	1	170.0	44.0	0.5
Total	356			

Table 5. Species sampled by cross-stream seining (3 hauls) with a 6' x 50' x 3/16" mesh seine at North Fork Grand River, Site 2 on 17 June 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Haul
Fathead minnow	1	70.0	43.0	1.0
Northern pike	1	835.0	>3,000.0*	1.0
Sand shiner	15	-	1.9	15.0
Shorthead redhorse	1	243.0	131.0	1.0
Total	18			

Table 6. Species sampled by kick seining (1 hauls) with a 6' x 50' x 3/16" mesh seine at North Fork Grand River, Site 2 on 17 June 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Haul
Fathead minnow	1	54.0	1.0	1.0

No fisheries management options are recommended for North Fork Grand River at this time. Survey was designed for collection of baseline data.

N:\Common\Fish\Streams\96report\96prairi\ngrnd96 14:56 3/10/97

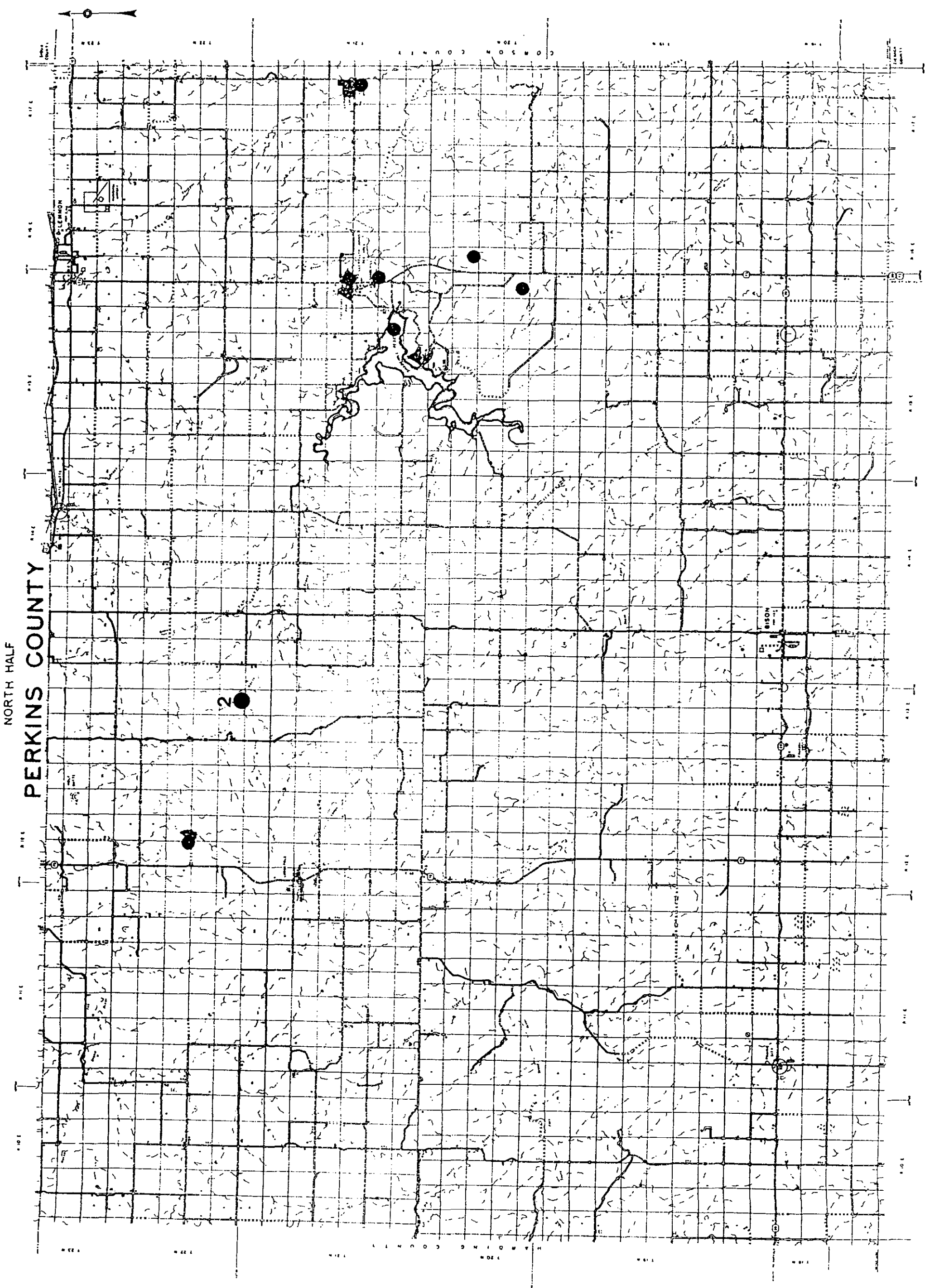


Figure 1. Stream survey Site 2, North Fork Grand River, Perkins County, South Dakota.

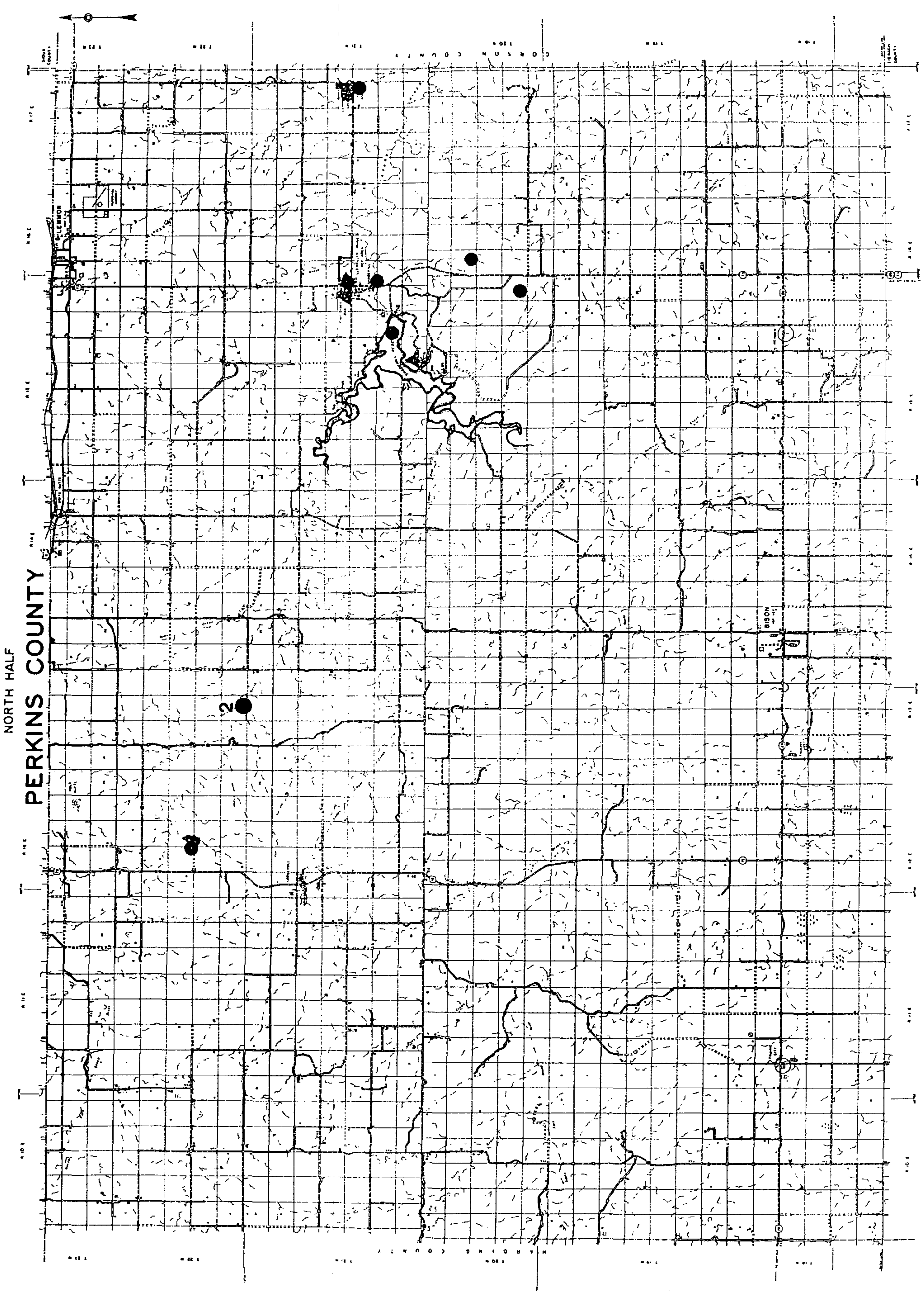


Figure 1. Stream survey Site 2, North Fork Grand River, Perkins County, South Dakota.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

Name: South Fork Grand River County: Perkins

A stream survey was conducted on South Fork Grand River, Site 1 on 25 June 1996. Site location was Sec. 09, R14E, T19N (Figure 1). The length of stream sampled was 362 m. with an average width of 20.1 m. Water quality is shown for parameters sampled in Table 1.

Table 1. Results of water chemistry collected at South Fork Grand River, Site 1 on 25 June 1996.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)	Air Temp. (°C)
8.5	1,642	23.6	8.5	0.09	25.5

Downstream seining 311.4 m., trap nets, and minnow traps were used to sample fish populations. Fifteen species were collected as shown in Tables 2 and 3. No fish were collected by use of minnow traps.

Table 2. Species sampled by downstream seining 311.4 meters with a 6' x 50' x 3/16" mesh seine at South Fork Grand River, Site 1 on 25 June 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Black crappie	1	79.0	4.0	0.3
Brassy minnow	3	80.3	3.0	1.0
Carp	1	216.0	135.0	0.3
Channel catfish	21	202.4	122.9	6.7
Emeral shiner	24	68.6	2.7	7.7
Fathead minnow	23	44.9	1.0	7.4
Flathead chub	26	168.9	40.4	8.3
Goldeye	4	375.6	494.5	1.3
Plains minnow	30	80.9	4.8	9.6
River carpsucker	4	119.8	49.5	1.3
Sand shiner	58	38.0	0.5	18.6
Shorthead redhorse	2	221.5	117.5	0.7
Stonecat	6	134.0	27.7	1.9
Western silvery minnow	81	68.1	5.8	26.0
White sucker	4	248.5	167.8	1.3
Total	288			

Table 3. Species sampled by trap netting at South Fork Grand River, Site 1 on 25 June 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Net
Channel catfish	19	185.9	60.8	19.0
Flathead chub	10	168.7	41.0	10.0
Shorthead redhorse	1	195.0	66.0	1.0
Stonecat	2	152.0	32.5	2.0
Total	32			

A stream survey was conducted on South Fork Grand River, Site 2 on 16 July 1996. Site location was Sec. 13, R13E, T19N (Figure 1). The length of stream sampled was 227 m. with an average width of 12.6 m. Water quality is shown for parameters sampled in Table 4.

Table 4. Results of water chemistry collected at South Fork Grand River, Site 2 on 16 July 1996.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)	Air Temp. (°C)
8.8	2,095	20.6	6.1	-	22.0

Downstream seining 227 m. and cross seining (3 hauls) were methods used to sample fish populations. Seining operations were difficult due to the rocky substrate encountered. Six species were collected and are shown in Tables 5 and 6.

Table 5. Species sampled by downstream seining 227 meters with a 6' x 50' x 3/16" mesh seine at South Fork Grand River, Site 2 on 16 July 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Emerald shiner	11	71.3	3.7	4.8
Flathead chub	11	153.0	28.5	4.8
Goldeye	1	208.0	73.0	0.4
Sand shiner	20	46.2	1.5	8.8
Total	43			

Table 6. Species sampled by cross seining (3 hauls) with a 6' x 50' x 3/16" mesh seine at South fork Grand River, Site 2 on 16 July 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Haul
Channel catfish	1	125.0	11.0	0.3
Emerald shiner	1	60.0	2.0	0.3
Flathead chub	6	147.7	28.0	2.0
Stonecat	1	59.0	3.0	0.3
Total	9			

A stream survey was conducted on South Fork Grand River, Site 5 on 20 May 1996. Site location was Sec. 33, R10E, T20N (Figure 1). The length of stream sampled was 237 m. with an average width of 13.2 m. Water quality is shown for parameters sampled in Table 7.

Table 7. Results of water chemistry collected at South Fork Grand River, Site 5 on 20 May 1996.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)	Air Temp. (°C)
8.5	1,183	17.0	8.6	-	19.0

Downstream seining 134 m. and cross seining (2 hauls) were methods used to sample fish populations. Seining operations and holding block nets in place were difficult due to rapid current and encountering barbed wire. The first 79 meters downstream seined only netted 7 fish. Six species were collected and are shown in Tables 8 and 9.

Table 8. Species sampled by downstream seining 134 meters with a 6' x 50' x 3/16" mesh seine at South Fork Grand River, Site 5 on 20 May 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Fathead minnow	1	58.0	1.0	0.7
Flathead chub	35	78.9	5.3	26.1
Longnose dace	2	70.0	4.0	1.5
Plains minnow	7	56.1	1.0	5.2
River carpsucker	2	66.5	3.5	1.5
Sand shiner	19	42.9	1.0	14.2
Western silvery minnow	41	62.1	1.7	30.6
Total	107			

Table 9. Species sampled by cross seining (2 hauls) with a 6' x 50' x 3/16" mesh seine at South fork Grand River, Site 5 on 20 May 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per Haul
Emerald shiner	2	78.5	3.0	1.0
Fathead minnow	8	53.1	1.6	4.0
Flathead chub	33	91.1	9.8	16.5
Longnose dace	37	72.0	3.4	18.5
Plains minnow	1	55.0	1.0	0.5
Sand shiner	4	44.5	1.0	2.0
Stonecat	5	135.6	52.4	5.0
Western silvery minnow	2	65.0	2.0	1.0
White sucker	1	220.0	134.0	0.5
Total	9			

No fisheries management options are recommended for South Fork Grand River at this time. Survey was designed for collection of baseline data.

N:\Common\Fish\Streams\96report\96prairi\sfgrn96 14-Feb-97 11:24:09

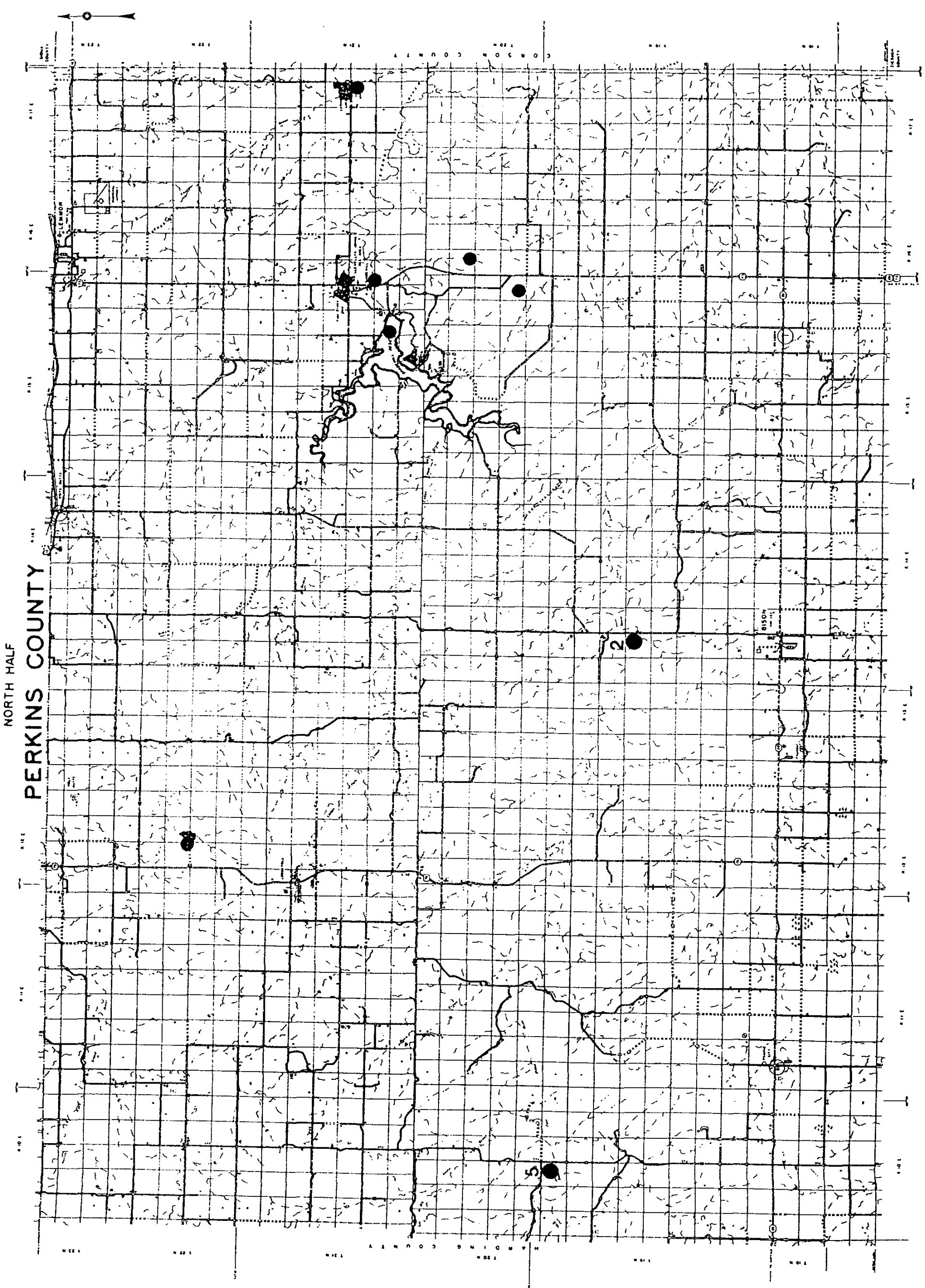


Figure 1. Stream survey Sites 1, 2 and 5, South Fork Grand River, Perkins County, South Dakota.

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

Name: Big Nasty Creek County: Perkins

A stream survey was conducted on Big Nasty Creek, Site 4 on 21 May 1996. Site location was Sec. 23, R10E, T20N (Figure 1). The length of stream sampled was 100 m. with an average width of 4.8 m. Water quality from parameters sampled is shown in Table 1.

Table 1. Results of water chemistry collected at Big Nasty Creek, Site 4 on 21 May 1996.

pH	Conductivity (uhos/cm)	Water Temp. (°C)	D.O. (mg/l)	Secchi Disc (meters)	Air Temp. (°C)
8.6	2,874	18.0	8.3	-	23.8

Downstream seining 100.0 m. and cross seining (number of hauls not recorded) were used to sample fish populations. Sixteen species were sampled as shown in Tables 2 and 3.

Table 2. Species sampled by downstream seining 100.0 meters with a 4' x 15' x 3/16" mesh seine at Site 4, Big Nasty Creek, on 21 May 1996.

Species	Total Number	Mean Length(mm)	Mean Weight(g)	Catch Per 100 Meters
Black bullhead	3	162.0	85.3	3.0
Carp	1	560.0	1,508.0	1.0
Emeral shiner	38	71.0	2.4	38.0
Flathead chub	21	167.8	45.4	21.1
Fathead minnow	256	61.8	2.1	256.0
Goldeye	3	411.7	788.7	3.0
Green sunfish	1	40.0	1.0	1.0
Plains minnow	54	67.0	2.4	54.0
River carpsucker	20	210.5	140.3	20.0
Sand shiner	7	52.4	1.0	7.0
Shorthead redhorse	4	113.3	25.2	4.0
Stonecat	5	130.8	38.4	5.0
Western silvery minnow	26	61.6	2.1	26.0
White sucker	1	159.0	39.0	1.0
Total	440			

Table 3. Species sampled by cross-stream seining (number of hauls not recorded) with a 4' x 15' x 3/16" mesh seine at Site 4, Big Nasty Creek, on 21 May 1996.

Species	Total Number	Mean Length (mm)	Mean Weight (g)	Catch Per Haul
Black bullhead	3	156.7	88.3	-
Channel catfish	1	57.0	1.0	-
Emerald shiner	9	72.9	3.0	-
Fathead minnow	42	-	2.1	-
Longnose dace	1	72.0	3.0	-
Plains minnow	6	68.2	2.3	-
River carpsucker	18	201.7	106.1	-
Sand shiner	1	45.0	1.0	-
Shorthead redhorse	4	112.5	24.5	-
Stonecat	5	94.8	18.4	-
Western silvery minnow	5	63.0	2.2	-
Total	95			

No fisheries management options are recommended for Big Nasty Creek, Perkins County. Survey was designed for collection of baseline data.

N:\Common\Fish\Streams\96report\96prairi\Bgnas96 18-Feb-97 15:35

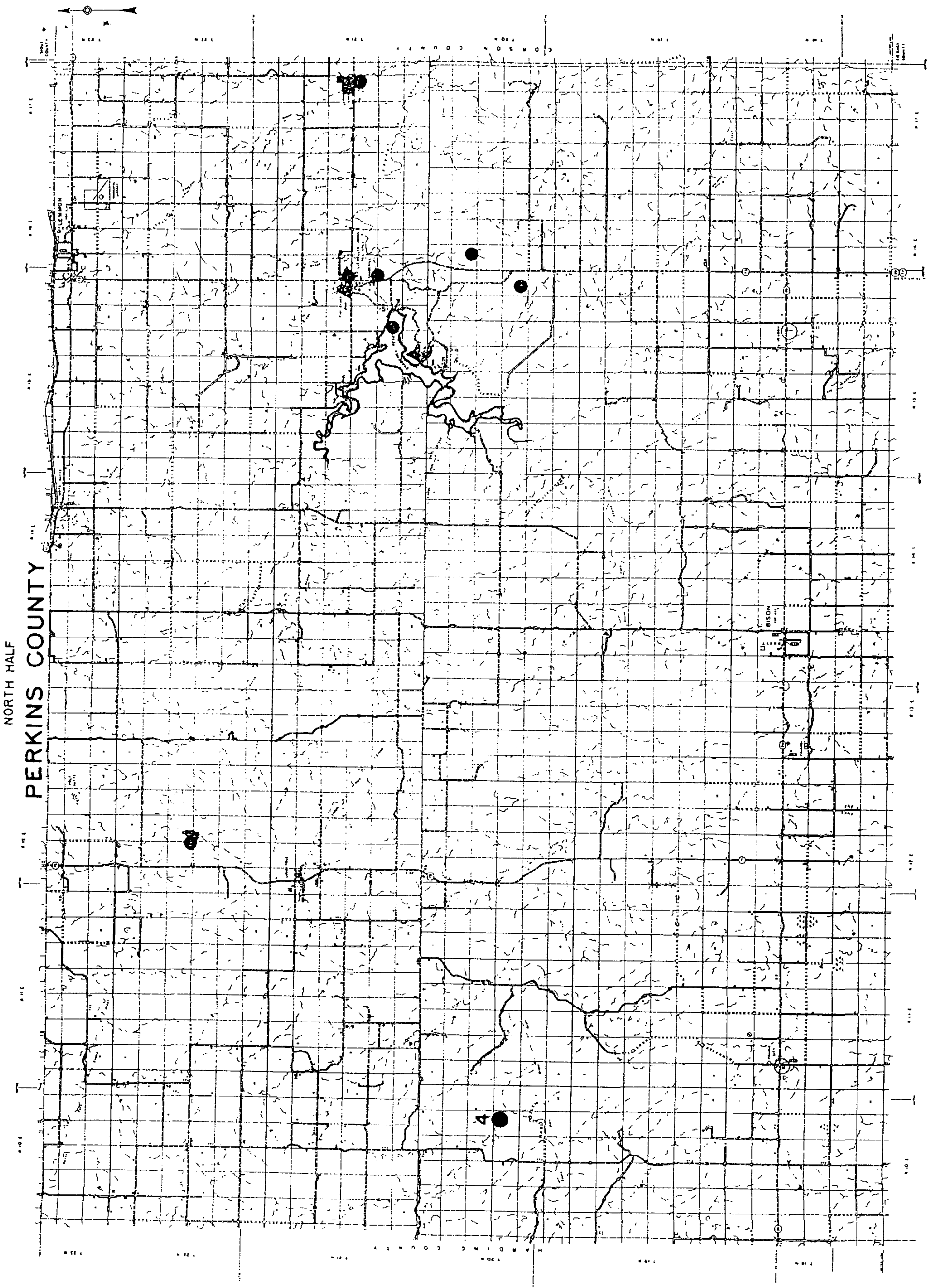


Figure 1. Stream survey Site 4, Big Nasty Creek, Perkins County, South Dakota.

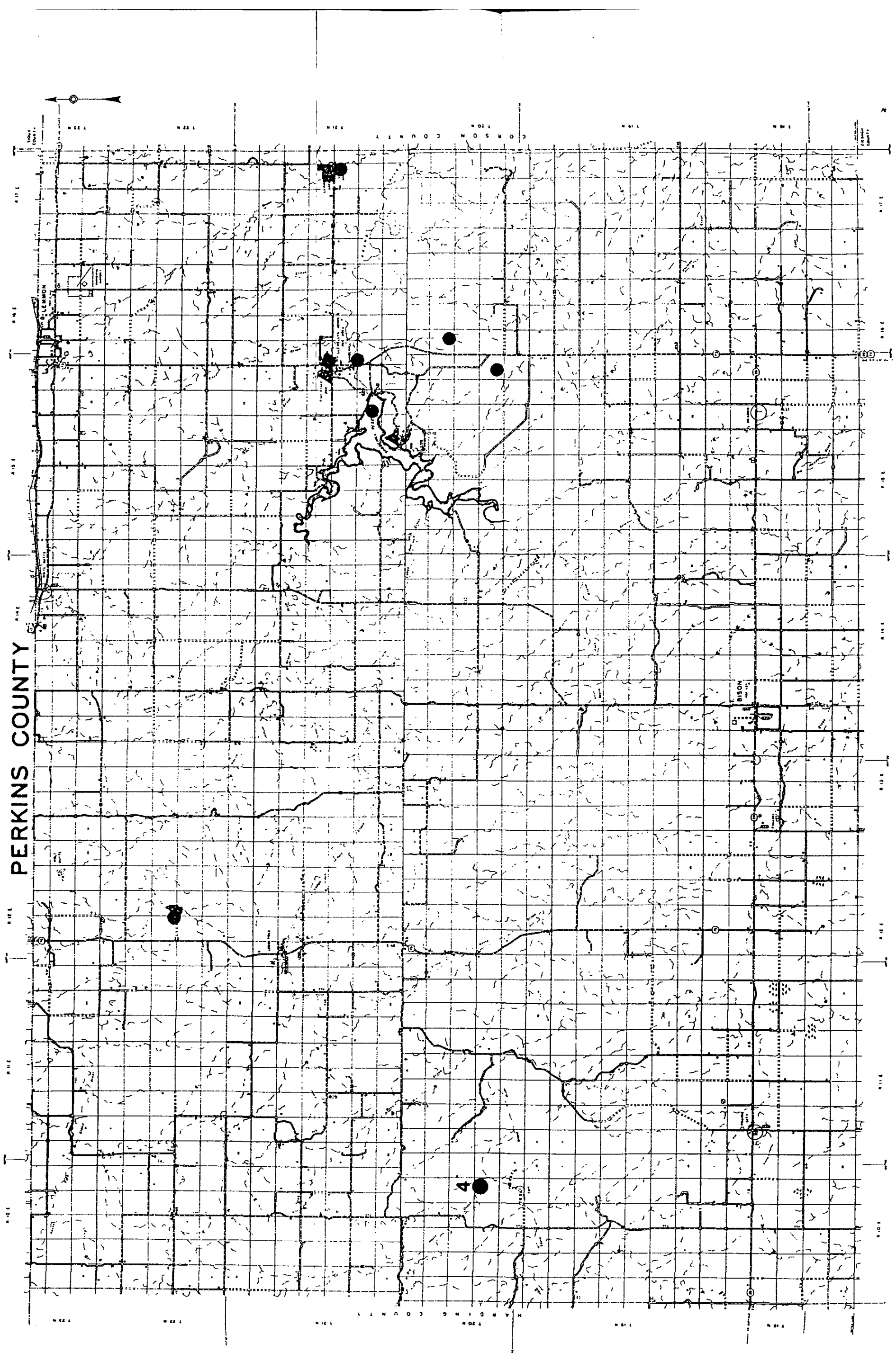


Figure 1. Stream survey Site 4, Big Nasty Creek, Perkins County, South Dakota.

APPENDIX IX – Threatened and Endangered Species Data

RARE, THREATENED OR ENDANGERED SPECIES DOCUMENTED IN THE GRAND RIVER WATERSHED, SOUTH DAKOTA

SOUTH DAKOTA NATURAL HERITAGE DATABASE
SOUTH DAKOTA DEPT. OF GAME, FISH AND PARKS

DECEMBER 29, 2000

```
NAME                            TOWNSHIP         LAST          FEDERAL   STATE
STATE        GLOBAL   EODATA
                                RANGE & SECTION  OBSERVED      STATUS    STATUS
RANK         RANK

FERRUGINOUS HAWK                019N006E         1976-77
S4B,SZN      G4       ACTIVE FERRUGINOUS HAWK
  BUTEO REGALIS                    32
NEST 1976-1977.
FERRUGINOUS HAWK                019N006E         1976-77
S4B,SZN      G4       ACTIVE FERRUGINOUS HAWK
  BUTEO REGALIS                    28
NEST 1976-1977.
FERRUGINOUS HAWK                018N005E         1976-77
S4B,SZN      G4       ACTIVE FERRUGINOUS HAWK
  BUTEO REGALIS                    03
NEST 1976-1977.
FERRUGINOUS HAWK                019N006E         1976-77
S4B,SZN      G4       ACTIVE FERRUGINOUS HAWK
  BUTEO REGALIS                    27
NEST 1976-1977.
FERRUGINOUS HAWK                018N004E         1976-77
S4B,SZN      G4       ACTIVE FERRUGINOUS HAWK
  BUTEO REGALIS                    30
NEST 1976-1977.
FERRUGINOUS HAWK                019N005E         1976-77
S4B,SZN      G4       ACTIVE FERRUGINOUS HAWK
  BUTEO REGALIS                    12
NEST 1976-1977.
FERRUGINOUS HAWK                018N003E         1976-77
S4B,SZN      G4       ACTIVE FERRUGINOUS HAWK
  BUTEO REGALIS                    10
NEST 1976-1977.
FERRUGINOUS HAWK                018N005E         1976-77
S4B,SZN      G4       ACTIVE FERRUGINOUS HAWK
  BUTEO REGALIS                    06
NEST 1976-1977.
FERRUGINOUS HAWK                020N007E         1976-77
S4B,SZN      G4       ACTIVE FERRUGINOUS HAWK
  BUTEO REGALIS                    27
NEST 1976-1977.
WHOOPING CRANE                  021N015E         1970-10-23    LE        SE
SZN          G1       1 INDIVIDUAL OBSERVED 23
  GRUS AMERICANA
OCTOBER 1970.
BREWER'S SPARROW                019N005E         1973-06-17
S2B,SZN      G5       ADULT FEEDING YOUNG
```

```
  SPIZELLA BREWERI
OBSERVED BY SPRINGER.
BAIRD'S SPARROW               022N005E         1968-06-09
S2B,SZN      G4       ONE SINGING MALE OBSERVED
  AMMODRAMUS BAIRDII
BY BAYLOR AND ROSINE.
STURGEON CHUB                 020N028E         1952-08-24   C        ST
S2           G2       SAMPLE COLLECTED 24 AUG
  MACRHYBOPSIS GELIDA            26
1952 BY ALLUM, BAILEY,

AND HARRIS.
BLACK-FOOTED FERRET           018N030E                      LE       SE
S1           G1       ONE INDIVIDUAL OBSERVED
  MUSTELA NIGRIPES               20
IN PRAIRIE DOG TOWN IN

SUMMER OF 1958 BY RALPH

BLOCK.
LYNX                          021N024E         1925-10-06   LT
SA           G5       MALE LYNX OBTAINED BY
  LYNX CANADENSIS                24
J.N.MARTIN 6 OCT. 1925.
FALSE MAP TURTLE              019N029E         1991-04-18            ST
S3           G5       6" DIAMETER
  GRAPTEMYS PSEUDOGEOGRAPHICA    23
SHORT-HORNED LIZARD           019N005E         1967-07-13
S2           G5       SPECIMEN COLLECTED
  PHRYNOSOMA HERNANDESI          7
SMOOTH GOOSEFOOT              018N005E         1994-07-08
SU           G3G4     FORTY-SEVEN PLANTS
  CHENOPODIUM SUBGLABRUM         03
COUNTED IN MOSTLY BARE

SAND OF BLOWOUT, WITH

RUMEX VENOSUS, PSORALEA

LANCEOLATA, AND AMBROSIA.

WIDE RANGE OF STATURE,

INCLUDING BOBUST,

MULTI-BRANCHED PLANTS.
YELLOW EVENING PRIMROSE       019N005E         1910-08-17
SU           G5       "COMMON ON SANDY
  OENOTHERA FLAVA
FLOODPLAIN....RARE IN

BADLANDS."
DAKOTA BUCKWHEAT              020N015E         1986-08-30
S3           G3       SEVERAL HUNDRED PLANTS
  ERIOGONUM VISHERI              26
OBSERVED AS LOCALIZED
```

COLONIES ON HELL CREEK

FORMATION.
DAKOTA BUCKWHEAT 020N019E 1986-08-30
S3 G3 SEVERAL DOZEN PLANTS
ERIOGONUM VISHERI 32
OCCURRING ON MOSTLY

BARREN SLOPES AND BENCHES

OF HELL CREEK FORMATION.
DAKOTA BUCKWHEAT 021N015E 1986-08-30
S3 G3 SEVERAL HUNDRED PLANTS
ERIOGONUM VISHERI 36
OBSERVED IN EACH AREA ON

BARREN HELL CREEK

FORMATION SLOPES, MOUNDS

AND OUTWASH. A LARGE AREA

HAS BEEN SEARCHED BUT

ONLY 3 LOCALITIES HAVE

BEEN FOUND IN THIS

VICINITY. SEE FIELD

NOTES.

NAME			TOWNSHIP	LAST	FEDERAL	STATE
STATE	GLOBAL	EODATA	RANGE & SECTION	OBSERVED	STATUS	STATUS
RANK	RANK					

DAKOTA BUCKWHEAT 021N016E 1971-07-17
S3 G3 ABUNDANT IN DRY GRAVELLY
ERIOGONUM VISHERI 17
CLAY SOIL. SEVERAL

PRECISELY LOC- ATED

COLONIES ARE KNOWN IN

THIS GENERAL VICINITY.
DAKOTA BUCKWHEAT 021N016E 1986-08-28
S3 G3 >10,000 PLANTS OBSERVED
ERIOGONUM VISHERI 33
AS LOCALIZED COLONIES ON

MOSTLY BARREN SLOPES AND

```
OUTWASH.
DAKOTA BUCKWHEAT               020N016E         1986-08-28
S3           G3      >>10,000 PLANTS OBSERVED
  ERIOGONUM VISHERI               15
AS LOCALIZED COLONIES ON

MOSTLY BARREN SLOPES AND

OUTWASH.
DAKOTA BUCKWHEAT               020N017E         1986-08-30
S3           G3       SEVERAL THOUUSAND PLANTS
  ERIOGONUM VISHERI               19
AS WIDELY SCATTERED

LOCALIZED COLONIES ON

SLOPES AND OUTWASH WITH

DISTICHLIS, ARTEMISIA

FRIGIDAGUTIERREZIA, AND

ATRIPLEX ARGENTEA IN

80-90% BARE CLAY SOIL

WITH LIMONITE COBBLES.
DAKOTA BUCKWHEAT               020N017E         1986-08-28
S3           G3       SEVERAL THOUSAND PLANTS
  ERIOGONUM VISHERI               08
AS WIDELY SCATTERED

LOCALIZED COLONIES ON

MOSTLY BARREN SHALE

SLOPES AND OUTWASH.
DAKOTA BUCKWHEAT               020N018E         1983-08-17
S3           G3       FAIRLY ABUNDANT ON
  ERIOGONUM VISHERI               32
SHALE-CLAY SHELVES AND

SLOPES AMONG LIMONITE

ROCKS AND COBBLES.

OCCURRING WITH

GUTIERREZIA SAROTHRAE AND

MACHAERANTHERA CANESCENS.
```

APPENDIX X – Benthic Macroinvertebrate Data

APPENDIX XI