# PHASE 1 ENVIRONMENTAL ASSESSMENT
# OF THE WHITE RIVER WATERSHED
# WHITE RIVER, SOUTH DAKOTA

Topical Report RSI-1820

*prepared for*

South Dakota Department of Environment
and Natural Resources
523 East Capitol Avenue
Pierre, South Dakota 57501

September 2007

SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

RESPEC CONSULTING & SERVICES

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# EXECUTIVE SUMMARY

| | |
|---|---|
| **Project Title:** White River Watershed Assessment Project | |
| **Project Start Date:** October 1, 2003 | **Project Completion Date:** December 31, 2004 |
| **Funding:** | **Total Budget:** $ 80,000 |
| **Total EPA Budget:** | $ 48,000 |
| **Total Expenditures of EPA Funds:** | $ 48,000 |
| **Total Section 319 Match Accrued:** | $ 32,000 |
| **Budget Revisions:** | No Revisions |
| **Total Expenditures:** | $ 80,000 |

## SUMMARY OF ACCOMPLISHMENTS

The White River is the second largest western tributary to the Missouri River in South Dakota [Fryda, 2001]. It enters Lake Francis Case, a reservoir located in central South Dakota on the Missouri River, just south of Oacoma, South Dakota, and has a contributing drainage area of approximately 9,940 square miles. The largest contributing drainage area of a tributary to the White River is the Little White River, with a drainage area of approximately 1,670 square miles. The White River was listed on South Dakota's 303(d) list of impaired waterbodies for exceedences of water-quality standards for total suspended solids (TSS) and fecal coliform bacteria. The White River flows out of northwestern Nebraska into southwestern South Dakota and follows an easterly route until it discharges into the Missouri River. Shortly after it enters the state of South Dakota, the river flows through Badlands National Park, which is famous for its rugged, steep terrain with little to no vegetation on the easily weathered side slopes.

A geographic information system (GIS) sediment loss model was created using the Revised Universal Soil Loss Equation (RUSLE). This model created a relative magnitude raster image of potential sediment erosion. The results of this analysis were used to identify areas of high potential erosion and sediment loss and to ensure proper distribution of physical habitat sampling locations.

Ten sites were established for assessment of physical habitat and biologic integrity following procedures presented in the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring Assessment Program (EMAP) field operating procedure [U.S. Environmental Protection Agency, 2001a]. These sites ranged in location from Crawford, Nebraska, near the headwaters, to the mouth near Oacoma, South Dakota. An index of biologic integrity (IBI) was created for benthic macroinvertebrates and periphyton samples. A multimetric approach was used for the development of IBIs with seven metrics being used for the benthic IBI and eleven metrics used for the periphyton IBI. Regression analysis was performed between physical habitat assessment data, biological data and historic discharge, and water-quality data to identify relations between channel morphology, riparian vegetation characteristics, biologic integrity, and water quality.

The White River has long been a river of special interest because of the Missouri River Reservoirs and the impact the White River might have on reservoir storage. Historical gage data were available for the White River, dating as far back as 1928 at the station near the mouth of the river, the White River near Oacoma. A statistical analysis of the historic data set was performed to characterize hydrologic conditions in the watershed. The hydrology of the watershed was analyzed at 19 long-term gage stations for stream discharge. Water-quality data were also analyzed at nine stations, with TSS and fecal coliforms being the focus. No new discharge or water-quality data were collected for this project.

The data suggest the White River can be broken down into three distinct reaches: (1) from the headwaters to the confluence of Willow Creek, roughly 5 miles downstream of the gage station near Oglala; (2) from Willow Creek to the confluence of the Little White River; and (3) from the confluence of the Little White River to the mouth of the river near Oacoma, South Dakota. These reaches are shown in Figure ES-1. Reach 2 in and around Badlands National Park, was identified as the transitional and critical reach by all methods of analysis. In this reach, the river receives a large percentage of its TSS and fecal coliform load. The physical habitat and river morphology change considerably with biologic integrity degrading. The confluence of the Little White River also represents a second change in the White River. The measured physical habitat changed slightly, mainly regarding riparian vegetation. Also, the fecal coliform concentrations are less below this location while the general hydrology of the river changes slightly.

Because of the large natural background of TSS in this system, the TSS standard of 158 milligrams per liter (mg/l) is not attainable. Best management practices (BMPs) will only reduce the TSS loading a minimal percent. BMPs for fecal coliforms can be implemented to attain the water-quality standard of 2,000 colony-forming units per 100 milliliters (cfu/100 ml). Suggested BMPs for fecal coliform reduction, such as a grazing management system, off-site water, and riparian vegetation stabilization, will also have the potential to reduce the TSS loading.

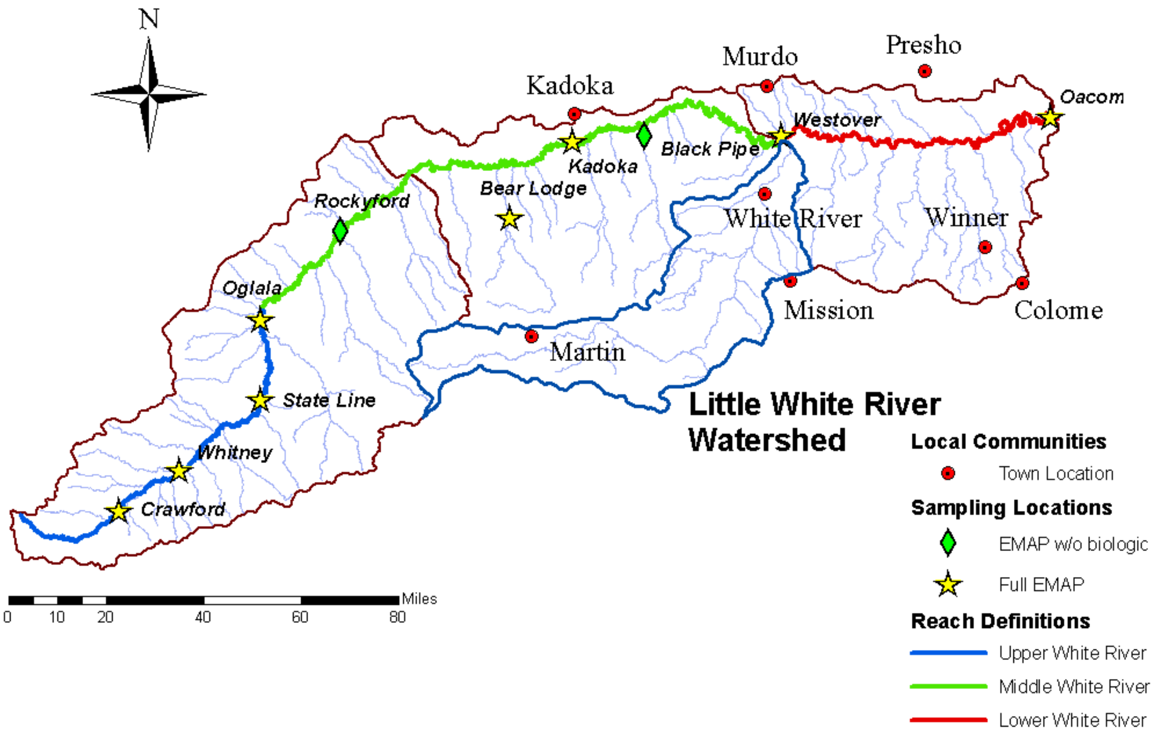


**Figure ES-1.** Reach Definitions.

## ACKNOWLEDGEMENTS

Cooperation and input from the following organizations and people are greatly appreciated. Without their support, this project would have been difficult to complete.

- South Dakota Department of Environment and Natural Resources

  —Bob Smith

  —Gene Stueven

- South Dakota School of Mines and Technology

  —Dr. Scott Kenner

  —Dr. Thomas Fontaine

- United States Geological Survey

  —Joyce Williamson

- Mellette County Conservation District

  —Kara Krogman

- Badlands Resource, Conservation and Development (RC&D)

  —Geri Livermont

  —Gayle Kocer
- South-Central RC&D

  —Theresa Benda
- Bureau of Indian Affairs

  —Paul Hoffman
- Counties of and cities within the White River Watershed.

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# 1.0 INTRODUCTION

The White River discharges into Lake Francis Case on the Missouri River. The watershed is approximately 9,940 square miles and is located in southwest South Dakota with its headwaters originating in northwest Nebraska. It is identified as Hydrologic Unit Code 101402 (10140201, 1040202, 10140203, and 10140204). The White River Watershed starts in the Nebraska counties of Sioux, Dawes, Sheridan, and a small portion of Cherry and flows into South Dakota counties of Fall River, Shannon, Bennett, Jackson, Todd, Mellette, Jones, Lyman, and Tripp. A small portion of the watershed is in Pennington County (Figure 1-1). Portions of Pine Ridge and Rosebud Reservations are within the watershed as well as Buffalo Gap National Grassland and Badlands National Park.

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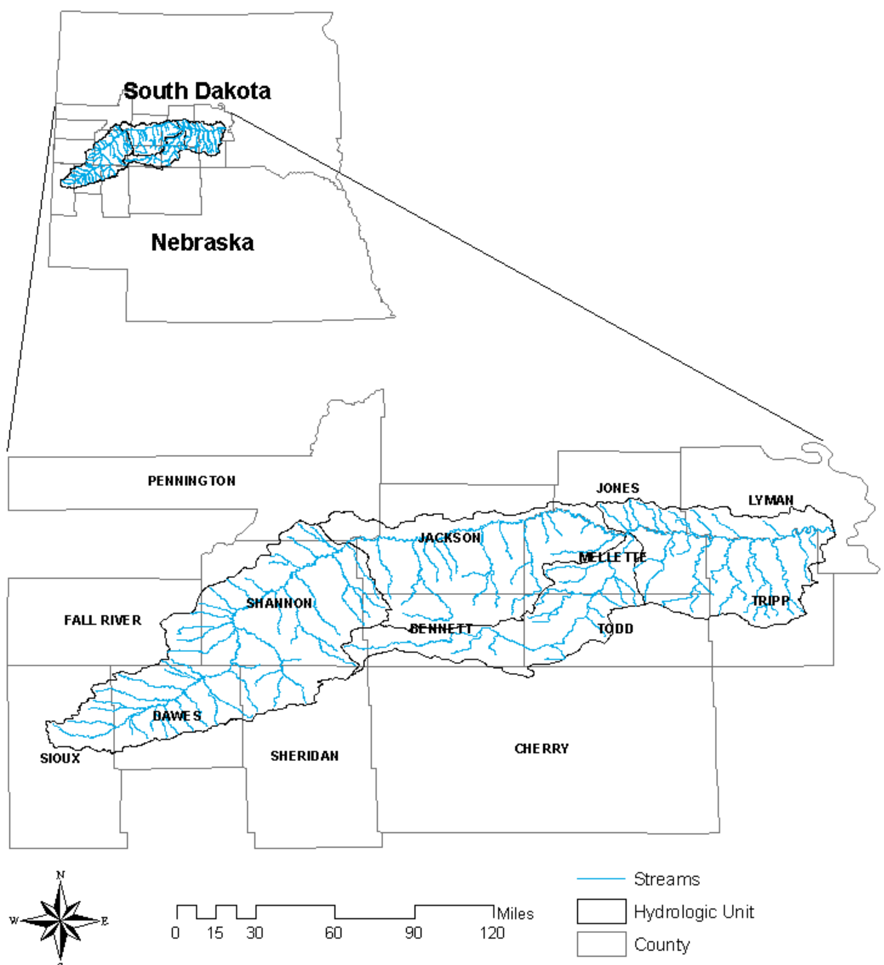


**Figure 1-1.** White River Watershed Location in South Dakota and Nebraska.

The White River Watershed is within the Northwestern Great Plains ecoregion. More specifically, the most significant Level IV ecoregions are Keya Paha Tablelands and Subhumid Pierre Shale Plains. Less significant ecoregions are River Breaks and White River Badlands. The Keya Paha Tableland's physiography is unglaciated, level to rolling plains. Elevations range from 2,200 to 3,600 feet. Soils are Anselmo, Kadoka, Keith, Manter, Rosebud, Epping, Keota, Ronson, and Vetal. Annual precipitation ranges from 16–20 inches. Land use includes cattle ranching with some dryland farming for alfalfa and winter wheat. The Subhumid Pierre Shale Plains's physiography is also unglaciated, undulating plains, with steep-sided incised streams. Elevations range from 1,700 to 2,800 feet. Soils are Millboro, Lakoma, Opal, Promise, Sansarc, Midway, and Ottumwa. The precipitation ranges from 15–17 inches. Land use includes cattle grazing with some dryland farming for winter wheat, alfalfa, and sorghum [Bryce et al., 1998].

The White River was initially listed on the 1998 South Dakota 303(d) list of impaired waterbodies for exceedences of total suspended solids (TSS) and fecal coliform bacteria. The South Dakota Department of Environment and Natural Resources (SD DENR) is responsible for assessing all impaired waterbodies listed on the 303(d) waterbody list. SD DENR has identified impairments for TSS and fecal coliforms in the White River Watershed from the Nebraska–South Dakota border to the mouth as high priorities for the preparation of a Total Maximum Daily Load (TMDL). The White River is listed in four reach segments in the *2004 South Dakota Integrated Report for Surface Water Quality Assessment* [South Dakota Department of Environment and Natural Resources, 2004]: (1) from the Nebraska border to Interior, South Dakota; (2) from Interior, South Dakota, to the confluence of Black Pipe Creek; (3) from the confluence of Black Pipe Creek to the confluence of Oak Creek; and (4) from the confluence of Oak Creek to the mouth of the river near Oacoma, South Dakota. All four reach segments are listed for impairment due to TSS loading while only the three segments downstream of Interior, South Dakota, are listed for impairment due to fecal coliform bacteria.

The White River has four beneficial uses listed: (1) warm-water, semipermanent fish life propagation; (2) limited contact recreation; (3) fish/wildlife propagation, recreation, and stock waters; and (4) irrigation waters. The criteria for TSS are 90 milligrams per liter (mg/l) for the 30-day average and 158 mg/l daily maximum based on the beneficial use for warm-water, semipermanent fish life propagation. The criteria for fecal coliform bacteria are 1,000 colony-forming units per 100 milliliters (cfu/100 ml) for the 30-day average and 2,000 cfu/100 ml daily maximum. Water-quality standards for fecal coliforms are in effect from May 1 through September 30 each year. The fecal coliform criterion is based on the beneficial use limited contact recreation water. South Dakota listing criteria are that if more than 20 samples have been collected in the last 5 years, no more than 10 percent of the samples may exceed the daily maximum.

This project was intended to be an initial phase of a multiphase watershed restoration project. Historical water-quality data analysis, stream discharge data analysis, and habitat assessment were used to identify sources of impairment. Feasible recommendations for watershed restoration are presented in this final report.

# 2.0 PROJECT GOALS, OBJECTIVES, AND TASKS

## 2.1 GOALS

The goals of the White River Watershed Phase I TMDL assessment are to locate and document major areas of impairment using existing data and to determine the need and scope of additional sampling and analysis. The project process was a phased approach. In Phase I, analysis of existing data was completed along with biological sampling and physical habitat analysis at nine sites. This information was used to support initial guidance for Best Management Practices (BMP) implementation. This Phase I report presents recommendations for additional monitoring and modeling assessment required to further refine the identification of nonpoint source pollution in the watershed and to produce feasible focused restoration recommendations.

Specifically, Phase I evaluated existing data for fecal coliforms and TSS from available historical data. Benthic and periphyton samples were collected and analyzed at nine sites on the White River. This project resulted in summaries of historical data, water-quality statistics, and biologic statistics.

To accomplish the goals of Phase I of the White River Watershed TMDL, the effort was divided into four major objectives. These objectives were:

1. Compile and analyze historical flow data.
2. Compile and analyze historical water-quality data.
3. Identify high potential sediment load contributors outside the riparian zone.
4. Collect and analyze benthic and periphyton data along with stream assessment at the sites.

Figure 2-1 presents a conceptual process flow diagram of the approach to the project. Each objective and subtasks are discussed in more detail in the following paragraphs.

## 2.2 OBJECTIVES AND TASKS

### *OBJECTIVE 1: Compile and Analyze Historical Flow Data*

Flow records for this watershed date back to 1928. Most of the United States Geological Survey (USGS) gage stations started collecting flow information before 1945 with a few new stations initiated in 1980. The objective was to compile this data and develop statistical relationships between stations for the years of available record.

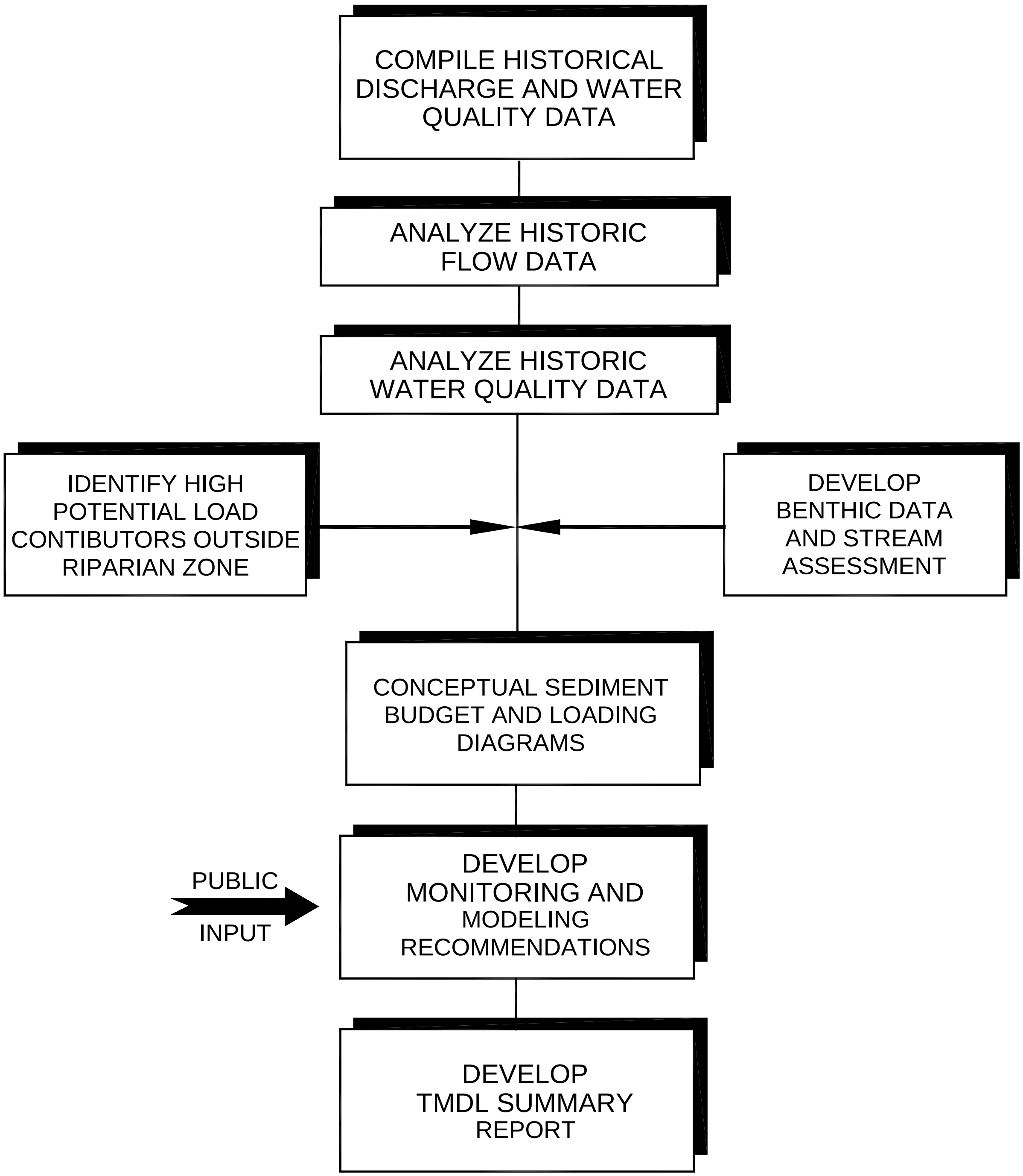


**Figure 2-1.** Schematic Diagram of the White River Phase I Total Maximum Daily Load Assessment Project.

**Task 1 Retrieve and Develop Hydrologic Budget for the White River Watershed**

There were numerous long-term and temporary USGS flow gage stations within the watershed. Table 2-1 lists the USGS sites, containing at least 10 years of data. The data from these stations were compiled and evaluated using various statistical methods to determine seasonality and to characterize the annual hydrograph. Seasonality was determined by evaluating monthly flow data and by examining statistical differences using nonparametric techniques such as Kruskal-Wallis. The annual hydrograph identified the major contributors.

Products: Annual runoff hydrograph characteristics.

**Table 2-1. USGS Stations Within the White River Watershed**

| USGS Station Number | Name | Hydraulic Unit |
|---|---|---|
| 06445685 | White River near Nebraska-South Dakota State Line | 10140201 |
| 06446000 | White River near Oglala | 10140201 |
| 06446700 | Bear in the Lodge Creek near Wanblee | 10140202 |
| 06447000 | White River near Kadoka | 10140202 |
| 06447230 | Black Pipe Creek near Belvidere | 10140202 |
| 06447500 | Little White River near Martin | 10140203 |
| 06448000 | Lake Creek above Refuge, near Tuthill | 10140203 |
| 06449000 | Little Creek below Refuge, near Tuthill | 10140203 |
| 06449100 | Little White River near Vetal | 10140203 |
| 06449500 | Little White River near Rosebud | 10140203 |
| 06450500 | Little White River below White River | 10140203 |
| 06452000 | White River near Oacoma | 10140204 |

**Task 2 Develop Statistical Flow Relationships Between Stations**

Flow records at the long-term stations and temporary stations were analyzed using regression techniques to develop the flow relationships between stations. This relationship was critical to understanding the water-quality data when flows were not measured (the majority of the historic SD DENR data do not have associated flows). Using this information, flow values could be estimated for the dates at temporary stations when chemical data were collected and flow data were not.

Products: Estimated flow for water-quality samples taken without flow data.

### *OBJECTIVE 2: Compile and Analyze Historical Water-Quality Data*

Water samples have been collected and analyzed by many organizations in the past. SD DENR, USGS, and Nebraska Department of Environmental Quality (NE DEQ) have collected water-quality samples. USGS has been collecting daily TSS samples during different time periods for over 20 years at USGS 06452000, White River near Oacoma, South Dakota. This data source provides a foundation to compare other "grab sample type" water-quality results within the watershed and to look for relationships that further the understanding of nonpoint source pollution and potential remediation measures.

#### Task 3 Retrieve TSS Data for the White River Watershed

Available data were compiled from the Internet and by contacting the appropriate responsible agencies. A great historical record of TSS was used to develop statistical comparisons of precipitation and flow with other water-quality monitoring stations similar to the analysis described in Task 1.

Products: Electronic file of TSS data for the White River Watershed.

#### Task 4 Develop Statistical Comparisons for TSS at the Oacoma Site

Statistical comparisons were developed at the Oacoma site for TSS versus seasonality, precipitation, and flow. Flow, concentration, and load diagrams were developed for the period of record and annual trends were investigated. To develop the relationship of flow and concentration, **FLUX**, a computer program developed by U.S. Army Corps of Engineers (USACE), was used [Walker, 1999]. **FLUX** was designed for use in estimating the loadings of suspended solids or other water-quality components passing a tributary sampling station over a given period of time. A relationship of flow and concentration was developed using the available data. This relationship was then used to extrapolate concentration as a function of flow, using the long-term daily flow records for the USGS stations. Finally, a loading estimate was developed by multiplying the monthly flow and concentration averages for the USGS stations, resulting in a tons/month estimate. Seasonality and precipitation relationships to suspended solids were evaluated using a regression analysis. The data analyses at this site were a cornerstone for similar analyses using the data from other sites. It was expected that there would be seasonality in flow data as well as a good relationship between flow and TSS. The relationship between TSS and precipitation were evaluated to determine the contribution of surface runoff to TSS.

Products: Flow, TSS concentration, and TSS loading diagrams for the Oacoma site.

**Task 5 Develop Statistical Comparison for TSS at Other Water-Quality Monitoring Stations and USGS Gage Sites Within the White River Watershed**

Statistical comparisons were developed at water-quality monitoring (WQM) stations for TSS versus seasonality, precipitation, and flow similar to the approach described for Task 4. A summary of the active water-quality monitoring stations managed by SD DENR is presented in Table 2-2. Additional historic data for other stations were available from SD DENR.

**Table 2-2. Water-Quality Monitoring Stations Within the White River Watershed**

| SD DENR Station Number | Name | Hydrologic Unit |
|---|---|---|
| WQM 11 | White River near Kadoka | 10140202 |
| WQM 12 | White River near Oacoma | 10140204 |
| WQM 13 | Little White River near White River | 10140203 |
| WQM 42 | White River near Oglala | 10140201 |
| WQM 152 | White River at Highway 83 Crossing | 10140202 |

Products: Flow, TSS concentration, and TSS loading diagrams for the WQMs other than the Oacoma site.

**Task 6 Develop TSS Concentration Comparison by Location for the White River**

Using logic similar to that described for the Oacoma site, flow, concentration, and load diagrams were developed for the period of record for the USGS gage stations and water-quality monitoring stations where sufficient data existed. A combination of **FLUX** and regression analysis was used to investigate these relationships.

Products: Flow, TSS concentration, and TSS loading diagrams for the Oacoma site.

**Task 7 Develop Conceptual Sediment Budget for the White River**

Based on the analysis and literature from similar studies, a qualitative conceptual sediment budget diagram was prepared. The diagram presented potential sources of sediment and relative contributions to the system.

Products: Conceptual sediment budget for the White River Watershed.

**Task 8 Compile Fecal Coliform Data for the White River**

Water-quality data from SD DENR and USGS were compiled for fecal coliforms.

Products: Electronic file of fecal coliform data for the White River Watershed.

**Task 9 Develop Statistical Comparison for Fecal Coliforms at the USGS Gage Sites and SD DENR Water-Quality Monitoring Stations Within the White River Watershed**

Statistical comparisons were developed at sites for fecal coliforms versus TSS, seasonality, precipitation, and flow. Recent literature in this area documented cases where there is a strong relationship between TSS and fecal coliforms. Stepwise regression analysis was preformed using the water-quality data to investigate a relationship between TSS, fecal coliforms, and other water-quality parameters. Since TSS and fecal coliforms did not have a strong relationship, FLUX was used to investigate the flow concentration relationship with fecal coliforms.

Products: Written results and interpretation of statistical comparisons.

**Task 10 Develop Fecal Coliforms Concentration Comparisons by Location for the White River**

Flow, concentration, and load diagrams were developed for the period of record for the USGS gage stations and water-quality monitoring stations where sufficient data exist (similar to those described in Task 5). A combination of FLUX and regression analysis was used to investigate these relationships.

Products: Flow, concentration, and load diagrams for fecal coliforms.

***OBJECTIVE 3: Identify High Potential Sediment Load Contributors Outside the Riparian Zone***

Using existing geographic information system (GIS) coverage of soil erodibility (U.S. Department of Agriculture- (USDA-) NRCS State Soil and Geographic Database (STATSGO)), elevation, and land use, areas of high potential soil erosion outside of the riparian zone were identified.

**Task 11 Develop a Rating Map for the White River Watershed for the Relative Potential to Contribute Surface Soils to the Stream System as TSS**

The Revised Universal Soil Loss Equation (RUSLE) was used to create a raster image map with each pixel representing a ranking of the soil erosion potential. Soil erodibility, land use, and the length of slope were all used for the calculation.

Products: Map of high potential surface erosion areas.

***OBJECTIVE 4: Collect and Analyze Benthic and Periphyton Data Along With Stream Assessment at the Sites***

Biologic indicators can be used to indicate longer-term quality of a waterbody. Some of the advantages of biologic monitoring are the following:

- Biological communities reflect overall ecological integrity. Thus biosurvey results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act [U.S. Environmental Protection Agency, 2001a].
- Biological communities integrate the effects of different stressors and, thus, provide a broad measure of their aggregate impact.
- The status of biological communities is of direct interest to the public as a measure of a pollution-free environment.

Therefore, biological communities may be a better indication of the overall water quality than grab samples that measure the quality of water at the time of sampling.

**Task 12 Benthic and Periphyton Sample Locations**

Nine sample locations for benthics on the White River and major tributaries were selected. Biologic sampling of the Little White River was planned for 2003 under a different study; thus, samples were not collected on the Little White River. The specific location of biological sampling sites took into consideration potential impacted sites within the watershed. Additionally, sample sites were coordinated with water-quality sampling sites, where possible. The locations of the sites were approved by SD DENR before implementation.

Products: Nine sample sites approved by SD DENR.

**Task 13 Collect Benthic and Periphyton Samples**

One reach composite benthic macroinvertebrate sample was collected at each of the nine sites. The sampling technique was consistent with methods identified in the *Standard Operating Procedures for Field Samplers, Tributary and In-Lake Sampling Techniques* [South Dakota Department of Environment and Natural Resources, 2003]. Table 2-3 identifies the section within the procedure to follow.

Products: Nine composite samples and one quality assurance/quality control (QA/QC) sample sent to the laboratory.

**Table 2-3. Physical Habitat Assessment Sections**

| Title | Section |
|---|---|
| Benthic Macro Invertebrate Sampling | 6.0 |
| Tributary Periphyton Sampling | 5.0 |
| Physical Habitat Characterization | 9.0 |

**Task 14 Stream Channel Classification**

The stream channel at each of the benthic sites was classified using SD DENR Physical Habitat Characterization. This assessment identified seven general physical habitat attributes important in influencing stream ecology:

- Channel Dimensions
- Channel Gradient
- Channel Substrate Size and Type
- Habitat Complexity and Cover
- Riparian Vegetation Cover and Structure
- Anthropogenic Alterations
- Channel-Riparian Interaction.

Products: Summary data sheets and written interpretation of results.

**Task 15 Benthic and Periphyton Analysis**

Benthic samples were sent to an independent laboratory for taxonomic identification to the genus level (including Chironomidae and Oligochaeta).

Periphyton taxonomic identification was enumerated from diatoms to species. The determination of periphyton and dry ash weight was also conducted.

Products: Laboratory report.

**Task 16 Taxometric Analysis**

The taxonomic data were reported and simple metrics of biological indices were calculated, including abundance, taxonomic diversity, family biotic index, and EPT/C ratio. Relative impairment was evaluated using Kruskal-Wallis tests for each of the indices to create an index of biotic intergrity (IBI) score. In addition, multiple regression analyses were performed to determine if a relationship exists between the biological indices and TSS and fecal coliforms.

Products: Results of analysis and written summary interpreting the results.

## 2.3 PLANNED AND ACTUAL MILESTONES, PRODUCTS, AND COMPLETION DATES

The White River Watershed assessment began in September 2003. Field work associated with the physical habitat work and biologic assessment began in October 2003 with the collection of the biologic samples. The physical habitat assessment was completed in March and April 2004. The analysis of the historical discharge and water-quality data did not start in full until May 2004 and was completed in November 2004. A draft version of the report was completed in December 2004. However, based on the findings of this project, additional work related to fecal coliform bacteria was conducted on two subsequent projects. Findings from those two projects related to fecal coliform analysis in this project were added to the final report. The final report for this project was completed in January 2007. The complete schedule of predicted and actual completion dates can be seen in Figure 2-2.

## 2.4 EVALUATION OF GOAL ACHIEVEMENT

The goals of this project, as outlined in Section 2.1, were all met. This project also met one of the goals of the Nonpoint Source (NPS) program by assessing an impaired waterbody on the 303(d) list for South Dakota. Specifically, the White River assessment identified the area between Kadoka and Oglala as a major source of fecal coliforms and TSS loading and impairment. Biological and physical sampling and analysis were completed for eight stations on the White River as well as two tributary stations. From this and the analysis of historical discharge and water-quality data, initial guidance for BMP implementation was provided as well as recommendations for future monitoring and modeling in the White River Watershed. A possible Phase II would address the implementation of these recommendations.

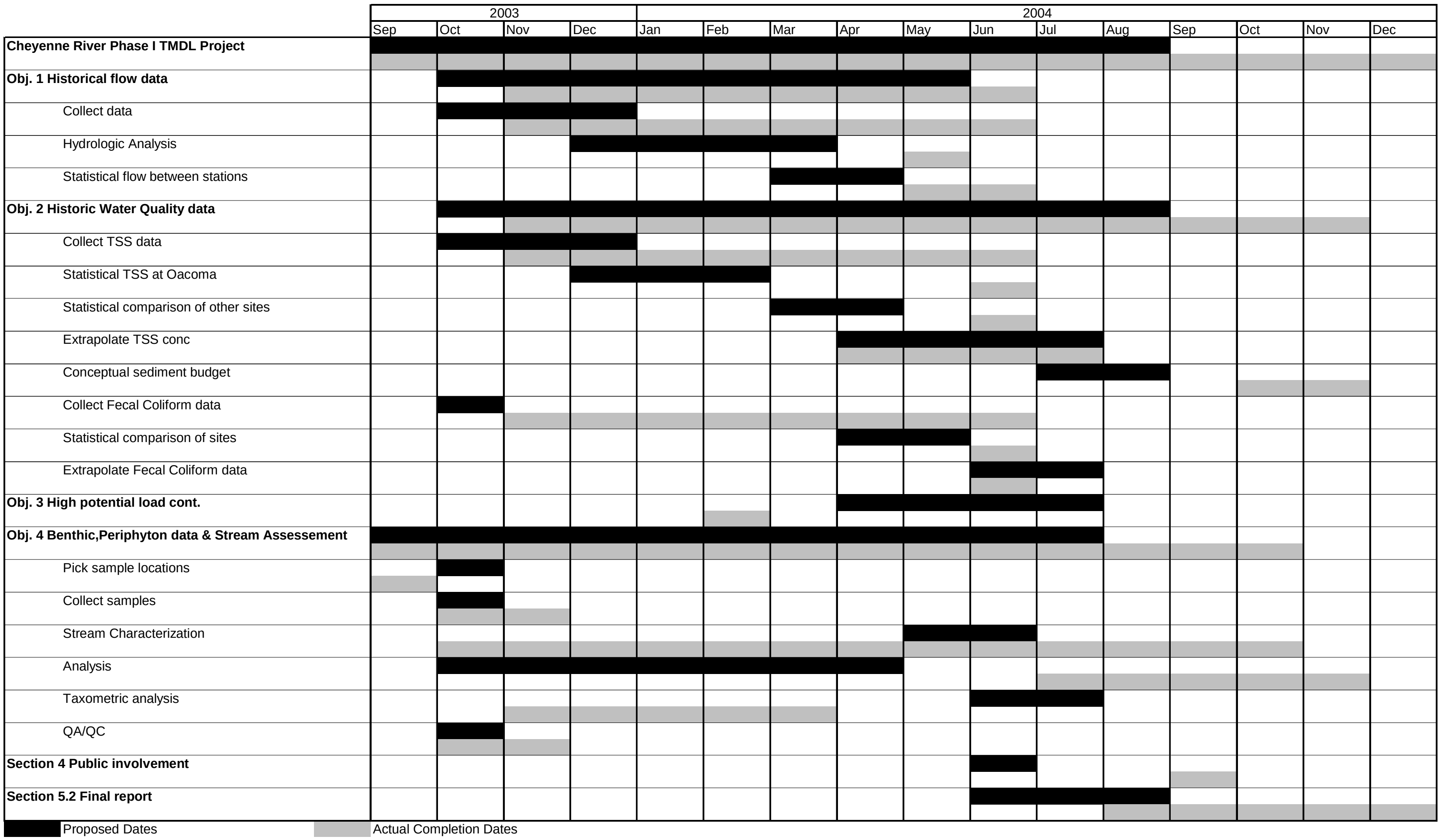


**Figure 2-2.** Proposed and Actual Completion Dates for the White River Watershed Assessment Project.

# 3.0 DATA ANALYSIS, METHODS, AND RESULTS

## 3.1 WATERSHED HYDROLOGY AND WATER QUALITY

### 3.1.1 Precipitation

Precipitation data from 11 locations in and near the White River Watershed were obtained from EarthInfo precipitation data CDs [EarthInfo, Inc., 2003]. Locations of these stations are shown in Figure 3-1. The Fort Robinson and Crawford stations each had a limited period of record that did not overlap with each other. These two stations were less than 5 miles apart and were, therefore, combined into one data set for analysis. The data from all stations were analyzed for annual and monthly averages as well as for seasonality. The average annual precipitation ranged from 15.89 inches at Chadron, Nebraska, to 21.43 inches at Chamberlain, South Dakota, while generally increasing farther north and east into the watershed. The average annual precipitation for each station is listed in Table 3-1. Seasonality was established by performing Kruskal-Wallis Z tests on the monthly data to establish which months were above or below the median precipitation. The results of this work are summarized in Table 3-2; the positive values (wet months) are displayed with no shading and the negative values (dry months) are shaded in gray.

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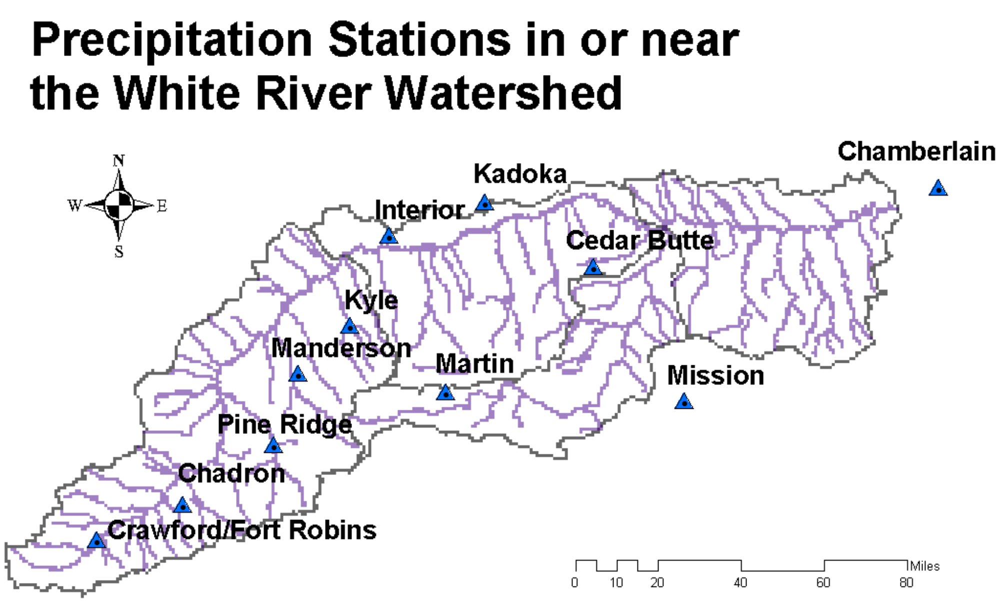


**Figure 3-1.** Locations of Precipitation Gage Stations Used for Analysis.

**Table 3-1. Annual Average Precipitation for Selected Stations in the White River Watershed**

| City | Annual Average Precipitation (inches) | City | Annual Average Precipitation (inches) |
|---|---|---|---|
| Cedar | 18.30 | Kyle | 16.06 |
| Chadron | 16.45 | Manderson | 17.99 |
| Chamberlain | 21.43 | Martin | 17.57 |
| Crawford/Fort | 15.89 | Mission | 19.70 |
| Interior | 18.80 | Rushville | 17.16 |
| Kadoka | 19.13 | | |

The average monthly pattern found throughout the White River Watershed, shown in Figure 3-2, was similar at every station. Each station has a peak monthly average rainfall of nearly 5 inches, which occurs in June. The two stations in Nebraska (Chadron and Crawford/Fort Robinson) had peak monthly values that occurred in May, indicating a slightly earlier wet period than South Dakota. The similarity between the sites indicates that differences in precipitation in the watershed do not have a large impact on water quality.

### 3.1.2 Hydrologic Analysis

The longest period of stream flow record in the White River Watershed is for the gage located at Oacoma, with the period of record beginning in 1928 and operation continuing at the time of this project. The locations of 19 discharge stations throughout the watershed, with a minimum of 5 years of data, are shown in Figure 3-3. The period of record for each station is shown in Figure 3-4 for the White River and Figure 3-5 for the Little White River. The data from these stations were analyzed to gain insight into the hydrology of the White River Watershed and to characterize the annual hydrograph.

Data from each gage station were used to create histograms and monthly box plots to characterize the flow regime. Histograms based on the flow data normalized to the contributing drainage area at each station were also created. Descriptive statistics, including the number of daily values, mean, standard deviation, minimum, maximum, median and inter-quartile range, were calculated for each station on an annual basis as well as by month.

Kruskal Wallis Z values were calculated for each month to determine seasonality of flow at each station. The seasons were used in the **FLUX** modeling of the annual sediment load estimates. Drainage areas above the gage stations were taken from the USGS Internet site [U.S. Geological Survey, 2003].

**Table 3-2. Seasonality Patterns for Rainfall Data in the White River Watershed, With Positive Values Representing Wet Months and Negative Values Representing Dry Months**

| Month | Chamberlain | Kadoka | Interior | Kyle | Manderson | Pine Ridge | Chadron | Crawford/ Fort | Cedar | Mission | Martin |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | –6.28 | –4.04 | –5.91 | –3.65 | –5.37 | –4.1 | –5.29 | –5.5 | –5.73 | –7.25 | –5.39 |
| 2 | –5.38 | –2.33 | –5.29 | –2.48 | –3.06 | –1.83 | –3.71 | –3.37 | –3.61 | -4.27 | –3.02 |
| 3 | –2.61 | –0.38 | –2.04 | –0.67 | –0.82 | 0.05 | –0.83 | –0.66 | –1.66 | –1.9 | –1.55 |
| 4 | 4.53 | 3.86 | 4.28 | 3.96 | 4.72 | 1.98 | 5.08 | 4.03 | 5.3 | 3.7 | 3.72 |
| 5 | 9.35 | 6.07 | 8.25 | 4.89 | 8.83 | 6.31 | 10.56 | 8.77 | 7.96 | 7.85 | 6.47 |
| 6 | 9.11 | 8.4 | 9.75 | 4.99 | 8.6 | 7.17 | 8.68 | 8.22 | 8.31 | 8.84 | 8.6 |
| 7 | 4.03 | 2.72 | 5.09 | 1.75 | 3.04 | 3.15 | 4.58 | 2.97 | 4.35 | 5.21 | 4.05 |
| 8 | 1.18 | 0.32 | 0.66 | 0.04 | –1.07 | –1.44 | –1.46 | –1.21 | 0.36 | 2.63 | 1.57 |
| 9 | –0.26 | –1.59 | –0.69 | –0.14 | –1.91 | –0.14 | –0.38 | 0.06 | –1.04 | 0.25 | –0.86 |
| 10 | –2.53 | –3.55 | –2.7 | –1.53 | –3.38 | –3.15 | –4.71 | –3.37 | –3.16 | –2.84 | –3.24 |
| 11 | –5.36 | –3.86 | –4.93 | –3.4 | –5.19 | –4.24 | –6.64 | –5.08 | –4.69 | –5.73 | –4.98 |
| 12 | –5.81 | –5.14 | –6.86 | –3.62 | –5.16 | –3.48 | –5.9 | –4.88 | –6.23 | –6.57 | –5.53 |

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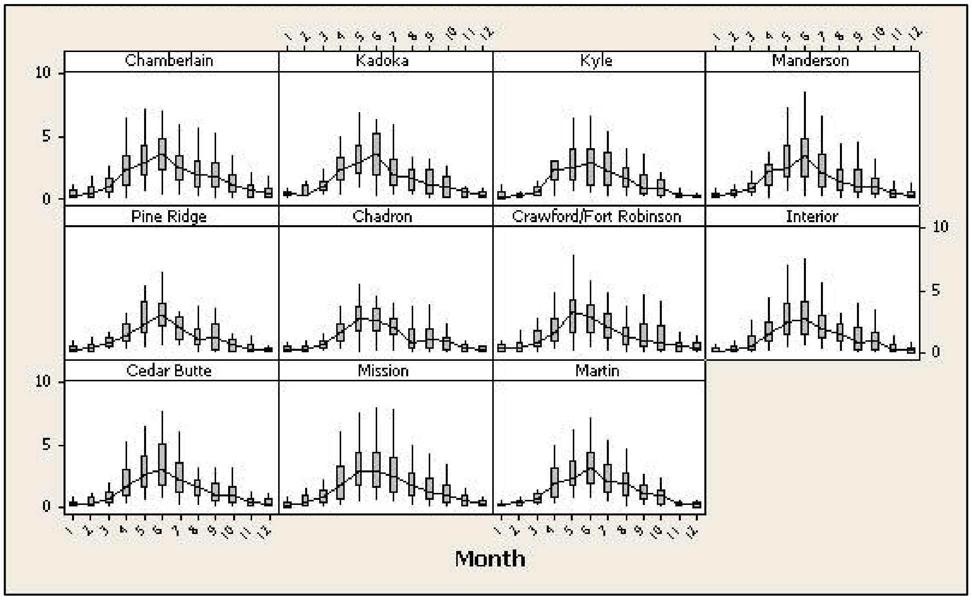


**Figure 3-2.** Box Plot of Monthly Average Precipitation in the White River Watershed for Eleven Stations.

RSI-1465-04-007

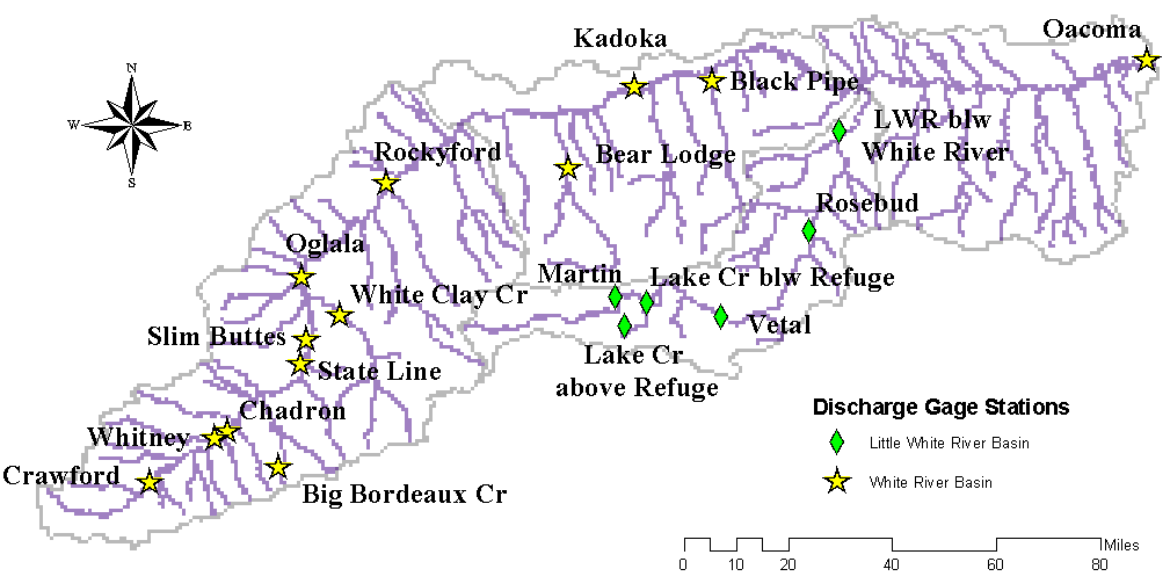


**Figure 3-3.** Discharge Gage Stations in the White River Watershed Used for Hydrologic Analysis.

RSI-1465-04-008

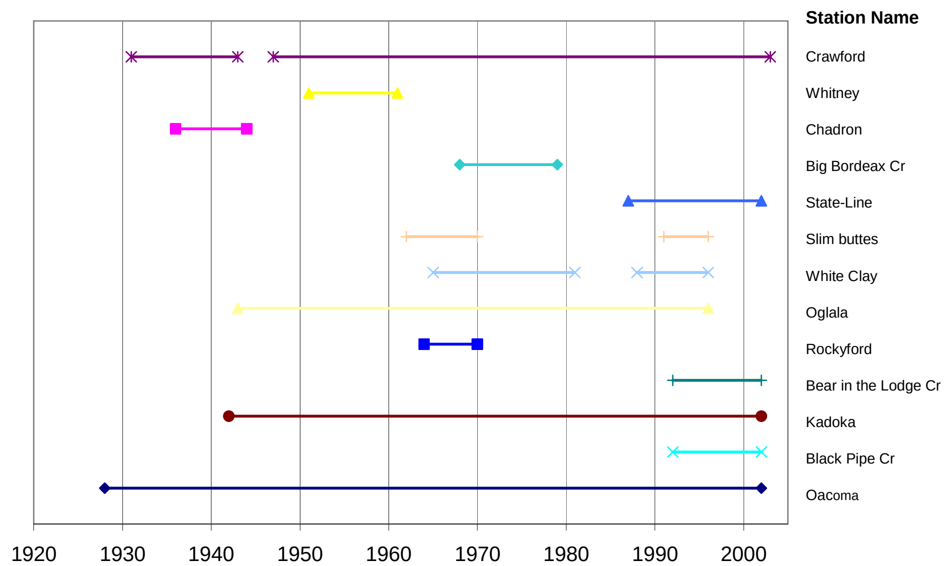


**Figure 3-4.** Period of Record for Gage Stations Located in the White River Watershed.

RSI-1465-04-009

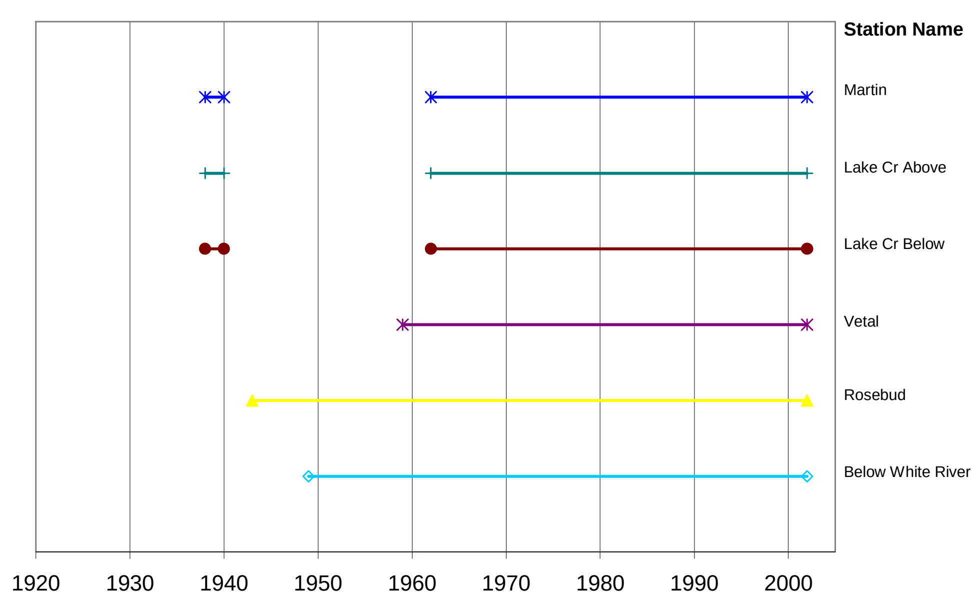


**Figure 3-5.** Period of Record for Gage Stations Located in the Little White River Watershed.

The flow was normalized to the upstream drainage areas and bar charts of the monthly data were created. By normalizing the discharge data, insight was gained into the flow regime as a function of the drainage area. Baseflow-dominated stations have higher normalized values, indicating the presence of larger springs that feed the stream. Conversely, stations dominated by runoff events that have high normalized values indicate lower infiltration rates and, therefore, higher runoff rates. In general, the pattern for the normalized data is decreasing values moving downstream from the Crawford station to Oglala, and then increasing again moving downstream from Oglala to the mouth of the river. The results of this analysis can be seen in graphical and tabular form in Appendix A.

Drainage areas of subbasins and the stream lengths between stations were used for the hydrologic analysis. The watershed and the subbasins were delineated using 30-meter-resolution digital elevation models (DEMs). A stream network shapefile was also created, which contained attributes for the stream lengths for each segment of the river and its tributaries. This procedure was completed using the HEC-GeoHMS extension in ArcView 3.2 following procedures presented in the HEC-GeoHMS user's manual [Hydrologic Engineering Center, 2000].

The largest contributing drainage area of a tributary to the White River is the Little White River with a drainage area of approximately 1,670 square miles. The Little White River drainage contains six of the nineteen long-term gage stations present in the White River Basin.

Of the six gage stations located in the Little White River Watershed, two are located on a major tributary—Lake Creek which feeds Lacreek National Wildlife Refuge upstream of the confluence with the Little White River. Of the remaining 13 stations in the mainstem White River Watershed, only 1 is below the confluence of the Little White River (the White River near Oacoma), and 4 are located on tributaries (Black Pipe Creek near Belvidere, Bear in the Lodge Creek near Wanblee, White Clay Creek near Oglala, and Big Bordeaux Creek near Chadron). All data sets from these stations represent daily mean discharge data for the period of record available.

The pattern shown by the annual flow hydrograph can be grouped into three categories based on the system controls: baseflow dominated, runoff event dominated, or a combination of the two. The hydrologic export coefficient, calculated as the annual volume divided by the drainage area, is a similar parameter to the discharge values normalized to drainage area. These values aid in determining hydrologic controls at each station. For this project, the total hydrologic export coefficient and the incremental hydrologic export coefficient were calculated. The hydrologic data are summarized in Figure 3-6. Hydrology for the White River and the Little White River are summarized in the following section, and a discussion of the pattern found for each type of system follows.

| White River Site Name | Tributary Site Name | Drainage Area (mi$^2$) | Mean Annual Discharge (cfs) | Median Annual Discharge (csf) | Normalized Mean Annual Discharge (csf) | Normalized Median Annual Discharged (csf) | Hydrologic Export Coefficient (acre-ft/acre) | Incremental Hydrologic Export Coefficient (acre-ft/acre) | Peak Mean Month | Peak Median Month | System Control |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Crawford** | | 313 | 20 | 19 | 0.065 | 0.061 | 0.074 | 0.074 | May | March/April | Baseflow |
| **Whitney** | | 676 | 17 | 6.5 | 0.026 | 0.010 | 0.029 | -0.009 | May | May | Combination |
| **Chadron** | | 750 | 25 | 7 | 0.033 | 0.009 | 0.037 | 0.111 | May | April | Event |
| | **Big Bordeaux Cr** | 9.42 | 1 | 0.4 | 0.060 | 0.042 | 0.067 | 0.067 | May | April/May | Baseflow |
| **State Line** | | 1440 | 47 | 18 | 0.033 | 0.013 | 0.037 | 0.037 | May | April | Combination |
| **Slim Buttes** | | 1500 | 44 | 16 | 0.030 | 0.011 | 0.033 | -0.055 | June | June | Event |
| | **White Clay Cr** | 340 | 10 | 7.5 | 0.030 | 0.022 | 0.034 | 0.034 | March | March/April | Baseflow |
| **Oglala** | | 2200 | 53 | 21 | 0.024 | 0.010 | 0.027 | 0.015 | June | March | Event |
| **Rockyford** | | 2904 | 123 | 30 | 0.042 | 0.010 | 0.048 | 0.111 | June | March | Event |
| | **Bear in the Lodge Cr** | 365 | 26 | 15 | 0.071 | 0.041 | 0.081 | 0.081 | June | April | Combination |
| **Kadoka** | | 5000 | 274 | 63 | 0.055 | 0.013 | 0.062 | 0.082 | June | March | Event |
| | **Black Pipe Cr** | 250 | 34 | 6.8 | 0.135 | 0.027 | 0.153 | 0.153 | June | April | Combination |
| **Oacoma** | | 9940 | 580 | 169 | 0.058 | 0.017 | 0.066 | 0.070 | May | March | Event |



| Little White River Site Name | Tributary Site Name | Drainage Area (mi$^2$) | Mean Annual Discharge (cfs) | Median Annual Discharge (csf) | Normalized Mean Annual Discharge (csf) | Normalized Median Annual Discharged (csf) | Hydrologic Export Coefficient (acre-ft/acre) | Incremental Hydrologic Export Coefficient (acre-ft/acre) | Peak Mean Month | Peak Median Month | System Control |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Martin** | | 230 | 22 | 14 | 0.095 | 0.061 | 0.107 | 0.107 | March | March | Baseflow |
| | **Lake Cr Abv** | 23 | 21 | 20 | 0.934 | 0.870 | 1.056 | 1.056 | March | March/April | Baseflow |
| | **Lake Cr Blw** | 60 | 20 | 14 | 0.336 | 0.233 | 0.380 | -0.040 | April | April | Baseflow |
| **Vetal** | | 415 | 60 | 45 | 0.146 | 0.108 | 0.165 | 0.236 | April | April | Baseflow |
| **Rosebud** | | 760 | 118 | 95 | 0.156 | 0.125 | 0.176 | 0.190 | March | April | Baseflow |
| **Below White River** | | 1310 | 141 | 97 | 0.108 | 0.074 | 0.122 | 0.047 | March | April | Baseflow |

**Figure 3-6.** Hydrologic Summary Stream Flow Characteristics for Stations in the White River Watershed.

#### 3.1.2.1 White River Hydrology Summary

The White River Watershed is a mix of baseflow conditions and event-driven conditions. In general, the upper portions of the watershed are most highly affected by baseflow, with the Crawford station and the tributary stations of White Clay Creek and Big Bordeaux Creek being classified as baseflow dominated. Each of the stations below the State-Line is classified as event dominated, with the State-Line being classified as a combination system. These stations are prone to losing flow during dry periods, with zero flows being common. A jump in the incremental hydrologic export coefficient occurs between the Oglala and Rockyford stations. This jump, which corresponds to changes in physical habitat and geology discussed in a later section of this report, indicates a change in infiltration rates. Higher runoff rates occur in this area causing the increase in the export coefficient value.

Negative values for the incremental hydrologic export coefficient indicating loss zones are found at two stations, Whitney and Slim Buttes. A diversion structure for irrigation exists above the Whitney station, which may account for some of the losses. The values for both the Whitney station and the Chadron station may be influenced by a short period of record occurring in different time periods (Figure 3-4). The loss of baseflow influence found at the State-Line station, probably due to evapotranspiration, most likely explains the negative value of the hydrologic export coefficient calculated at Slim Buttes. The effects of evapotranspiration are discussed further in the combination system control section.

#### 3.1.2.2 Little White River Hydrology Summary

In general, the Little White River is typical of a system dominated by spring-fed baseflow. Much of the spring flow in this basin appears to originate in the southern portions of the basin, where the largest tributaries originate. This area is part of the Sand Hills ecoregion [U.S. Environmental Protection Agency, 2001b]. While the farthest downstream station on the Little White River, the Little White River below White River, is still dominated by baseflow, the increase in baseflow between this station and the station near Rosebud is minimal. The median value of discharge at Rosebud is 95 cubic feet per second (cfs) while the median value below White River is 97 cfs. Most of the increases in flow in this reach are due to runoff events. Baseflow additions are offset by losses present in this reach.

One loss zone was identified in the Little White River Watershed, occurring on Lake Creek between the station above Lacreek National Wildlife Refuge and the station below the refuge. Lacreek Wildlife Refuge is a series of small lakes and wetlands located in an area in southern Little White River Watershed near Tuthill, South Dakota. The wildlife refuge represents a loss zone with water being lost to infiltration and evapotranspiration. Lake Creek below the refuge represents 47 percent of the mean discharge and 50 percent of the median flow of the Little White River below the confluence with Lake Creek, assuming no significant additions occur between Lake Creek and the station near Martin, South Dakota.

The Little White River below White River station accounts for 24 percent of the mean flow and 57 percent of the median flow of the station near the mouth of the White River, the White River near Oacoma. In general, the Little White River is a significant addition to the baseflows of the lower White River while the flood events in the White River are more heavily influenced by the White River above the confluence of the Little White River.

#### 3.1.2.3 Baseflow-Dominated Gage Station

The baseflow pattern is recognizable by smooth changes in median values from month to month. Mean and median values tend to be similar in magnitude and follow the same pattern. Generally, the peak values for both the median and mean discharge occur in the spring of the year with the low flow period occurring in late summer, usually September. These stations seldom run dry. This pattern is clear in the data for the station at Lake Creek above the refuge (shown in Figure 3-7). The station on Lake Creek is clearly a stream that is baseflow dominated, having never been dry in the period of record, and contains the highest values of normalized discharge of any of the stations analyzed. This pattern is also clear in the White River Watershed at the Crawford station (shown in Figure 3-8), Big Bordeaux Creek, and White Clay Creek.

#### 3.1.2.4 Event-Dominated Gage Station

The stations dominated by runoff events display a distinctive pattern of high mean discharge values when compared to the median discharge patterns. A distinct bimodal pattern exists in the monthly discharge, usually in both the mean and median values. The first peak occurs in the spring of the year, usually in March, and is a function of snowmelt, while the second peak corresponds to the peak rainfall month, which occurs during the month of June for most of the White River Watershed. Stations dominated by runoff events frequently have periods of record with zero flows. The White River near Kadoka, shown in Figure 3-9, shows the typical pattern found at stations dominated by runoff events.

#### 3.1.2.5 Mix Flow Regime-Dominated Gage Stations

The pattern found at stations where both baseflow and runoff events influence the hydrology are similar to both of the other patterns in certain ways while being distinctly different. The smooth transitions between months are present in the median monthly discharge data, especially for the first half of the year. Median data only contains one peak in the spring of the year, usually in April. The mean monthly discharge values are clearly larger than the median values representing the effects of events. Mean values contain the bimodal pattern with peaks due to snowmelt and rainfall runoff. Zero flows are also common at these stations. This pattern is clear at the State-Line station, as shown in Figure 3-10.

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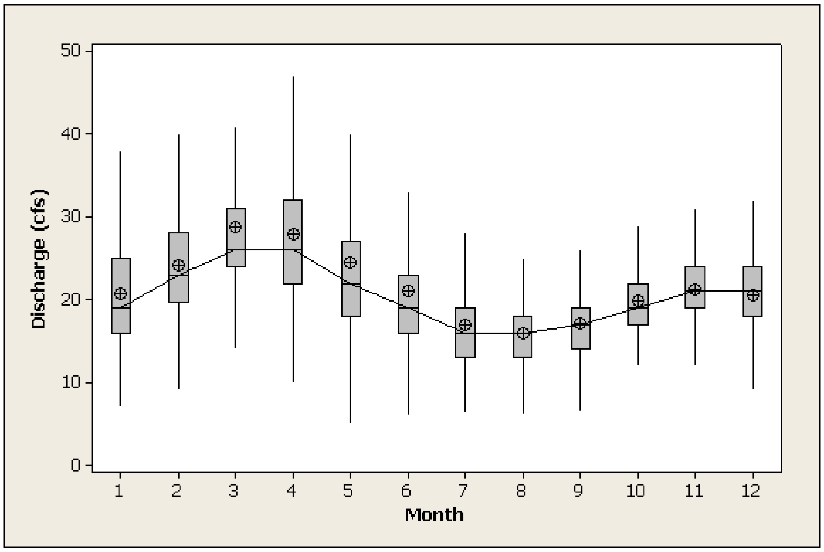


**Figure 3-7.** Box Plot of Monthly Discharge at Lake Creek Above the Refuge Showing the Median Connect Line and Mean Symbols.

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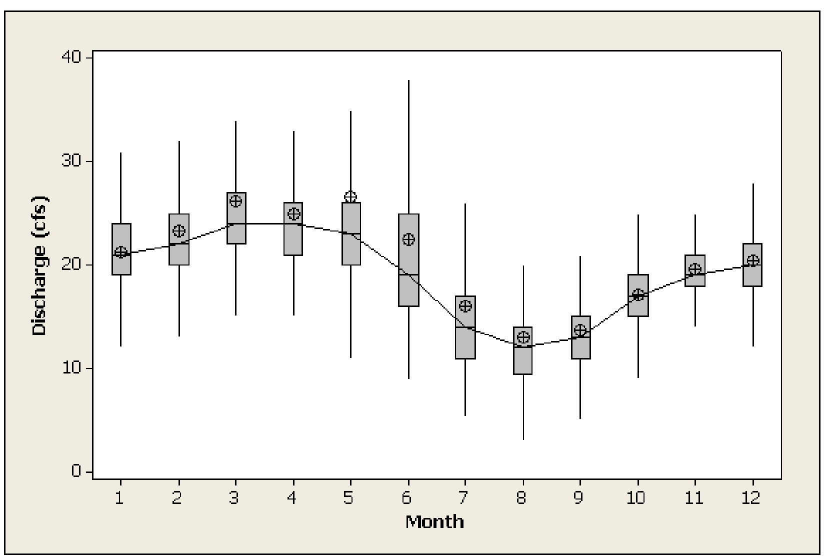


**Figure 3-8.** Box Plot of Monthly Discharge at Crawford Showing the Median Connect Line and Mean Symbols.

RSI-1465-04-013

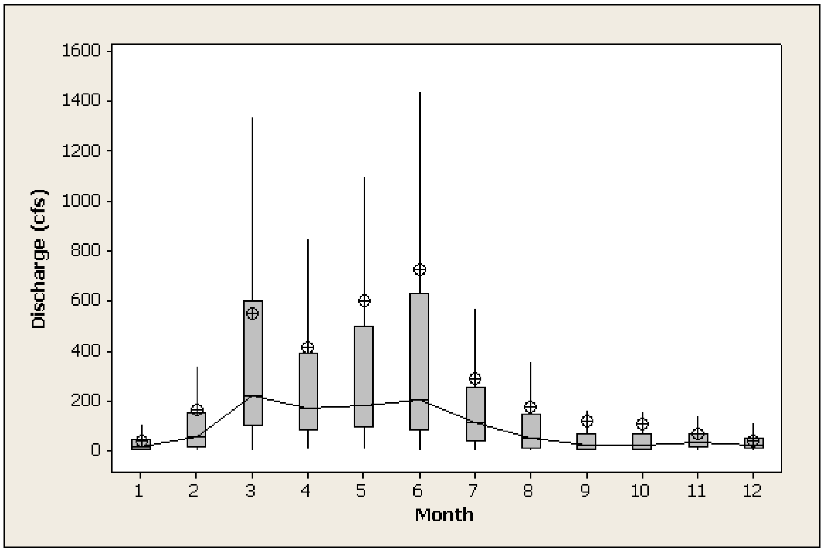


**Figure 3-9.** Box Plot of Monthly Discharge at Kadoka Showing the Median Connect Line and Mean Symbols.

RSI-1465-04-014

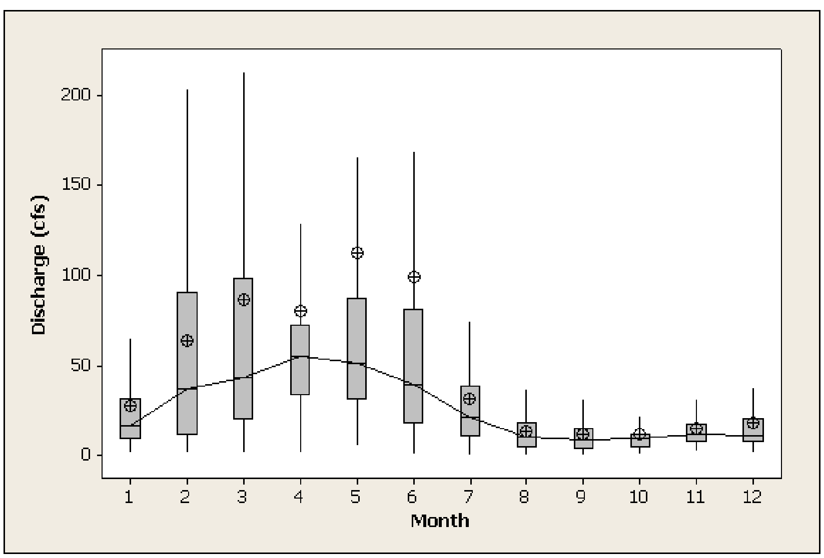


**Figure 3-10.** Box Plot of Monthly Discharge at the State-Line Showing the Median Connect Line and Mean Symbols.

Mixed flow regime stations tend to be affected largely by evapotranspiration, mainly in the later half of the summer when the riparian vegetation has the most foliage. During the spring months, the baseflow component sustains flows in the stream channel. When the riparian vegetation gains its foliage and rainfall totals decline, the potentiometric surface for baseflow is lowered to subsurface levels. This theory was augmented from discussions with local ranchers in the Black Pipe drainage basin and stated at public meetings that Black Pipe Creek is a spring-fed creek that flows with a consistent pattern every year. Local ranchers stated that the creek flows every year usually until the month of July when it tends to dry up. In the fall, flows reappear shortly after the Cottonwoods have dropped their leaves. Good subsurface alluvial flow is claimed to still exist, as many ranchers have wells into the alluvium, but the riparian vegetation lowers the water table to subsurface elevations. The only flows in the stream during the late summer and fall are in response to storm events. The stream is also prone to flood events during spring months, with spring-fed baseflow still dominating. This explanation fits the data very well and appears to be valid. The effects of evapotranspiration are clear in abrupt decline in mean monthly values during the summer months at Black Pipe Creek shown in Figure 3-11.

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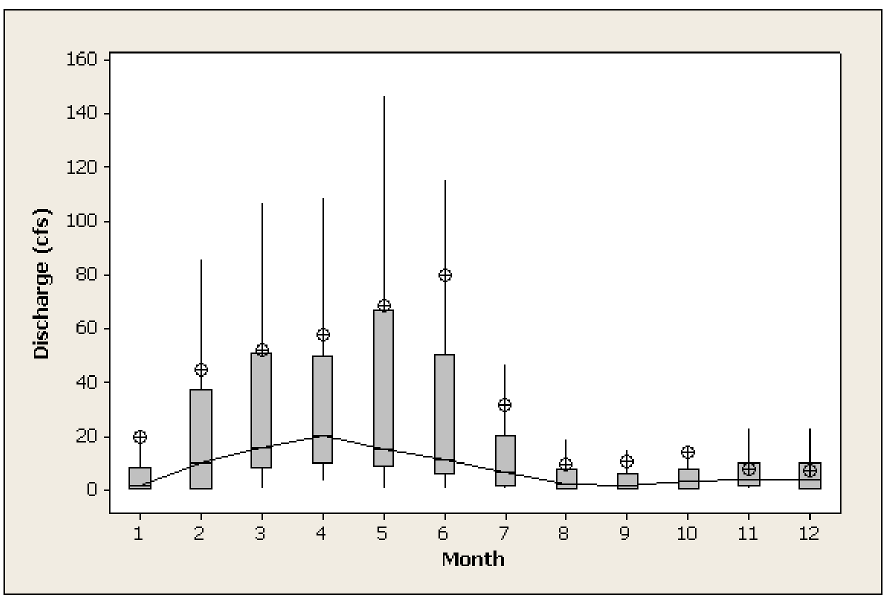


**Figure 3-11.** Box Plot of Monthly Discharge on Black Pipe Creek Showing the Median Connect Line and Mean Symbols.

### 3.1.3 Water-Quality Analysis

Water-quality data were available for nine gage stations and were summarized for general conditions present in the watershed: Crawford, Whitney, Chadron NW, Chadron, Bordeaux Creek, Oglala, Kadoka, Little White River below White River, and Oacoma. Water-quality data from these stations were downloaded from the USGS water resources Web site and the U.S. Environmental Protection Agency (EPA) Storet site, which manages much of the SD DENR water-quality data. The water-quality variables of concern were TSS, suspended sediment (SS), turbidity, fecal coliforms, specific conductivity, and dissolved oxygen. Of nine stations, only Oacoma contained all of the parameters listed above, with turbidity data only available at Oacoma. The data were used to determine annual trends, seasonal characteristics, and to analyze any correlations present between the parameters, including flow. A complete set of the results can be seen in Appendix B.

Regression analysis was performed between the water-quality variables and flow to evaluate the possibility of expanding water-quality data sets to periods of flow record without water-quality data. TSS, fecal coliforms, and dissolved oxygen were regressed versus discharge. TSS was also regressed versus fecal coliforms, specific conductance, SS, and turbidity where data were available. No significant correlations were found between any of the parameters at any of the stations. The best correlation obtained was between SS and TSS at the Oacoma station ($R^2$ = 0.26 percent). The lack of correlation between water quality and discharge indicates that the White River is a complex system with other variables influencing the water quality besides discharge. For example, seasonality may be a key parameter influencing the TSS loading. Differences in vegetation, frozen ground, and rainfall event characteristics, which all change with season, will have a profound effect on runoff and erosion rates, which will in turn, affect TSS loading of the river. Therefore, no data sets were extended with predicted values in the watershed assessment. A complete set of regression graphs with the R-squared values are shown in Appendix B.

Water-quality data for TSS and fecal coliforms were analyzed using six water-quality stations on the White River and one station on the Little White River. Additionally, the available data from a relatively new gage, White River near the town of White River, South Dakota, was analyzed for loading and percent exceedence. The locations of these sites can be seen in Figure 3-12. Of the eight sites analyzed for TSS and fecal coliforms, all but two sites had daily mean flow data available for a time period covering the period of record for the water-quality parameters. The sites labeled Chadron and Chadron NW did not contain any flow data. The period of record for the variables of TSS and fecal coliform bacteria are summarized in Table 3-3.

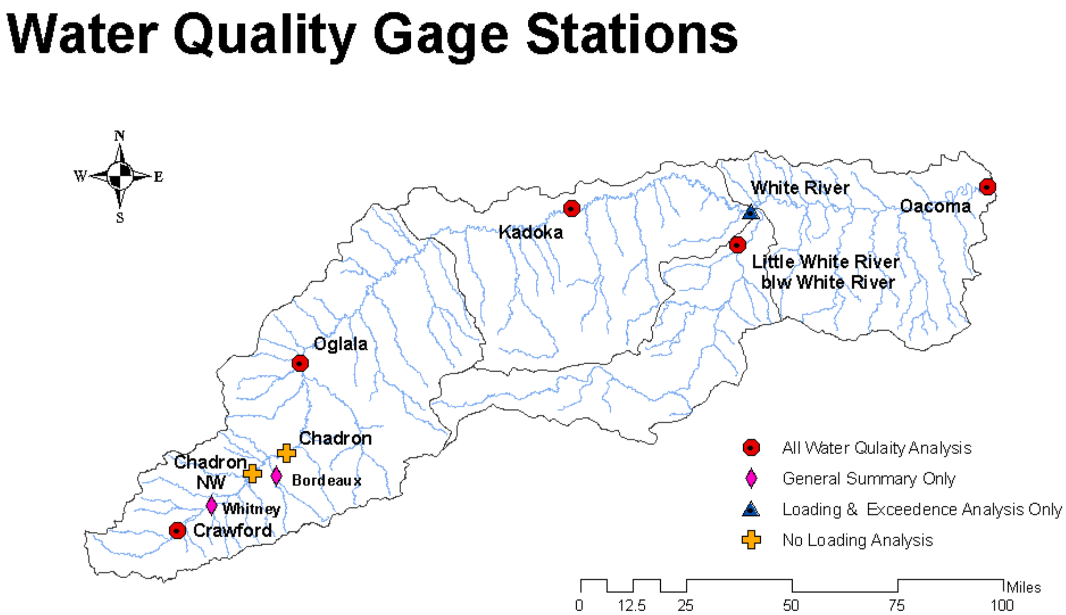


**Figure 3-12.** Water-Quality Gage Station Locations.

**Table 3-3. Summary of Water-Quality Data Available for Analysis**

| | TSS | | | Fecal Coliform Bacteria | | |
|---|---|---|---|---|---|---|
| **Station Name** | **n** | **Start Date** | **End Date** | **n** | **Start Date** | **End Date** |
| Oacoma | 297 | 04/30/1968 | 12/17/2002 | 184 | 03/27/1969 | 09/17/1996 |
| LW blw WR | 316 | 05/22/1968 | 12/17/2002 | 221 | 05/22/1968 | 09/17/1996 |
| WR near White River | 52 | 06/22/1999 | 2/24/2004 | 20 | 06/22/1999 | 08/19/2003 |
| Kadoka | 316 | 05/22/1968 | 12/17/2002 | 183 | 05/22/1968 | 09/17/1996 |
| Oglala | 164 | 07/15/1974 | 10/08/2003 | 119 | 07/15/1974 | 07/16/1996 |
| Chadron | 170 | 03/23/1976 | 4/20/1993 | 171 | 06/05/1973 | 04/20/1993 |
| Chadron NW | 27 | 10/05/1977 | 12/09/1980 | 30 | 06/05/1973 | 12/09/1980 |
| Crawford | 32 | 06/08/1976 | 12/08/1980 | 34 | 06/08/1976 | 12/08/1980 |

#### 3.1.3.1 Exceedence Analysis

The South Dakota water-quality standards may not be exceeded in more than 10 percent of the samples without being in violation of the standard, if more than 20 samples have been collected. The standard for fecal coliform bacteria applies during the months of May through September [South Dakota Department of Environment and Natural Resources, 2004]. Exceedence analysis was performed on the eight water-quality stations to determine (1) the percent of samples in which the standard was exceeded, (2) the concentration level at which only 10 percent of the samples would exceed, and (3) the percent of reduction needed to meet the required water-quality standard for both TSS and fecal coliform bacteria. Ten percent exceedence concentration is where the water-quality standard would need to be for the waterbody to be in compliance based on available data. When the 10 percent exceedence level is less than the current water-quality standard, the data indicate that the waterbody is in compliance. Exceedence analysis was performed on the complete data set for fecal coliforms, including data points collected on all dates and on the partial data set containing data points collected during the months of May through September. The results for the exceedence level analysis are summarized in Table 3-4 for TSS and Tables 3-5 and 3-6 for fecal coliforms.

**Table 3-4. Exceedence Table for TSS Sampling Stations in the White River Basin**

| Station Name | TSS | | | | | |
|---|---|---|---|---|---|---|
| | Percent Exceedence | Q1 | Median | Q3 | 10% Exceedence | Required Reduction |
| Crawford | 14% | 15 | 57 | 109 | 245 | 35% |
| Chadron NW | 23% | 25 | 52 | 150 | 601 | 74% |
| Chadron | 33% | 31 | 98 | 185 | 522 | 70% |
| Oglala | 47% | 42 | 139 | 374 | 1,535 | 90% |
| Kadoka | 78% | 154 | 1,118 | 5,688 | 17,408 | 99% |
| WR near White River | 70% | 87 | 482 | 3,620 | 7,140 | 98% |
| LW blw WR | 59% | 80 | 185 | 384 | 754 | 79% |
| Oacoma | 79% | 216 | 1,075 | 5,400 | 14,517 | 99% |

Note: TSS Standard = 158 mg/l

#### 3.1.3.2 Load Duration Curves

Load duration curves were created following procedures presented by Cleland [2002]. The data for the load duration curves came from the stations on the White River near Oacoma, near the town of White River, near Kadoka, near Oglala, and at Crawford, and the station on the Little White River near the town of White River. Additional load duration curves were created for the Oglala, Kadoka, and Oacoma stations, based on the May through September data for fecal coliform bacteria. The water-quality stations of Chadron and Chadron NW did not have flow data; therefore, loading duration curves and loading estimates were not possible. Load duration curves for each site are shown in Appendix C.

**Table 3-5. Exceedence Table for Fecal Coliform Sampling Stations in the White River Basin**

| Station Name | Fecal Coliform Bacteria | | | | | |
|---|---|---|---|---|---|---|
| | Percent Exceedence | Q1 | Median | Q3 | 10% Exceedence | Required Reduction |
| Crawford | 4% | 121 | 450 | 710 | 1,166 | – |
| Chadron NW | 13% | 8 | 38 | 324 | 3,221 | 38% |
| Chadron | 6% | 20 | 56 | 314 | 1,020 | – |
| Oglala | 4% | 10 | 46 | 270 | 846 | – |
| Kadoka | 25% | 30 | 200 | 1,850 | 8,920 | 78% |
| WR near White River | 25% | 163 | 540 | 1,950 | 5,660 | 65% |
| LW blw WR | 4% | 40 | 130 | 330 | 900 | – |
| Oacoma | 15% | 10 | 120 | 1,000 | 2,500 | 20% |

Note: Fecal Standard = 2000 cfu/100 ml

**Table 3-6. Exceedence Table for Fecal Coliform Sampling Stations in the White River Basin (May–September)**

| Station Name | Fecal Coliform Bacteria | | | | | |
|---|---|---|---|---|---|---|
| | Percent Exceedence | Q1 | Median | Q3 | 10% Exceedence | Required Reduction |
| Crawford | 9% | 143 | 550 | 760 | 1,870 | – |
| Chadron NW | 35% | 238 | 336 | 3,705 | 8,200 | 76% |
| Chadron | 14% | 165 | 360 | 955 | 2,100 | 5% |
| Oglala | 9% | 98 | 370 | 732 | 1,670 | – |
| Kadoka | 54% | 350 | 2,400 | 7,500 | 16,200 | 88% |
| WR near White River | 25% | 163 | 540 | 1,950 | 5,660 | 65% |
| LW blw WR | 4% | 130 | 230 | 493 | 1,110 | – |
| Oacoma | 29% | 185 | 695 | 2,075 | 5,900 | 66% |

Note: Fecal Standard = 2000 cfu/100ml

Duration curves were created using the complete data set available from each site. The *y*-axis represents the estimated load for the day the sample was collected based on the mean daily flow times the concentration of the water-quality sample collected that day. The *x*-axis represents the percent of time (in days) the mean daily flow is greater than a specified flow. The daily loading estimates versus the flow duration interval on the sampling date are displayed as points. Allowable load based on flow duration curves and the South Dakota water-quality standard are shown as the lower of the two lines on the figures. The upper of the two lines represents the 10 percent exceedence concentrations for the entire flow interval. The difference between these two lines represents the amount of reduction required to meet the current water-quality standard. The *x*-axis has been divided into five intervals: 0–10 percent flow exceedence representing the flood conditions, 10–40 percent flow exceedence representing moist conditions, 40–60 percent flow exceedence representing midrange flows, 60–90 percent flow exceedence representing dry conditions, and 90–100 percent flow exceedence representing drought conditions. In each range, the median and the 10 percent exceedence levels of the estimated loads based on the water-quality samples are displayed. The results are discussed in Section 3.1.4 by site.

#### 3.1.3.3 Annual Load Estimates

Average annual loads were computed using the **FLUX** computer model [Walker, 1999]. **FLUX** modeling was performed in order to establish a relationship between TSS and discharge and to use this relationship to attain the best possible estimates for the annual loads at each station. Data for modeling came from SD DENR and USGS. Six stations were selected for modeling, which are shown in Figure 3-12. The stations modeled were White River near Oacoma, White River near the town of White River, White River at Kadoka, White River near Oglala, White River near Crawford, and Little White River below the town of White River. The station on the White River near the town of White River is just upstream of the confluence of the Little White River and only contains 2 years of flow data from which to base the loading estimate. Therefore, comparison between this station and the other stations within the watershed is not feasible.

The procedure used was the same for all stations and was based on the typical application sequence suggested in the **FLUX** user manual [Walker, 1999]. The **FLUX** model requires two separate data files for modeling annual loads, the first of which is a file containing the complete flow record available, with the second being the water-quality data for the parameter being modeled along with the flow data for the date sampled. This water-quality file can contain multiple parameters if desired. The model is only capable of handling 8,000 data points for discharge and 900 data points for water quality. Since the White River contains a large period of record for flow data, the flow data files for the individual sites were shortened to 8,000 lines, which included only the most recent data points. No site contained more than 900 water-quality samples.

The modeling sequence that was followed is listed below:

- Enter the proper data files for the site and parameter being modeled.
- Run a comparison of the data files for adequacy of the water-quality sample compared to the total flow record.
- Calculate loads using the six different regression methods incorporated into the model, taking special note of the loading values as well as the coefficients of variation.
- Regress the water-quality data versus the flow record.
- Stratify the data by season based on the Kruskal-Wallis Z values.
- Rerun the comparisons and the loading calculations based on flow stratification.
- Stratify by flow using two or three different strata and repeat the comparisons and loading calculations.

The modeling output results can be seen in Appendix D.

When importing data files, units of the model need a user-specified conversion factor to convert the units of flow and water-quality data to the required units for the model. The **FLUX** model uses flow values expressed in million cubic meters per year (cubic hectometers per year ($hm^3/yr$)) and concentration values expressed in milligram per cubic meter ($mg/m^3$). The flow data for the White River are given in cubic feet per second, which requires a conversion factor of 0.8937 to convert to $hm^3/yr$. The TSS data are given in mg/l, which requires a conversion factor of 1,000 to convert to $mg/m^3$. The fecal coliform data are in units of colony-forming units (cfu) per one hundred milliliters (cfu/100 ml). A cfu is not a unit of mass, which is required for modeling. This is a special case of modeling where mass flux is not involved. In order to address this problem, it is assumed for sake of calculation that 100 cfu equals 1 mg. Therefore, a conversion factor of 100 was used for the modeling of fecal coliforms. This converts the fecal data to 100 $cfu/m^3$, while the model treats the data as $mg/m^3$. Therefore, when analyzing the modeling results, it is important to recognize that where units are reported in kilograms, it is necessary to convert back to colony-forming units using the conversion factor of $1.0 \times 10^8 = 1$ kg.

The estimation technique selected for calculating annual loads was based on the stratification regime with the smallest coefficient of variation and the tightest grouping of estimates for the six estimation techniques. Because of the poor correlation between flow and TSS and fecal coliforms, the flow-weighted average, Method 2, was used for all of the model estimates. For TSS, the stratification was by flow regime in all cases using two stratification intervals for all of the stations on the White River and three stratification flow regimes for the site on the Little White River. The improvement in load estimates based on three stratification regimes suggests that the TSS loading may be more closely related to flow on the Little White River than on the main stem of the White River. No stratification was used for fecal loading estimates for the station at Crawford or near White River due to the small data sets. All other stations used two stratification regimes for estimating the fecal coliform loading. The sites near Oacoma and Oglala had the best estimates with stratification based on the flow seasonality determined from the Kruskal Wallis Z values by month. Stratification based on flow regime was best for the station near Kadoka and the station on the Little White River.

Fecal coliform bacteria standards only apply during the time period of May through September. Because of this fact, loading estimates for fecal coliform bacteria were also estimated using a two-season stratification, based on the time period that standard is in effect. The results for the fecal coliform load estimates are reported for both the annual and seasonal load. It should be noted that at two locations, Oglala and the Little White River, the seasonal load from May to September was estimated higher than the total annual load. This is because the two season stratification based on the standard is not an optimal stratification, leading to a higher coefficient of variation (CV). At both of these sites, the majority of the fecal load (greater than 90 percent) occurs during the May through September time period. The higher CV value results in a higher annual load estimate, which causes a higher seasonal load estimate than the annual load estimate with a more optimal stratification scheme. The results of the modeling are given in Table 3-7 and in Figure 3-13, Figure 3-14, and Figure 3-15 for TSS and fecal coliform annual and seasonal loads, respectively. The results are discussed in Section 3.1.4 by site.

#### 3.1.3.4 Fecal Coliform Source Tracking

When allocating fecal coliform bacteria loads, an understanding of the bacteria source by animal group is often needed. Bacterial Source Tracking (BST) methods are available that identify genetic fingerprints used to identify the animal group that was the source of the bacteria. The South Dakota State Health Lab currently uses a BST method called ribotyping, which compares RNA sequencing within the bacteria using Pulse-Field Gel Electrophoresis (PFGE) to a database of bacteria from known sources.

Two public meetings were held in 2004 during the final preparation of this document. Meetings were held in Kadoka and White River, South Dakota, to disseminate findings and to receive stakeholder comments on the White River Watershed assessment project. The general consensus among stakeholders was that the study did not adequately address and allocate sources to fecal coliform bacteria in the White River. Concern was expressed that livestock and local ranchers would be assigned large portions of the overall fecal coliform loading to the White River when wildlife, especially prairie dogs, may be a significant source of fecal coliforms because of large populations in the middle and upper segments of the White River. Because of these concerns and concerns expressed by State Senator Lintz of District 30, portions of two additional projects (Cottonwood Creek Watershed assessment and the Conata Basin Watershed project) were undertaken to refine and allocate sources of fecal coliform bacteria in the White River Basin. During the Cottonwood Creek Watershed assessment project, monthly fecal

**Table 3-7. FLUX Loading Estimates for TSS and Fecal Coliforms at Stations on the White River**

| | Annual Flow ($hm^3$/yr) | TSS (kg/yr) | TSS Criteria (kg/yr) | Fecal Coliform (cfu/yr) | Fecal Criteria (cfu/yr) | Seasonal Flow ($hm^3$/Season) | Fecal Coliform (cfu/Season) | Fecal Criteria (cfu/Season) |
|---|---|---|---|---|---|---|---|---|
| Crawford | 6.55E+08 | 2.27E+06 | 2.93E+06 | 2.20E+14 | 3.71E+14 | 2.57E+08 | 1.91E+14 | 1.46E+14 |
| Oglala | 1.52E+09 | 8.91E+07 | 6.82E+06 | 2.52E+14 | 8.63E+14 | 8.05E+08 | 3.62E+14 | 4.56E+14 |
| Kadoka | 8.70E+09 | 3.60E+09 | 3.89E+07 | 1.53E+16 | 4.93E+15 | 4.99E+09 | 1.49E+16 | 2.83E+15 |
| WR Near White River | 4.56E+09 | 8.84E+08 | 2.04E+07 | 5.83E+15 | 2.59E+15 | 1.91E+09 | 2.44E+15 | 1.08E+15 |
| Little White River | 5.04E+09 | 9.40E+07 | 2.25E+07 | 1.55E+15 | 2.85E+15 | 210E+09 | 1.85E+15 | 1.19E+15 |
| Oacoma | 2.25E+10 | 5.67E+09 | 1.01E+08 | 2.02E+16 | 1.28E+16 | 9.3E+09 | 1.96E+16 | 5.27E+15 |

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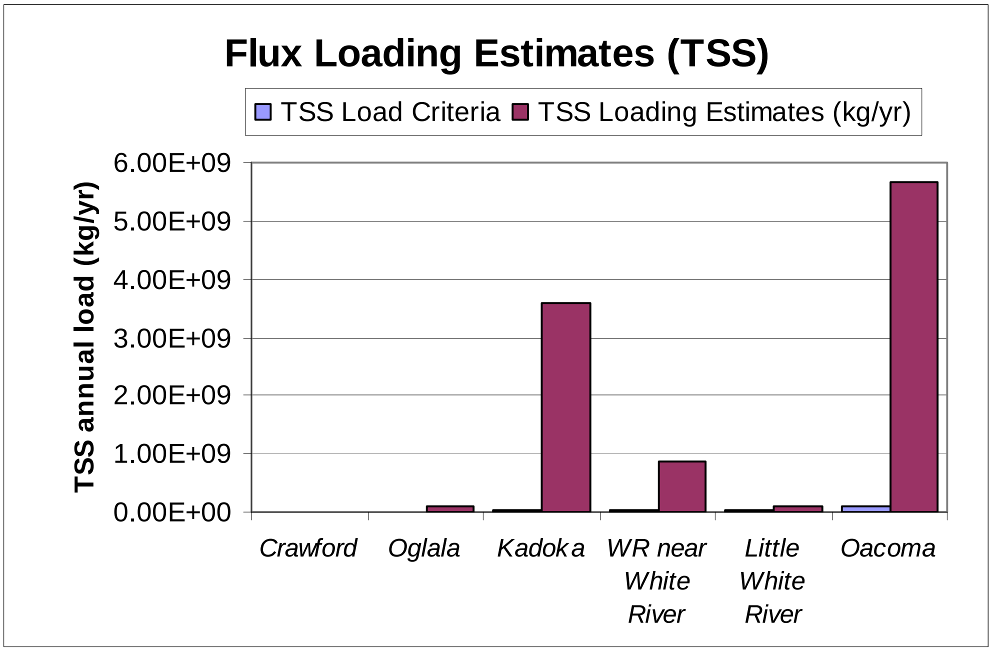


**Figure 3-13.** Annual Loading Estimates for TSS for Stations in the White River Watershed. Note: The Crawford Estimates Are Too Small to Show on This Scale.

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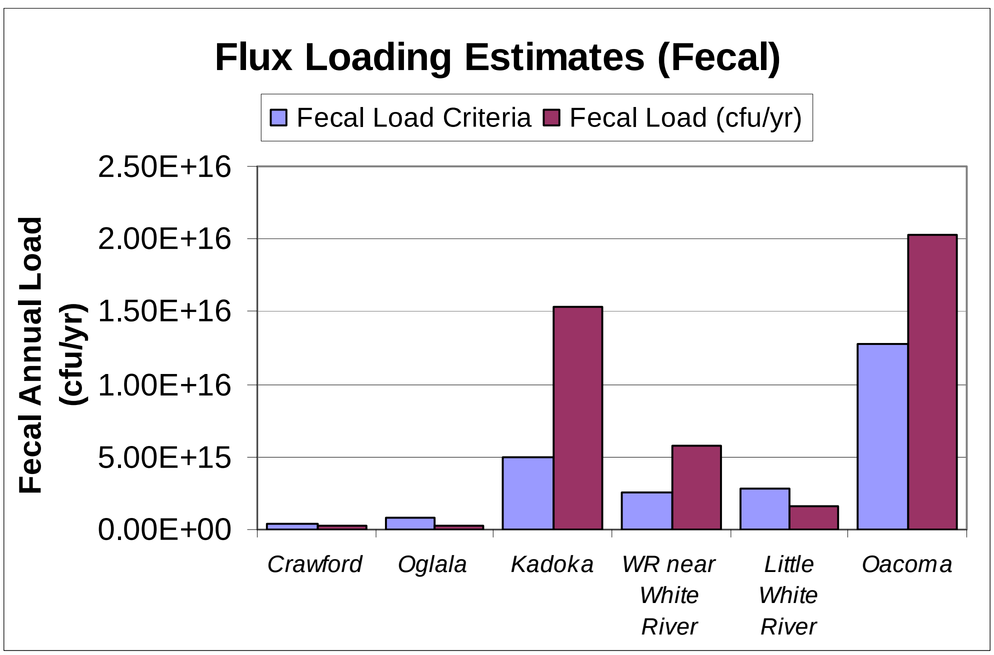


**Figure 3-14.** Annual Loading Estimates for Fecal Coliforms for Stations in the White River Watershed.

coliform and E. coli samples were collected and analyzed at three locations on the White River—Oglala, Kadoka and Oacoma. Samples were collected in the time period from May 1 through September 30, 2005. During the Conata Basin Watershed project (2006), fecal samples were collected directly from prairie dog fecal pellets and E. coli bacteria colonies were analyzed using PFGE to be included as known isolates in South Dakota's RNA database. PFGE bands from E. coli samples collected in the White River during 2005 were matched with known E. coli bands, including prairie dogs, in the RNA database to identify species-specific sources of coliform bacteria in the White River Basin.

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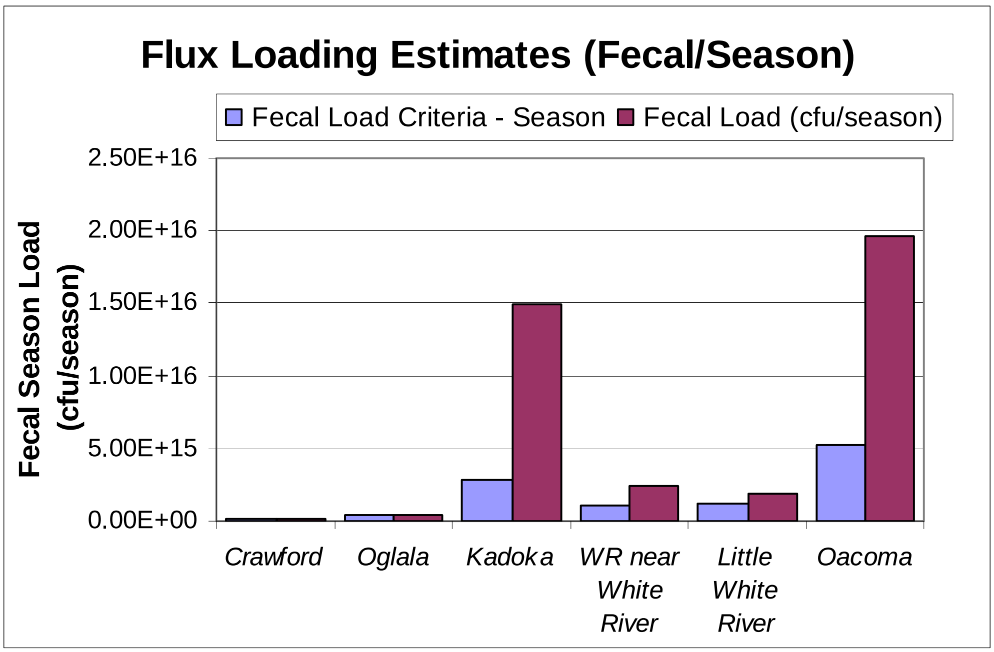


**Figure 3-15.** Seasonal Loading Estimates for Fecal Coliforms for Stations in the White River Watershed.

BST-identified organisms were placed into three generalized source types with human only, domestic livestock (combined cattle, horses, pigs, and sheep) and wildlife (combined cats, dogs, prairie dogs, and turkeys). Each site had a certain percentage of isolates that did not match the database and were listed as unknown. These isolates were incorporated into the wildlife category because they were more than likely uncommon species not in South Dakotas' DNA database and presumably would be of wildlife origin. Isolate counts and percentages by group and sampling site are provided in Table 3-8.

**Table 3-8. Generalized Source Percentages of Fecal Coliform Bacteria Based on E. Coli Bacteria in the White River in 2005**

| Generalized Source Type | Oglala | Percent | Kadoka | Percent | Oacoma | Percent | Overall | Percent |
|---|---|---|---|---|---|---|---|---|
| **Human** | 11 | 17.7 | 3 | 5.7 | 8 | 13.5 | 22 | 12.7 |
| **Domestic Livestock** | 29 | 46.8 | 31 | 58.5 | 22 | 37.3 | 82 | 47.1 |
| **Wildlife** | 22 | 35.5 | 19 | 35.8 | 29 | 49.2 | 70 | 40.2 |
| **Total** | **62** | 100.0 | **53** | 100.0 | **59** | 100.0 | **174** | 100.0 |

The largest percentage of isolates sampled at Oglala was livestock at 46.8 percent, followed by wildlife at 35.5 percent, with the remaining 17.7 percent assigned to human. The largest percentage of isolates sampled at Kadoka was livestock at 58.5 percent, followed by wildlife at 35.8 percent, with the remaining 5.7 percent assigned to human. The largest percentage of isolates sampled at Oacoma was wildlife at 49.2 percent, followed by livestock at 37.3 percent with the remaining 13.5 percent assigned to human.

The 2005 sampling data suggest that in the upper two-thirds of the watershed, fecal coliform contributions from domestic livestock were higher than wildlife. Source tracking results suggest a shift in fecal coliform contribution percentages from domestic livestock to wildlife in the lower one-third of the watershed. The highest percent contribution from human sources occurs in the reach of river with the lowest loadings and concentrations of fecal coliform bacteria, which is currently not listed as impaired. The large increase in loading between Oglala and Kadoka originates mostly from livestock sources, with wildlife also being a large contributor. The largest percent contribution from wildlife occurs at the downstream station, in the reach of the river with the most vegetated riparian corridor—an area where wildlife would be expected to congregate.

Stakeholders expressed concern that prairie dogs may be a significant portion of the fecal coliform load to the White River. Source tracking data collection in 2005 yielded 174 isolates that were analyzed and run against the DNA database in 2006. Data indicate only one isolate sourced as prairie dog out of the 174 isolates collected in the White River from May 1 through September 30, 2005. Assessment data suggest only six-tenths of 1 percent of the fecal coliforms sampled during the study were from prairie dogs. Based on this study, stakeholder concerns about prairie dogs being a significant source of fecal coliforms to the White River were not supported.

#### 3.1.3.5 Trend Analysis

A simple linear trend model was applied to water-quality data at three stations with the most data points (Oglala, Kadoka, and Oacoma). The trend analysis was performed on TSS and fecal coliform data at these three stations. This analysis was performed to identify changes in concentrations with time. TSS water-quality data plotted versus time with the fitted trend line for Oacoma are shown in Figure 3-13. Trend analysis plots for each station for TSS and fecal coliform bacteria are shown in Appendix E. The time scale shown on the *x*-axis in these plots represents months beginning at the start of water-quality sampling, which began in the early 1970s.

The slope of a fitted line created in the trend model indicates if changes with time are occurring. In each case, the trend lines for TSS data had a negative slope, while the trend lines for the fecal coliform analysis had a positive slope. The slopes of fitted trend lines are not large enough to clearly identify changes in TSS and fecal coliform bacteria concentrations with time.

Data suggest there may be a slight downward trend for TSS and a slight upward trend for fecal coliforms; however, when compared to the magnitude of concentrations, the impact of the trend in concentrations is minimal, if it is occurring. The trend found in the data could be attributed to changes in sampling techniques, especially for fecal coliform bacteria. As sampling plans evolve to include more high flow runoff events, trends in the data may appear where no real trend in concentrations are occurring. For the rest of this document, it will be assumed that no significant changes in concentration levels occurred during the sampling period. Recommendations will be based on concentrations and loadings estimated in the data analysis.

### 3.1.4 <u>Water-Quality Results</u>

Water-quality results are summarized by station in the following sections.

#### 3.1.4.1 Crawford

Crawford has 68 years of flow data; however, it only has 32 samples for TSS and 34 samples for fecal coliforms, all from the late 1970s. The load duration analysis for TSS shows that the South Dakota criteria were being met for four of the five flow ranges. Only during the moist conditions, 10–40 percent flow exceedence, are the criteria not being met, suggesting that during low flow conditions, the water is carrying very little sediment. As flows increase, the sediment load increases. The Crawford station shows the lowest annual sediment load of any of the sites, although it still exceeds the South Dakota standard of 158 mg/l with a median value of 57 mg/l and a 10 percent exceedence level of 245 mg/l. The TSS trend by month shows that the highest loading occurs between February and May. This is indicative of loading due to snowmelt and early season rainfall. Storm events during the summer months do not appear to have a large affect on the sediment loading.

Fecal coliform data show loading fairly uniform across all flow ranges. This station does not exceed the standard of 2,000 cfu/100 ml in more than 10 percent of the samples. The month of August has the highest values; however, there are only three samples, one of which was on an order of magnitude higher with a value of 41,000 cfu/100 ml and a flow of 9 cfs. It should be noted that the highest discharge recorded for a day when a water-quality sample was collected was 32 cfs, which has a 7.7 percent exceedence level for daily average discharge. However, in an urban area with quick response times, a hydrograph from short, intense storm events may not be easily recognizable in daily flow value. It is possible, when coupled with the distribution of samples on the load duration curve, that few, if any, samples were collected during high flow storm events when the highest values of fecal loading would be expected. Therefore, the actual exceedence level calculated for fecal coliforms may not be representative.

#### 3.1.4.2 Whitney

The Whitney station has 31 samples for TSS and 32 samples for fecal coliforms collected during the late 1970s. However, no flow data were available for this time interval; therefore, no exceedence or loading analysis was performed on this station. This station has a small peak for TSS in March and the largest peak in August, showing that spring runoff and late summer thunderstorms have the largest effect on TSS loading. Fecal coliforms follow a similar pattern to the Crawford station, with relatively low and stable concentrations for all months, except August where there is a large increase in the concentrations.

#### 3.1.4.3 Chadron NW

There are 27 samples for TSS and 30 samples for fecal coliforms available for the Chadron NW site, collected mostly in the 1970s. This site has a lower median than the Crawford site at 52 mg/l; however, the 10 percent exceedence level is higher at 601 mg/l. This site is less dominated by base flow, with large events in May and August having an impact on sediment loading.

The same pattern found for TSS holds true for fecal coliform bacteria with May and August having the highest monthly values. The median value is lower than the Crawford site with a value of 38 cfu/100 ml. This site exceeds the South Dakota water-quality standard for fecal coliforms with a 10 percent exceedence value of 3,221 cfu/100 ml. This site is mostly impacted by storm events washing fecal coliforms into the stream channel. No flow data were available at this location; therefore, no loading analysis was performed. It is likely that the loading for fecal coliforms at this location originates outside of the riparian zone while entering the river system during storm driven runoff events. This assumption is based on the low median value along with the two peaks which coincide with the peak rainfall month and the thunderstorm season.

#### 3.1.4.4 Chadron

The Chadron station has a large period of record for water quality starting in the mid-1970s and continuing through 1993. There are 170 samples for TSS and 171 samples for fecal coliforms. There are two small peaks in median values for TSS; the first peak is in March and the second peak occurs in May. The months of March, May, and August all have high mean values with August being the largest, indicating runoff events add a large load compared to the base flow conditions. The annual median for TSS is 98 mg/l with a 10 percent exceedence level of 522 mg/l.

The highest monthly median for fecal coliforms occurs in the month of August, while the peak mean value occurs in July. Again, fecal coliforms enter this system from outside the channel during runoff events. The annual median is 56 cfu/100 ml with the 10 percent exceedence level of 1,020 cfu/100 ml. This site is in compliance with the South Dakota water-quality standard. No flow data were collected at this station; therefore, no loading analysis was performed.

#### 3.1.4.5 Bordeaux Creek

Bordeaux Creek is a tributary that enters the White River northeast of Chadron, Nebraska. The water-quality station is downstream of the stream flow gage station on the north fork of Bordeaux Creek that is summarized in the hydrologic analysis section of this report. During the late 1970s, 29 TSS samples and 30 fecal coliform samples were collected at this location. This station exhibits a much smoother monthly pattern than the other sites, while maintaining similar trends for both TSS and fecal coliforms. There is a small peak in March and a larger peak again in July for TSS. Fecal coliforms exhibits one peak in August, most likely due to livestock in or near the river. This site is much more dominated by base flows than the other sites on the White River, meaning runoff events do not have as large of an impact on water quality as they do at other stations. No exceedence or loading analysis was performed on this station.

#### 3.1.4.6 Oglala

The Oglala station has 164 samples for TSS and 119 samples for fecal coliforms. TSS loading in the river increases consistently from the station at Crawford to this location. The median value for TSS is 139 mg/l with a 10 percent exceedence level of 1,535 mg/l. Monthly median values peak in June, with the mean values being significantly higher. The pattern for TSS follows the pattern of precipitation almost exactly. Load duration curves show that the water-quality standard is being met during periods of low flow with the 10 percent exceedence values based on flow regime exceeding the loading criteria during moist and flood conditions. The load duration curve and monthly median pattern indicate that the loading at this station is dominated by large storm events and high flow periods.

This pattern suggests the TSS loading is coming from in-channel scouring as well as the general overland erosion. The TSS standard is not being met coming into South Dakota from Nebraska; however, it is not known how much of the difference between the Chadron station and the Oglala site originates in Nebraska and how much originates in South Dakota. It is likely that some of the loading at this station originates in the White Clay Creek sub-watershed, the largest contributing watershed between these two stations. It should be noted that White Clay Creek has a small subimpoundment located just upstream of the confluence with the White River, which probably has some effect on the TSS loading.

The fecal coliform loading has a similar monthly pattern as the precipitation, with the medians increasing into June and decreasing afterward. The difference between the mean and median is higher for the months of July and August, suggesting the larger, intense storm events add fecal loading during the summer months. The annual median value for fecal coliforms is 139 cfu/100 ml with a 10 percent exceedence level of 1,535 cfu/100 ml. The median value for the months of May through September is 370 cfu/100 ml with a 10 percent exceedence level for this time period of 1,670 cfu/100 ml. This indicates that fecal concentrations are higher during the summer months than the winter months; however, the data still show that this station meets the current water-quality standard. The load duration curves show that the standard is being met over all flow ranges that were sampled.

#### 3.1.4.7 Kadoka

The Kadoka station contains the most water-quality samples for TSS (316) in the White River Watershed. It has the third most samples for fecal coliforms (183), containing only one less sample than Oacoma. The sampling interval for both variables started in 1968 and continues at the present time with the last sampling date available for analysis in October 2002. Both TSS and fecal coliforms follow a similar pattern with median monthly concentrations increasing steadily with the peak occurring in July and then steadily decreasing through the end of the year.

The Kadoka station also has the highest median concentration values and 10 percent exceedence levels for TSS of any of the sites. The median value for TSS is 1,118 mg/l, with a 10 percent exceedence level of 17,408 mg/l. This represents a 700 percent increase in the median value and a 1,000 percent increase in the 10 percent exceedence level when compared to the upstream station at Oglala. The water-quality standard is not being met in any of the flow regimes on the load duration curve for TSS. The total estimated annual load is $3.6 \times 10^9$ kg/yr, which exceeds the annual load associated with the water-quality standard by 9,100 percent.

Fecal coliform loading exceeds the water-quality standard in each of the flow regimes on the load duration curve. The largest reduction is needed during high flow events. The total percent decrease needed for the annual concentration fecal coliforms at this station is 78 percent with a median value of 200 cfu/100 ml and a 10 percent exceedence level of

8,920 cfu/100 ml. The data for the May through September time period have a median value of 2,400 cfu/100 ml and a 10 percent exceedence level of 16,200 cfu/100 ml. Data indicate the summer months have higher fecal coliform concentrations than the winter months. Fecal coliform concentrations, similar to TSS loading, have the greatest increase between Oglala and Kadoka. The median value for the summer months increases 549 percent while the 10 percent exceedence level increases by 925 percent between these two locations.

Most of the loading for TSS and fecal coliforms originates between this station and the Oglala station. The incremental loading between stations is shown in Figure 3-16. The estimated annual load for TSS represents 63 percent of the estimated load near the mouth of the river. The estimated annual load for fecal coliforms at Kadoka accounts for 76 percent of the load near the mouth of the river.

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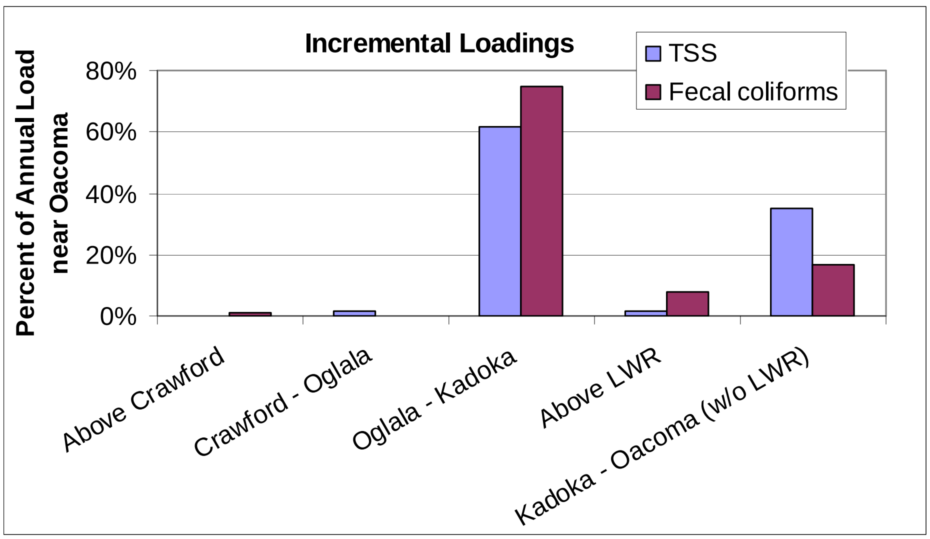


**Figure 3-16.** Percent of the Annual Load Represented by the Incremental Load Increase Between Stations.

#### 3.1.4.8 White River Near White River

The White River near White River station was established as a SD DENR WQM station in 1999 and a USGS gage station in 2001. No flows were measured at this location before it became a USGS gage station, limiting the number of sampling points that could be used for loading analysis. A total of 52 samples for TSS and 20 samples for fecal coliforms were available for analysis. This station is cited as the basis for the TSS and fecal coliforms listing in the South Dakota 2004 integrated report for the section of the White River from Black Pipe Creek down to Oak Creek. Therefore, the data from this site were used for exceedence and loading analysis. Monthly analysis, as well as regression between parameters, was not performed on this data set due to limited data.

The TSS loading exceeded the water-quality standard in all the flow ranges that were sampled (no samples were taken during the low flow conditions associated with a 90 percent or higher exceedence level). There were samples that met load-based criteria during the dry and midrange flow conditions while there were no samples that met the standard during high flow conditions. The median of the TSS samples was 482 mg/l while the 10 percent exceedence level is 7,140 mg/l, which represents a 59 percent decrease from Kadoka. This could be a function of the small data set.

The fecal coliform concentrations exceeded the water-quality standard in 25 percent of the samples. The median value of the samples is 540 cfu/100 ml with a 10 percent exceedence level of 5,660 cfu/100 ml. This value for the 10 percent exceedence falls between the values for Kadoka and Oacoma. Samples that exceed the standard were taken in both high and low flow regimes.

#### 3.1.4.9 Little White River Below White River

The number of water-quality samples at the Little White River below White River station were 391 for TSS and 221 for fecal coliforms. The Little White River is currently not listed for fecal coliform bacteria, while it is listed for TSS. It is currently the focus of a separate TMDL assessment being conducted by SD DENR in cooperation with the Mellette County Conservation District. Data at this station were only analyzed in order to assess the contributions of TSS and fecal coliforms to the White River.

The required reduction in concentrations for TSS is the lowest of any White River Watershed sites in South Dakota, with a median concentration value of 185 mg/l and a 10 percent exceedence level of 754 mg/l. This station is below a small hydroelectric impoundment that operates with periodic flushing flows that may add considerable loading. However, based on **FLUX** modeling, only 1.8 percent of the total volume occurred at flow rates exceeding the maximum flow rate. Data indicate that 5 days of flow data were sampled where the flow exceeded the maximum sampled flow rate. This indicates that the sampling occurred over most of the flow ranges present and the influence of flushing flows may be minimal.

Loading at this station was estimated at $9.40 \times 10^{7}$ kg/yr for TSS and $1.55 \times 10^{16}$ cfu/100 ml for fecal coliforms. This represents 2 percent of the annual TSS load and 8 percent of the annual fecal coliform load estimated at the Oacoma station near the mouth of the river. Based on this, even a large percentage decrease in loading in either of these parameters in the Little White River will result in negligible decreases in the total loading of the White River.

#### 3.1.4.10 Oacoma

The Oacoma station contains a large sample size for both TSS and fecal coliforms. Data follow a similar time pattern as at the Kadoka station with both the TSS and fecal concentrations increasing up to July and decreasing afterward.

The concentrations of both variables decrease between Kadoka and Oacoma while total annual load increases. Tributaries added in this reach, specifically the Little White River, carry a load that adds to the overall load of the river. However, the concentrations in these tributaries are not as great as the main stem, therefore, having a dilution effect in the White River, lowering the concentrations while increasing the load.

The median value for TSS is 1,075 mg/l with a 10 percent exceedence level of 14,517 mg/l. Samples exceed water-quality criteria in every flow regime with essentially no samples that meet the standard in the higher flow regimes. The estimated annual loading at this station is $2.25 \times 10^{10}$ kg/yr, which is a 58 percent increase from the site at Kadoka.

The fecal coliform median values are lower at this station than both Kadoka and the White River site with a median value of 120 cfu/100 ml and a 10 percent exceedence level of 2,500 cfu/100ml. During the summer months of May through September, the median value is 695 cfu/100ml with a 10 percent exceedence of 5,900 cfu/100 ml. Fecal coliform loading meets the criteria during low flow conditions and nearly meets the criteria in the midrange flow conditions. This suggests that at this station, fecal coliforms are settling out, dying, or being stored within the system and potentially being resuspended during high flow conditions. This supports the idea that the bacteria may be living for long time periods in the system due to high sediment loads. Some of this loading can be contributed to runoff events in the lower portion of the watershed. Also, at high flows, the contribution of the upstream load is larger due to faster velocities and greater transport distances.

## 3.2 GROUNDWATER

Groundwater monitoring did not take place on this project.

## 3.3 STREAM PHYSICAL, HABITAT, AND BIOLOGICAL MONITORING

### 3.3.1 Physical Habitat Field Methods

A total of ten sites were sampled following the Environmental Monitoring and Assessment Program (EMAP) physical habitat assessment protocol. Additional measurements were added, as outlined in the SD DENR standard operating procedure for field measurements [South Dakota Department of Environment and Natural Resources, 2003]. Additional measurements were added to ensure that the data collected on the White River would be comparable to data collected according to EMAP protocol as well as data collected by SD DENR on the Little White River. Complete procedures that were followed in the field are outlined in the following sections. Figure 3-17 shows the locations of sampling sites on the White River. A complete set of data sheets used is presented in Appendix F.

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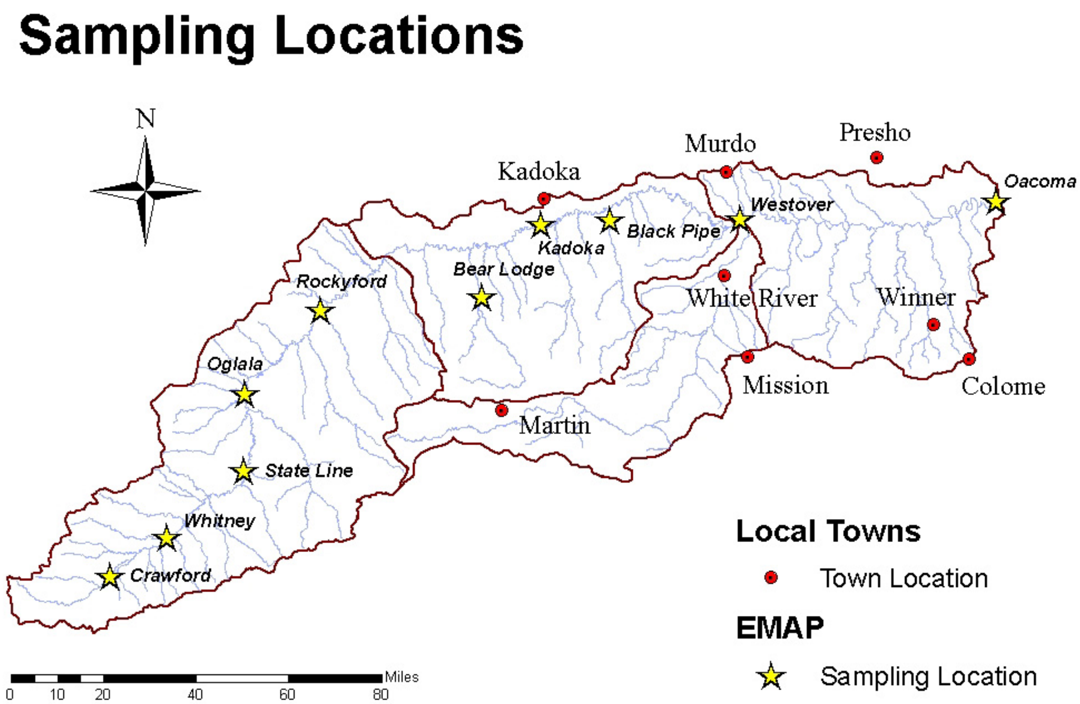


**Figure 3-17.** Physical Habitat Sampling Locations in the White River Watershed.

The physical habitat assessment occurred in two time periods. An initial fall visit took place in October 2003 when the site reach lengths were determined from the wetted widths. Benthic and periphyton samples were also collected at this time. The subsequent site visits occurred in March and April 2004 when the rest of the physical habitat assessment measurements were collected.

### 3.3.1.1 On-Site Description Data

Before field sampling, various initial observations and water-quality parameters were collected. Transect spacing was determined from preliminary wetted width measurements taken during low flow conditions at the time of the initial site visits in the fall of 2003, at which time, benthic macroinvertebrate and periphyton samples were collected. Ten preliminary wetted widths were taken at increments ranging from 30 to 100 feet, based on the size of the stream channel. The average wetted width for the stream was calculated and the total reach length was calculated as mean wetted width × 40. Reach lengths were broken into ten equal increments with a total of eleven transects established for sampling [U.S. Environmental Protection Agency, 2001a].

Water-quality parameters were also measured during the spring data collection visit at each site. Measurements were taken before habitat sampling, limiting the effects of stream disturbances caused by the stream sampling crew. The time of sampling, water temperature and air temperature in degrees Celsius, dissolved oxygen, and specific conductance were measured with a YSI data sonde with a 650 MDS hand-held data display unit.

Visual observations were recorded in the on-site description section of the stream sampling data forms. Stream odor, effects from septic tanks, dead fish, surface films, and ice cover were all classified according to SD DENR Standard Operating Procedures (SOP) into five categories: severe, extreme, moderate, mild, or none. These visual observations were recorded after sampling was completed and represented a ranking for the entire site reach. The weather conditions for the time of sampling as well as the 24-hour time period preceding the sampling were also recorded.

The number of the pool, riffle, and run habitat types were tabulated after sampling was complete [South Dakota Department of Environment and Natural Resources, 2003]. These measurements were estimated from the thalweg profile data described later in this section.

The last task of the on-site description portion of data forms was the sketching of a rough site map labeling features such as any areas of significant point bar deposition, bank erosion or slumpage, locations of the terraces and locations of prominent human disturbances, as well as any observations thought to be relevant to the habitat classification. The general compass direction of flow as well as a rough scale were also recorded on this sketch.

#### 3.3.1.2 Stream Discharge Data

Many of the sites that were sampled contained USGS real-time gaging stations. For these sites, no field discharge measurements were collected. Discharges were taken from the USGS Web site after the sampling was completed with a starting discharge as well as a final discharge recorded for the sampling period where significant change occurred. For sites where no real-time discharge data were available, discharge was estimated using standard field measurement techniques using either a Price AA or a Pygmy meter where appropriate [Edwards and Glysson, 1988]. These measurements were taken at transects where a uniform distribution of flow existed across the wetted width containing a relatively constant depth. These transects tended to be close to the site access point, usually at the downstream portion of the sites. At the Oglala site, no flow measurement device was available; therefore, a float method was used [U.S. Environmental Protection Agency, 2001a]—floating an object over a measured distance three times to estimate the mean velocity. This was performed with the transect being located in the center of the float distance where a detailed cross section was measured.

#### 3.3.1.3 Riparian Legacy Trees Data

Information on riparian “legacy” trees is used to assess the old growth characteristics of the riparian zone while giving insight to the historical conditions and the potential for growth [United States Environmental Protection Agency, 2001a]. Legacy trees were quantified over the entire reach length by categorizing the largest tree in the riparian zone on each side of the stream starting at each transect and looking upstream to the next transect. Legacy trees were placed into one of five categories for the diameter at breast height (DBH): 0–0.1 m, 0.1–0.3 m, 0.3–0.75 m, 0.75–2.0 m, and >2.0 m, as well as four categories for the height of the tree: <5 m, 5–15 m, 15–30 m, >30m. Finally, the trees were categorized as deciduous, coniferous, or broadleaf evergreen with the specific taxonomic category being recorded.

#### 3.3.1.4 Channel Constraint Data

The ability of a channel to migrate through a valley can have a profound effect on the stream morphology as well as the habitat available for aquatic organisms [U.S. Environmental Protection Agency, 2001a]. For this reason, part of the EMAP protocol calls for classifying the channel pattern, the channel constraint, and the constraining features as well as estimating the percent of the channel in contact with the constraining feature. The channel type was described as either a single channel, an anastomosing or complex channel, or a braided channel. Anastomosing channels have a dominant main channel with relatively long minor channels in a complex network. Braided channels also display a complex channel, with smaller, shorter subchannels being dominant with no obvious dominant channel being present. Next, the channel constraint is classified according to the type of valley the river is located in, such as: a constrained channel in a V-shaped valley, a channel constrained in a broad valley with constraint being due to its own incision, a channel in a narrow valley without significant constraint, or a unconstrained channel in a broad valley. The type of constraining feature is defined as bedrock, hillslope, terrace, human bank alterations, or no constraining feature if this is the case. Lastly, the percent of the channel in contact with the constraining feature and the visual estimate of valley width were recorded.

#### 3.3.1.5 Torrent Evidence Data

Large torrent floods, or floods that significantly overtop the banks and have a return interval greater than every 5 years, are natural events that are important to the natural “resetting” of a stream system. However, these events can have a profound impact on stream habitat and biota, which can complicate the interpretation of the stream sampling results [U.S. Environmental Protection Agency, 2001a]. For this reason, evidence of any recent torrent floods was recorded. Data forms contain ten categories that describe evidence of torrent scouring. If the type of evidence described in each class is present, the evidence category is checked. Additional notes are recorded if required.

#### 3.3.1.6 Stream Assessment Data

A stream assessment form was filled out for every site sampled. The main purpose of the form was for additional notes to be taken on any visual observations that were made before, during, and after sampling the stream reach. This form also contained information about certain site characteristics as well as activities and disturbances on the watershed level. Each waterbody sampled was classified from pristine to highly disturbed as well as from appealing to unappealing on a 1 to 5 scale, respectively. Beaver activity was characterized as absent, rare, or common with beaver modifications to the stream flow being characterized as none, minor, or major. The last site characteristics recorded was dominant land use being classified as forest, agriculture, range, urban, or suburban/town. If the land use was forest, the dominant age class of the forest would be classified as 0–25, 25–75, or >75 years. Watershed activities were classified in five different classes: residential, recreational, agricultural, industrial, and stream management. Each of these classes has several specific types of disturbances that were ranked as low, medium, or high. The complete group of disturbance types is listed in Table 3-9.

**Table 3-9. Observed Activities and Disturbances Within the White River Drainage Basin**

| Residential | Recreational | Agricultural | Industrial | Stream Management |
|---|---|---|---|---|
| Residences | Hiking Trails | Cropland | Industrial Plants | Liming |
| Maintained Lawns | Parks, Campgrounds | Pasture | Mines/Quarries | Chemical Treatment |
| Construction | Prinitive Parks, Camping | Livestock Use | Oil/Gas Wells | Angling Pressure |
| Pipes, Drains | Trash, Liter | Orchards | Power Plant | Dredging |
| Dumping | Surface Films | Poultry | Logging | Channelization |
| Roads | | Irrigation Equipment | Evidence of Fire | Water Level Fluctuations |
| Bridge/Culverts | | Water Withdrawal | Odors | Fish Stocking |
| Sewage Treatment | | | Commercial | Dams |

### 3.3.1.7 Stream Cross-Section Survey Data

The field sampling procedure was a mix of the EMAP protocol [U.S. Environmental Protection Agency, 2001a] and the standard operating procedure used by the SD DENR [2003]. Most samplings, as well as data sheets used to record the field data, came from the EMAP protocol. However, certain measurements at each cross section are required for the SD DENR protocol that are not in EMAP protocols. SD DENR SOP has a section for recording the presence or absence of bank slumpage on each bank [South Dakota Department of Environmental and Natural Resources, 2003]. Total bank lengths for both sides of the river were also measured at each cross section with the length of the bank being eroded, deposited, or vegetated also recorded. The SOP also calls for a descriptive classification of the riparian zone. Above each transect, the dominant landuse for each side of the river was classified as cropland, shrub, woodland/forested, pasture, rangeland, barnyard, prairie, developed, wetland, or other with the type being recorded if other was circled. Animal vegetation use on each bank was classified as none, moderate, low, or high with the riparian vegetation types described as sedge/rush, cottonwoods, willows, grass/forbs, silver maple, green ash, shrubs, or other. Riparian age classes of trees were also recorded if trees were present with the age classes being seedling/sprout, decadent, young/sapling, mature, or dead.

Each stream was classified using the Rosgen stream classification system. This system requires a detailed cross section near an inflection point between two meanders at where the cross section is typical of the overall river condition. Some measurements required for this system are not part of either the SD DENR SOP or the EMAP protocol. For this reason, a detailed cross-sectional survey was performed at multiple locations throughout the sampling reach. The main focus of this survey was to identify bankfull depths, bankfull widths, flood prone depth (which is equal to twice the bankfull depth), and flood prone width at the elevation corresponding to flood prone depth. The Rosgen classification also requires information about the substrate and the stream sinuosity. This information was collected for other sections of the sampling using the EMAP protocol.

Lastly, the White River is a river dominated by very low gradients. The lower section of the river is extremely wide when compared to the depth, leading to some sites that are extremely long, which causes spacing of transects to be large. Accuracy of the slope data using a clinometer over long reaches was somewhat questionable. Due to this fact, the slope over the sampling reach was measured using a surveying level and rod.

The added bank measurements for the SD DENR protocol, the channel profile for the Rosgen classification, and the slopes and bearing were added onto one new data sheet that was not present with EMAP data forms. It should be noted that the bearing was measured using a clinometer as called for in EMAP protocol except that readings were taken from downstream looking up instead of looking downstream. When calculating the mean direction of flow, the reciprocal of the mean bearing was used, in effect reversing the direction to the downstream direction.

#### 3.3.1.8 Channel Riparian Cross-Section Data

This section of the stream sampling contains sections for substrate, fish cover, visual riparian estimates, bank measurements, and canopy cover measurements. Each of these sections is part of the EMAP protocol, with a separate data sheet being filled out at each transect.

Substate size classes were measured at each transect within the sampling reach. A total of five substrate points are sampled at each transect within the wetted width, with the first and last points being located on the wetted perimeter and the other three being equally spaced across the wetted width. Substrate particle at each point was collected randomly by looking toward the bank while touching the channel bottom off the tip of the toe selecting the first particle touched. The selected particle was then measured using a SAH-97 hand-held particle size analyzer, sometimes referred to as a gravelometer [Potyondy and Bunte, 2003]. The different size classes measured with the gravelomter are given in Table 3-10.

Several bank measurements were also part of the channel/riparian section. Wetted width; bankfull width; bankfull height above the water surface elevation; and bar width, if present, were measured for each transect. Bank angle was measured from the toe of the channel bank to the first break in slope using a clinometer as well as the bank undercut distance if present.

Vegetation measurements and estimations were also made on this data form. The overhanging canopy cover was measured at each bank as well as in the four directions of the midchannel (upstream, downstream, looking left, and looking right) using a densiometer. The densiometer is a domed mirror with a series of cross hatches marked on it. A "V" is marked on the densiometer with 17 cross hatches located in the center of the "V." Canopy cover measurements are made by holding the densiometer 1 foot above the water surface while placing yourself in a position where your own reflection is visible below the "V." Counting the cross hatches that are covered by reflected canopy indicates the percent of overhanging canopy cover at each location.

Lastly, visual estimates are made for in-stream fish cover, riparian vegetation, and riparian human influence. Each category of vegetative cover is assigned a number based on its estimated percent of cover: 0 if absent, 1 if less than 10 percent, 2 if between 10 and 40 percent, 3 if between 40 and 75 percent, and 4 if greater than 75 percent. Also, the vegetation type of the canopy and understory is recorded as deciduous, coniferous, broadleaf evergreen, mixed, or none. The categories for classification are listed in Table 3-11.

**Table 3-10. Substrate Size Classes Measured With SAH-97 Sediment Size Analyzer**

| Class Name | Size Class (mm) | Minimum Diameter (mm) |
|---|---|---|
| Fines | 2 | 0 |
| Very Fine Gravel | 2.8 | 2 |
| Very Fine Gravel | 4 | 2.8 |
| Fine Gravel | 5.6 | 4 |
| Fine Gravel | 8 | 5.6 |
| Medium Gravel | 11 | 8 |
| Medium Gravel | 16 | 11 |
| Coarse Gravel | 22.6 | 16 |
| Coarse Gravel | 32 | 22.6 |
| Very Coarse Gravel | 45 | 32 |
| Very Coarse Gravel | 64 | 45 |
| Small Cobble | 90 | 64 |
| Small Cobble | 128 | 90 |
| Large Cobble | 180 | 128 |
| Large Cobble and Boulder | $\geq$181 | 180 |

### 3.3.1.9 Thalweg Profile Data

Data for a thalweg depth profile were collected at every sampling site for use with a longitudinal depth profile of the entire reach. Working upstream, the distance between each transect was divided into ten equal increments. At each of the established subintervals, a depth of the thalweg was recorded. It was noted if the thalweg was composed of entirely soft/small sediments (i.e., sand/silt/clay). The type of channel was also described as a plunge pool, trench pool, later scour pool, backwater pool, glide, riffle, rapid, cascade, falls, or dry channel. If the channel was defined as a pool, the pool-forming element was also recorded. Lastly, the presence or absence of a side channel, backwater, or a bar was recorded. At the fifth subinterval of the thalweg profile, five substrate measurements were taken across the channel. The pool-forming structure, if the habitat was a pool, and the presence of soft sediments, side channels, and back water were also recorded at the fifth subinterval.

**Table 3-11. In-Stream Fish Cover, Riparian Vegetation, and Human Influence Categories Recorded During Field Sampling**

| Fish Cover | Riaprian Vegetation | Human Influence |
|---|---|---|
| Filamentous Algae | **Canopy** | Wall/Dike/Revetment/Riprap/Dam |
| Macrophytes | Vegetation Type | Buildings |
| Woody Debris | Big tree >0.3 m | Pavement/Cleared Lot |
| Brush/Woody Debris | Small Trees <0.3 m | Road Railroad |
| Live Trees or Roots | | Pipes (Inlet/Outlet) |
| Overhanging Vegetation | **Understory** | Landfill/Trash |
| Undercut Banks | Vegetation Type | Park/Lawn |
| Boulders | Woody Shrubs and Saplings | Row Crops |
| Artificial Structures | Nonwoody Herbs, Grasses and Forbs | Pasture/Range/Hayfield |
| | | Logging Operations |
| | **Ground Cover** | Mining Activity |
| | Woody Shrubs and Saplings | |
| | Nonwoody Herbs, Grasses and Forbs | |
| | Barren, Bare Dirt or Duff | |

#### 3.3.1.10 Large Woody Debris Tally Data

Large woody debris present in the sampling reach was quantified by tallying all debris into classes based on their length and diameter. Only pieces of woody debris with a minimum diameter of 10 centimeters and length of 1.5 meters were included in the tally. The length classes were defined as 1.5–5, 5–15, and >15 meters. The diameter classes were 0.1–0.3, 0.3–0.6, 0.6–0.8, and >0.8 meter. Pieces that bridged over the bankfull channel were tallied separately from the woody debris contained within the channel.

### 3.3.2 Biologic Sample Collection

Biological sampling of the White River was limited to the collection of benthic macroinvertebrates and periphyton. Periphyton are the algae, fungi, bacteria, and protozoa associated with the stream substrate [U.S. Environmental Protection Agency, 2001a]. By studying the community composition of biological indicators, it is possible to infer certain aspects of stream condition based on community composition present in the stream. Biological indicators are good reflections of conditions present over the lifetime of the organisms and may give insight to the ecological health, which may not be apparent in individual water-quality grab samples.

Benthic macroinvertebrates were collected using procedures described in the *EMAP Field Operations Manual for Wadeable Streams* [U.S. Environmental Protection Agency, 2001a] using a D-framed kick net. Sampling took place in 30-second time intervals at each of the 11 transects. Each transect wetted width was visually broken into three sections with the samples collected in a rotating pattern from the left side, to the center, and the right side of the stream as the sampling moved upstream. The location of the first sample at transect A was determined randomly. All the samples collected from each transect were combined into a single reachwide composite sample. All samples were collected by stirring a 1-square-foot area. Samples collected in pools or slow-moving habitat type were collected by repeatedly dragging the net over the sampling area. The samples collected in fast-moving habitat types were collected using the movement of the water by placing the net directly downstream of the sampling area and letting the samples drift into the net. Both a reachwide composite and a riffle composite sample were collected. However, only the reachwide composite was analyzed.

Periphyton sample locations at each transect were determined using the same method as the benthic macroinvertebrates. Different techniques were used for erosional and depositional habitat types. In erosional habitats, the periphyton was collected by scraping the sample from a 12 $cm^2$ area of the substrate. This was collected in a composite sample bottle using a funnel and stream rinse water. Samples from depositional areas were collected using a syringe, collecting the top 1 centimeter of the substrate inside a 12-$cm^2$ delimiter (1.5-inch-diameter section of polyvinyl (PVC) pipe). This material was added to the reachwide composite sample. The final volume of the sample was recorded. Two subsamples were filtered using a vacuum filtration apparatus. The filtered samples were analyzed for chlorophyll *a* content and dry ash biomass weight (AFDW). The remaining sample was sent to EcoAnalysts for species identification of algae and diatoms.

Benthic macroinvertebrate samples were sent to EcoAnalysts for analysis. The first 300 specimens were identified to genus level. The total number of organisms was then estimated based on the volume sampled compared to the total volume of the sample. If 300 specimens were not found, the total sample was identified. A total of 80 metrics were then calculated and returned along with the raw data. The complete set of metrics and the taxonomic identification are shown in Appendix G.

A QA/QC sample for benthic macroinvertebrates and periphyton was collected at the site near the South Dakota-Nebraska state line. Both samples were collected on the same date and followed the same collection procedures. The QA/QC sample was collected immediately following the collection of the first sample using the same transect layout.

### 3.3.3 Bed Material Sampling Data

The White River has a substrate that is dominated by sands and silts. The substrate was measured using a sediment size analyzer (gravelometer), which measures the substrate size class but does not distinguish between sand and silt/clay particles. It was decided that a bed material sample might be beneficial to characterize the particle size distribution of the bed material, which in turn, will aid in understanding transport processes in the White River.

Two bed material samples were collected from each EMAP site using the US-BMH-53 bed material sampler following standard USGS sampling techniques for material smaller than medium gravel [Edwards and Glysson, 1988]. The wetted width of the stream was visually divided into six equal increments. The top inch of material was then collected at the five midchannel locations and each sample was placed in a single composite sample. This procedure was repeated at a second transect so that two separate composite samples were collected at each site.

Samples were labeled and stored in a dark cool location until the samples could be analyzed. Samples were preserved following procedures outlined by Fontaine et al. [1999]. One-half capful of bleach was added to each sample to destroy any biological material that may be living in the sample. Approximately 5 grams of Calgon, which has an active ingredient of hexameta-phosphate, were also added to the samples to prevent coagulation of the samples while being stored, which could adversely affect the particle size distribution analysis.

Samples were analyzed using the wet sieve and pipette settling technique presented by Guy [1969]. Fines were separated from sand and other coarse materials using the number 200 sieve with a pore size of .075 millimeters (mm). This was best accomplished by placing a minimal amount of distilled water in a bucket and "swirling" the sieve in the water until the material was cleaned. The remaining coarse material was placed in a large beaker and allowed to dry while the water containing the fines was poured into a 1,000-ml beaker for analysis. Once coarse materials were dry, they were sieved through a series of sieves, 4 mm to 0.075 mm. Some additional fines were present in the "pan" after sieving. These were added to the beaker of water containing the initial rinsed fines. Coarse material retained on each sieve was weighed and recorded.

The finer samples were then thoroughly stirred and a sample was taken for calculating the initial concentration and total mass of the fine materials with a diameter of less than 0.075 mm. The sample was again stirred thoroughly and a subsample was taken from this to be diluted to a total volume of 1,000 ml. The volume of these subsamples was determined to acquire a sample for analysis with the desired concentration of between 2,000 and 5,000 mg/l. The samples were then transferred to a 1,000-ml graduated cylinder where distilled water was added to dilute the sample to 1,000 ml. The samples were again thoroughly stirred and 10-ml samples were taken at the required depths and times for the particle size distribution analysis with the first sample being taken at $t$=0 for calculating an initial concentration. The times and depths of withdrawal are shown in Table 3-12.

**Table 3-12. Time of Pipette Withdrawal for Given Temperature of Withdrawal and Diameter of Particles [Guy, 1969]**

| Diameter of particle (mm) | 0.062 | | 0.031 | | | | 0.016 | | 0.008 | | 0.004 | | 0.002 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of withdrawal (cm) | 15 | 10 | 15 | | 10 | | 10 | | 10 | | 5 | | 5 | | 3 | |
| Time of withdrawal | (sec) | (sec) | (min) | (sec) | (min) | (sec) | (min) | (sec) | (min) | (sec) | (min) | (sec) | (hr) | (min) | (hr) | (min) |
| Temperature (°C) | | | | | | | | | | | | | | | | |
| 20 | 44 | 29 | 2 | 52 | 1 | 55 | 7 | 40 | 30 | 40 | 61 | 19 | 4 | 5 | 2 | 27 |
| 21 | 42 | 28 | 2 | 48 | 1 | 52 | 7 | 29 | 29 | 58 | 59 | 50 | 4 | 0 | 2 | 24 |
| 22 | 41 | 27 | 2 | 45 | 1 | 50 | 7 | 18 | 29 | 13 | 58 | 22 | 3 | 54 | 2 | 20 |
| 23 | 40 | 27 | 2 | 41 | 1 | 47 | 7 | 8 | 28 | 34 | 57 | 5 | 3 | 48 | 2 | 17 |
| 24 | 39 | 26 | 2 | 38 | 1 | 45 | 6 | 58 | 27 | 52 | 55 | 41 | 3 | 43 | 2 | 14 |
| 25 | 38 | 25 | 2 | 34 | 1 | 42 | 6 | 48 | 27 | 14 | 54 | 25 | 3 | 38 | 2 | 11 |
| 26 | 37 | 25 | 2 | 30 | 1 | 40 | 6 | 39 | 26 | 38 | 53 | 12 | 3 | 33 | 2 | 8 |
| 27 | 36 | 24 | 2 | 27 | 1 | 38 | 6 | 31 | 26 | 2 | 52 | 2 | 3 | 28 | 2 | 5 |
| 28 | 36 | 24 | 2 | 23 | 1 | 35 | 6 | 22 | 25 | 28 | 50 | 52 | 3 | 24 | 2 | 2 |
| 29 | 35 | 23 | 2 | 19 | 1 | 33 | 6 | 13 | 24 | 53 | 49 | 42 | 3 | 19 | 1 | 59 |
| 30 | 34 | 23 | 2 | 16 | 1 | 31 | 6 | 6 | 24 | 22 | 48 | 42 | 3 | 15 | 1 | 57 |

The values in this table are based on particles of assumed spherical shape with an average specific gravity of 2.65, the constant acceleration due to gravity=980, and viscosity varying from 0.010087 at 20°C to 0.008004 at 30°C.

All samples were dried at 90°C in an oven overnight and then cooled in desiccators. The sample containers were weighed initially before the sample was added and again after the drying period. Concentrations were then calculated based on the weight of the sediment and the volume of the sample taken from the graduated cylinder. The complete table of results is shown in Appendix H.

### 3.3.4 Physical Habitat Results

Physical habitat metrics were calculated for each sampling location following procedures presented in Kaufmann et al. [1999]. The complete list of metric definitions as well as the calculated values for each site is shown in Appendix I. These metrics were used for describing the types of habitat and internal variability within the White River Watershed as well as establishing correlations between physical habitat, water quality, and biological data.

Based on physical habitat metrics at ten stations, the White River can be divided into three reaches within the watershed. The physical habitat in the upper reaches of the watershed, including the stations of Crawford, Whitney, State-Line, and Oglala, are similar in several key habitat metrics. Similarly, the middle watershed stations, Rockyford and Kadoka, can be grouped together in a middle river reach, while the lower watershed stations, Westover and Oacoma, comprise the lower river reach. The station located on the tributary Bear in the Lodge Creek is more similar to the stations in the upper river reach, while the Black Pipe Creek station is more closely associated with the stations in the middle watershed reach. Several key metrics that separate the sites into the three groups are shown in graphical form in Appendix I as bar charts representing the data.

It should be noted that several metrics that were calculated do little to distinguish between the sites or to separate the sites into the different reaches. For example, the metric for mean substrate size class (SUB_X) is close to 2 mm at all locations. It is clear that the White River is a sand/silt-dominated system through most of the watershed. In general, the surface substrate pebble counts were dominated by the small size class codes. However, the size distribution analysis gives insight into the variability of the system. Differences in the river reaches are discussed in the subsequent section. Four key metrics, mean bankfull widths, mean thalweg depths, mean bank undercut distance, and canopy cover, are key in distinguishing the reaches and are shown in Figures 3-18 through 3-21.

Metrics for classifying habitat type (i.e., pool, riffle, or run) are somewhat erratic and conflict with other metrics that were calculated. There were some difficulties in classifying the habitat, especially with some of the larger, more complex sites where distinguishing between riffles and runs was difficult. It is clear, however, that for most of the river, pools are not a prominent stream habitat type, being absent at six of the sites and accounting for less than 10 percent of the stream at three of the other four sites, with the one outlier being Crawford with 51 percent pools. Part of the reason the Crawford site had such a high pool percentage was the prominence of beaver dams.

Lastly, the in-stream methods for measuring sinuosity (metric SINU) did not appear to measure the large-scale meandering pattern in the river. The White River is a highly sinuous river with large oxbows and meanders being common, especially in the lower reaches of the watershed. This pattern is not clear from the field measurements. It has been reported that sinuosity is related to the width and depth of a stream, with both of these being dependent variables of sinuosity [Julien, 2002]. It has also been reported that sinuosity is a dependent variable of the silt/clay content of the bank material. While the bank material was not measured directly, there was no relationship found between any of the substrate metrics, the bed material metrics, or the sediment-related, water-quality variables, nor was any relationship found between the widths or depths of the river. A stream with a sinuosity of less than 1.5 is described as straight [Leopold et al., 1964]. This threshold is exceeded at Bear in the Lodge Creek only.

RSI-1465-04-020

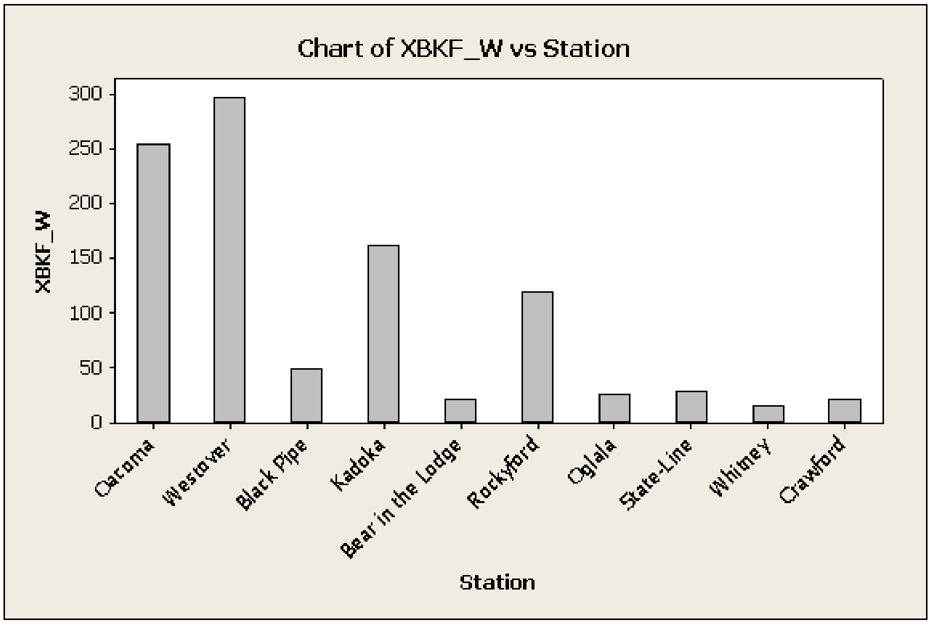


**Figure 3-18.** Mean Bankfull Widths by Station.

RSI-1465-04-021

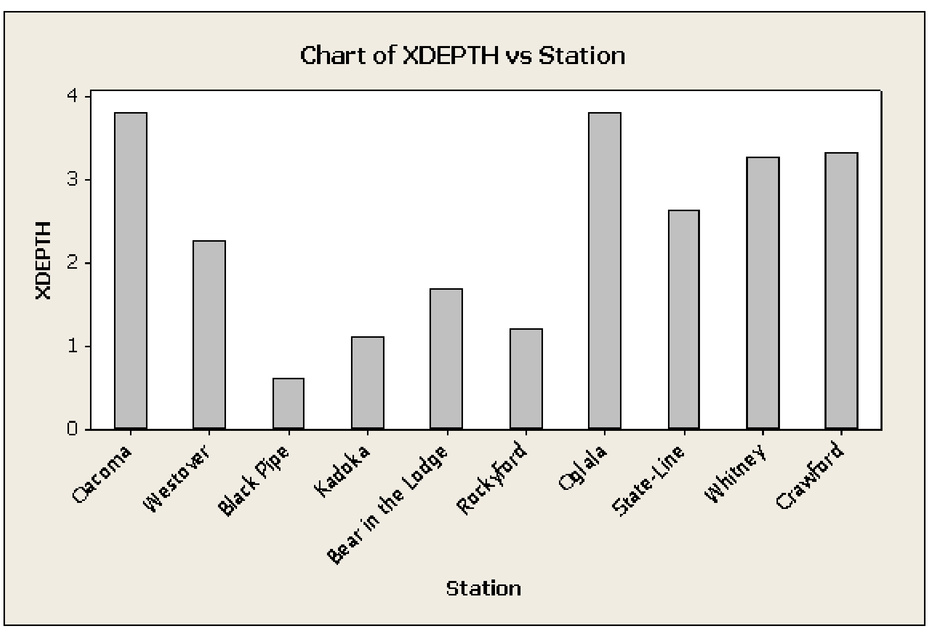


**Figure 3-19.** Mean Thalweg Depth by Station.

RSI-1465-04-022

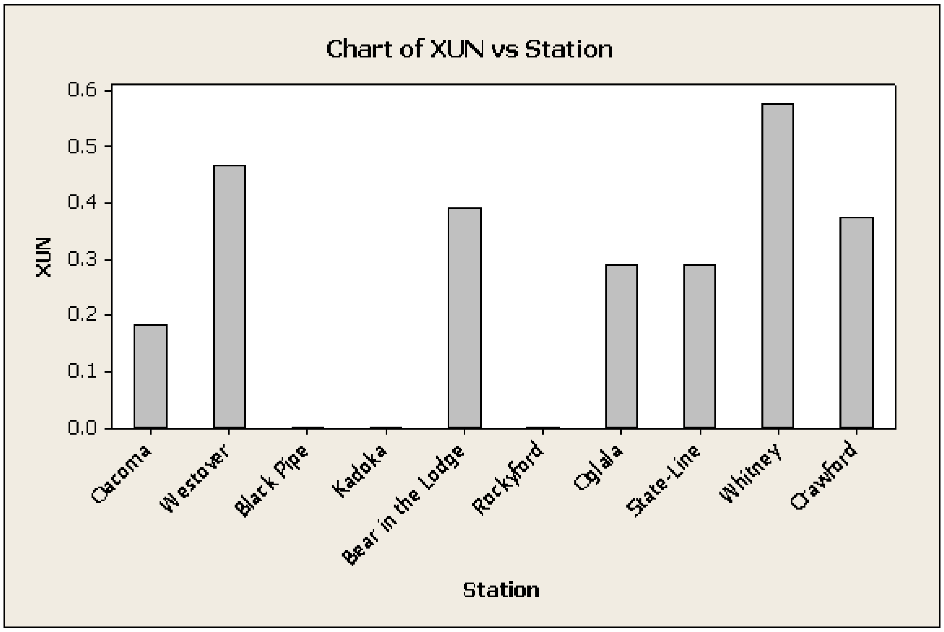


**Figure 3-20.** Mean Bank Undercut Distance by Station.

RSI-1465-04-023

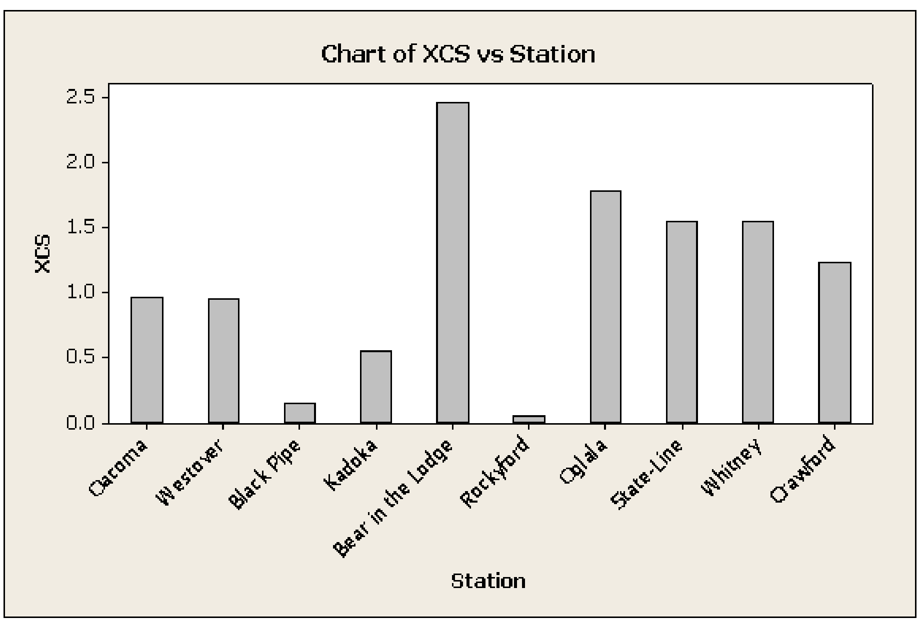


**Figure 3-21.** Canopy Cover of Small Trees by Station.

### 3.3.4.1 Upper Watershed Physical Habitat

The upper reach of the river is distinctly different from the middle and lower reaches. This reach is characterized by narrow bankfull widths (14.6–27.8 feet), deeper thalweg depths (2.6–3.8 feet), and low width-to-depth ratios (4.1–15.0). The bank morphology is distinctly different in the upper reaches as well with steep-sided banks (39.1–71.1 degrees) and large mean undercut distances (0.3–0.6 foot). Crawford had the most gently sloping banks in the upper section. This may be due to bank alterations in Crawford City Park. The banks appeared to be altered, with some buried rip-rap reemerging in some areas. The other three sites had mean bank angles greater than 60 degrees.

The metrics for percent gravel in the bed material sample (BM_GR) were used for the physical habitat assessment. Along with water surface gradient, insight was gained to the energy regime and sediment sources. The uppermost stations have a steadily declining gradient downstream to the Oglala station (0.03–0.19 percent), with Oglala having the lowest gradient of any of the stations. A different pattern from gradient is seen in the percent gravel. The lowest values are seen at the upstream and downstream stations while the highest values are found in the middle reaches of the river. The upstream stations at Crawford and Whitney have low values of 11 and 10 percent, respectively. The State-Line station increases a considerable amount with 35 percent gravel, Oglala decreasing again to the lower end with 14 percent. Then there is a jump at the Rockyford site, which has 75 percent gravel. The percent of gravel decreases continuously downstream from Rockyford to the Oacoma station.

The increase in mean sediment size at the State-Line indicates a sediment source of gravel present somewhere upstream. A decreasing particle size in the downstream direction is expected in the absence of tributaries, adding a significant load of sediment material [Leopold et al., 1964]. The presence of larger particle sizes indicates a closer proximity to the source. The presence of larger sizes may also indicate that this site is still incising to some degree, depositing the coarser material while incision removes some of the finer material present in the channel. The fact that this site has the highest bank angles of any of the sites, with lower bank undercut distances than compared to other stations in the upper reaches supports this. However, this site is clearly in transition from incision to widening with bank slumpage being present at 86 percent of the transect locations.

The upper stations had more heavily vegetated riparian zones with the highest values of overhanging vegetation. The range of riparian canopy cover was 2.5 at State-Line to 3.1 at Oglala. These numbers represent averages of the numerical rankings ranging from 0 to 4 assigned in the field and are, therefore, unitless. The canopy cover was comprised of both large trees, primarily cottonwoods, and a fair number of smaller trees, primarily green ash and young cottonwoods, with the range of canopy cover of small trees being 1.6 to 1.8. Canopy cover was the highest at the four sites in the upper reaches than any of the sites on the White River. The understory follows a similar pattern with the range being 1.8 at the State-Line to 3.4 at the

Oglala station. With the exception of the State-Line site, stations in the upper reaches had the highest values of understory of any of the stations on the White River.

Dense riparian vegetation is also reflected in the densiometer readings of overhanging channel vegetation (XCDENBK and XCDENMID) as well as in stream fish cover (XFC_ALL). Mean percent canopy density at the banks ranged from 72.8 percent at Crawford to 94.1 percent at State-Line, while the range of mean percent canopy cover for the middle of the channel is 34.8 percent at Oglala to 72.2 percent at Whitney. No other site on the White River had a value above 1 percent for the midchannel canopy cover. Most of the in-stream fish cover was in the form of brush and trees in the channel. The range of in-stream fish cover is 2.8 to 5.4, the highest of any of the reaches on the White River.

When comparing metric values at Bear in the Lodge Creek to metrics discussed above, it is clear that Bear in the Lodge Creek more closely resembles the habitat found in the upper reaches of the watershed than the habitat at the middle and lower reaches of the watershed. Of the 14 metrics used to summarize the physical habitat, all but 6 occur within the range of values found at the upper reach stations in the White River. The mean thalweg depth (1.68 feet) is less than the upper reaches as well as the lower reaches while being larger than the sites in the middle reach. However, the width-to-depth ratio is within the range of the upper sites, indicating the general channel morphology is similar to the upper sites. Both the water surface gradient and the percent of gravel in the bed material were highest at Bear in the Lodge Creek. These two metrics are most likely related to higher slopes, causing higher velocities and leading to larger bed material with fewer fines. The other three metrics, mean canopy cover, in-stream fish cover, and midchannel percent canopy cover, are all related to the riparian vegetation and are the highest of any of the sites. These metrics indicate that Bear in the Lodge Creek is more similar to the upper reaches of the White River.

#### 3.3.4.2 Middle Watershed Physical Habitat

A large change occurs in the physical habitat between Oglala and Rockyford, which are separated by a straight-line distance of 24 miles. The sites of Rockyford and Kadoka represent the middle reach of the White River, which extends from just downstream of Oglala to the confluence of the Little White River. The stations of Rockyford and Kadoka can be lumped together to represent the middle reach of the White River with wide widths and shallow depths, stable banks and low bank angles, and little undercutting. The riparian zone is sparsely vegetated with essentially no overhanging vegetation and little in-stream fish cover.

The mean wetted width in this reach increased to 68 feet while mean bankfull width increased to 118 feet at Rockyford, a 200 percent and a 381 percent increase, respectively, from Oglala. Mean thalweg depths at Rockyford and Kadoka are 1.2 and 1.1 feet, respectively, representing the lowest values of any stations on the White River. Kadoka has the highest width-to-depth ratio of any station at 98.1. Rockyford has the third highest width-to-depth ratio at 56.9, with the Westover station being slightly higher. These stations have stable banks with the mean bank angles being 20.5 and 28.2 degrees for Rockyford and Kadoka, respectively, with no measurable bank undercutting present at either site.

The water surface gradient increased slightly at Rockyford when compared to the upstream stations at Oglala and the State-Line with a water surface gradient of 0.10 percent. The gradient is similar for the rest of the stations in the White River. The percent of gravel in the bed material sharply increased between Oglala and Rockyford, with the value at Rockyford being 75 percent, the highest gravel content of any station present. The increase in percent gravel correlates to the increased energy associated with the increase in slope; however, it can not explain all of the increase, because both of the tributaries have higher slopes, as well as the two uppermost stations on the White River, while containing gravel contents that are much lower. It is clear that the Rockyford station is in close proximity to a large sediment source and that the geology dominating the system has changed from the upper portions of the river.

Riparian vegetation, as well as fish cover, decline considerably between Oglala and Rockyford. Values of canopy cover at Rockyford and Kadoka are 0.59 and 1.54, respectively, which are the lowest of any of the stations on the White River. Canopy cover of small trees and understory are also lowest in the middle stations with both being nearly absent from the Rockyford station with values of 0.04 for small trees and 0.18 for understory. This most likely is related to change in substrate and the high gravel content, which indicates a change in geology. The soil development in the flood plain is most likely not well developed with low nutrient content being deposited on the flood plain during flood events.

Geology of the White River Basin is shown in Figure 3-22. A transition occurs near the Oglala station with the main channel entering into the White River soil group while the tributaries become dominated by the Arikaree soil group. The White River group, the geologic formation that forms the steep, bare side slope bluffs in the Badlands National Park, is displayed in yellow. The percent of drainage area contributing between the Oglala and Kadoka stations containing the different geologic formations or groups is shown in Table 3-13. The Arikaree and White River groups are the dominant geology types in this river reach. They are both dominated by clay and siltstones with volcanic ash formations being common. A detailed description of each of these geologic formations is given in Figure 3-23. Much of the data analyzed indicates the critical reach of the river, in regard to the water quality as well as physical habitat characteristics, and occurs in the area of transition to the White River geological group, which corresponds to a change in soils. The river makes a significant change in direction roughly 5 miles north of the Oglala station, most likely due to the change in geology. It is at this point where the White River enters into and crosses the White River group. For the purpose of defining the different stream reaches, the clear break between the upper reach of the watershed and the middle reach should be defined at this break in direction and change in geology.

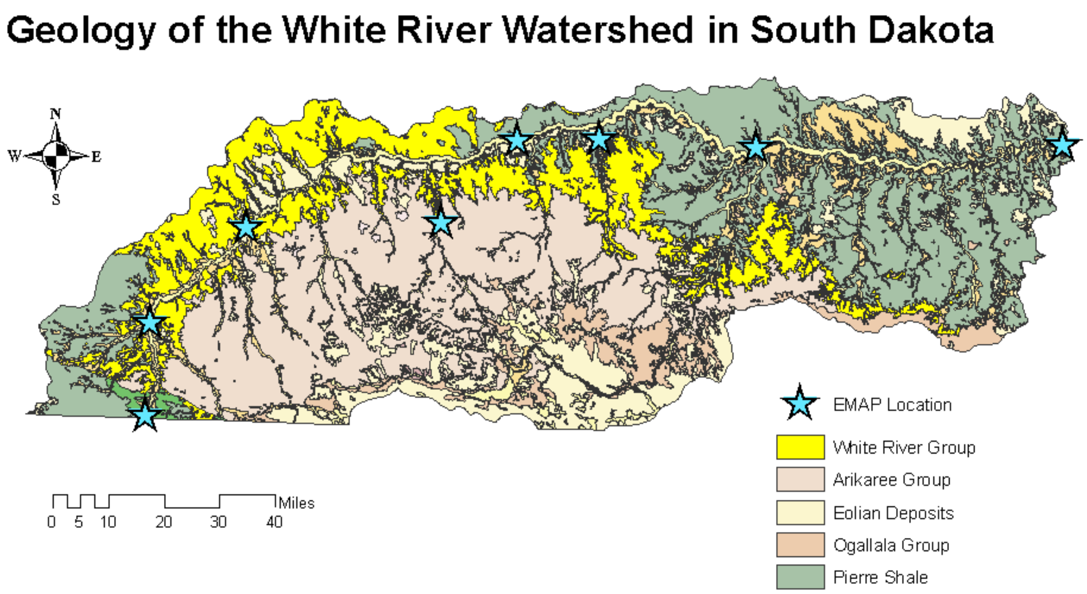


**Figure 3-22.** Geology of the White River Watershed in South Dakota.

**Table 3-13. Percent of the Drainage Area Between Oglala and Kakoka by Geological Formation**

| Symbol | Geological Name | Percent of Drainage Area |
|---|---|---|
| Kp | Pierre Shale | 6% |
| To | Ogallalla Group | 2% |
| Qal | Alluvium | 6% |
| Qe | Eolian Deposits | 11% |
| Qt | Terrace Deposits | 3% |
| Ta | Arikaree Group | 44% |
| Tw | White River Group | 28% |

Qal **Alluvium** (Quaternary) - Clay- to boulder-sized clasts with locally abundant organic material. Thickness up to 75 ft (23 m).

Qe **Eolian deposits** (Quaternary) - Silt to medium-grained sand. Deposited as: sand sheets; barchan, linear, and dome-like dunes; and as a veneer on uplands. Includes the Sand Hills Formation. Thickness up to 300 ft (91 m).

Qt **Terrace deposits** (Quaternary) - Clay- to boulder-sized clasts deposited as pediments, paleochannels, and terrace fills of former flood plains. Thickness up to 75 ft (23 m).

To **Ogallala Group** (Pliocene and Miocene) - Includes the Ash Hollow, Valentine, and Fort Randall Formations. Also includes the Thin Elk, Bon Homme, Herrick, Medicine Root, and "western derived" gravels.

**Ash Hollow Formation** (Miocene) - White, tan, and gray, well-cemented, calcareous sandstone and silty limestone often referred to as "mortar beds." Thickness 90-250 ft (27-76 m).

**Valentine Formation** (Miocene) - Gray, unconsolidated, fine- to coarse-grained, fluvial siltstone, channel sandstone, and gravel derived from western sources. Thickness 175-225 ft (53-69 m).

**Fort Randall Formation** (Miocene) - Pink and gray claystone with interbedded sandstone. Also includes green to gray orthoquartzite, bentonitic clay, and conglomerate. Thickness up to 130 ft (40 m).

Ta **Arikaree Group** (Miocene and Oligocene) - Includes the Rosebud, Harrison, Turtle Butte, Monroe Creek, and Sharps Formations.

**Rosebud Formation** (Miocene and Oligocene) - Pink siltstone with channel sandstone and concretions, may be in part equivalent to the Sharps Formation. Thickness up to 250 ft (76 m).

**Harrison Formation** (Miocene) - Gray, silty sandstone and reworked volcanic ash with calcareous siltstone and marl. Thickness approximately 180 ft (55 m).

**Turtle Butte Formation** (Miocene) - Light-green to gray siltstone with sandstone channels containing claystone pebbles. Thickness approximately 65 ft (20 m).

**Monroe Creek Formation** (Oligocene) - Tan to grayish-tan, massive, sandy siltstone and reworked volcanic ash. Thickness approximately 100 ft (30 m).

**Sharps Formation** (Oligocene) - Pink siltstone and claystone with concretionary layers, paleochannels, and beds of reworked volcanic ash. Thickness approximately 360 ft (110 m).

Kp **Pierre Shale** (Upper Cretaceous) - Blue-gray to dark-gray, fissile to blocky shale with persistent beds of bentonite, black organic shale, and light-brown chalky shale. Contains minor sandstone, conglomerate, and abundant carbonate and ferruginous concretions. Thickness up to 2,700 ft (823 m).

**Figure 3-23.** Geologic Units Found in the White River Watershed.

The tributary station on Black Pipe Creek is similar to sites on the middle reach of the river in regard to stream physical habitat. This station has a much higher width-to-depth ratio than any of the stations in the upper reach as well as the station on Bear in the Lodge Creek. The mean bank angle (23.9) falls in the range of the middle stations while also having no quantifiable bank undercut distance. The water surface gradient (0.12 percent) is similar to those of the middle stations as well as the percent gravel in the bed material (22 percent). Additionally, metric values for riparian vegetation and in-stream fish cover occur within the range of values found at Rockyford and Kadoka. The exception to this is the values for percent canopy density measured with the densiometer at the bank and at midchannel. The values measured at Black Pipe Creek are higher than those of the middle reach station; however, they still fall considerably below the values found at the upper reach station or at Bear in the Lodge Creek.

Sites at Black Pipe Creek and Bear in the Lodge Creek give additional insight to the impacts regional geology has on stream morphology and physical habitat. The Black Pipe Creek station occurs downstream of an area dominated by the White River group while Bear in the Lodge occurs in an area dominated by the Arikarree group. This would indicate that the White River group has more of an influence on the channel and cross-section morphology found in the middle reach of the White River.

#### 3.3.4.3 Lower Watershed Physical Habitat

The Westover and Oacoma stations are lumped together to form the lower reach of the White River. These two stations are similar to the two stations in the middle reach of the river with regard to general stream channel and cross-section morphology. The wetted widths, (167 and 211 feet), bankfull widths (297 and 254 feet), and thalweg depths (2.26 and 3.80 feet) are larger at these stations, while the width-to-depth ratios and bank angles are similar when compared to Kadoka and Rockyford. It should be noted that Oacoma is the furthest downstream station and has the largest wetted widths and thalweg depths; however, Westover has the larger bankfull width and width-to-depth ratio of the two. The water surface gradient also is very similar to those found in the middle stations.

There are other metrics that distinguish the lower reach from the middle reach. The most distinct change from the upstream middle reach is the presence of bank undercutting (0.18 and 0.47 feet). Riparian vegetation also increased with values for total canopy cover being 1.95 at both stations and the canopy cover of small trees being 0.95 for both. The understory cover also increased, being in the range of the upper sites (2.36 for both stations). A densiometer measured an increase in the percent canopy cover at the bank, with values of 31.3 and 21.4 for Westover and Oacoma, respectively. These values fall between the values found at the middle stations and the values found in the upper reach. The in-stream fish cover increased slightly with values of 1.54 and 0.54. The bed material at these stations had the lowest percent gravel of any of the stations, at 8 and 6 percent for Westover and Oacoma. This is not unexpected because these stations are the furthest downstream in the watershed and have the lowest slopes.

Based on all of the data collected, it is clear that there is a transition in the White River from the middle to the lower portion of the watershed. However, the largest distinction between the middle and lower reaches appears to be in the hydrology of the river, which can mainly be attributed to the large inflow of the Little White River. Therefore, the clear break between these two reaches of the White River is at the confluence of the Little White River. This corresponds to the change in the hydrologic unit code (HUC) from the lower White River Basin (HUC 10140204) to the middle White River Basin (HUC 10140202) [U.S. Environmental Protection Agency, 2004].

### 3.3.5 Physical Habitat Regression Analysis

Regression analysis was performed to evaluate relationships between physical habitat metrics, biological metrics, and water-quality parameters. Figure 3-24 displays the general conceptual approach used for the regression of the physical habitat data. The structure of the regression analysis was such that correlations between channel morphology and water quality were looked for as well as correlations between riparian vegetation and biological integrity. Riparian vegetation and biological integrity are assumed to be indirectly related through channel morphology and water quality but not directly related to each other.

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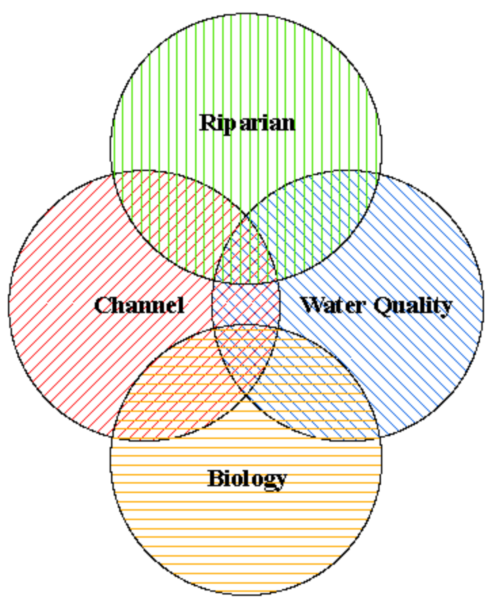


**Figure 3-24.** Conceptual Diagram of the Regression Analysis for Physical Habitat and Water Quality.

A total of 830 individual regressions were performed between different metrics and parameters. Of these, a total of 170 regressions had a coefficient of determination ($R^2$) greater than 50 percent with only 42 of those being greater than 80 percent. A list of the regressions with $R^2$ values higher than 50 percent is shown in Appendix I. The regression results by metric groups are discussed in the following sections.

### 3.3.5.1 Channel Morphology Versus Water Quality

The dominant controls on channel form are discharge and sediment load [Knighton, 1998]. This concept is reinforced with the regression analysis. Channel morphology was regressed versus the mean and median discharge, sediment loading, and fecal loading. This set of regression equations had 12 regressions with $R^2$ values greater than 80 percent, of which 7 were above 90 percent. This represented the most regressions with $R^2$ values over 90 percent of any of the regression groups. However, only five of the ten sampling sites had TSS and fecal coliform data available for regression analysis. Often, especially when plotting the TSS data, the data points occurred on the high and low ends of the scale with no points in the middle ranges, as is evident in Figure 3-25. Even with the high $R^2$ value, it is difficult to put much confidence in the regression equations. In general, the wetted width and the wetted width multiplied by thalweg depth is highly correlated to discharge, while the width-to-depth ratio is highly correlated to the TSS concentration. The drainage area is also highly correlated to wetted width.

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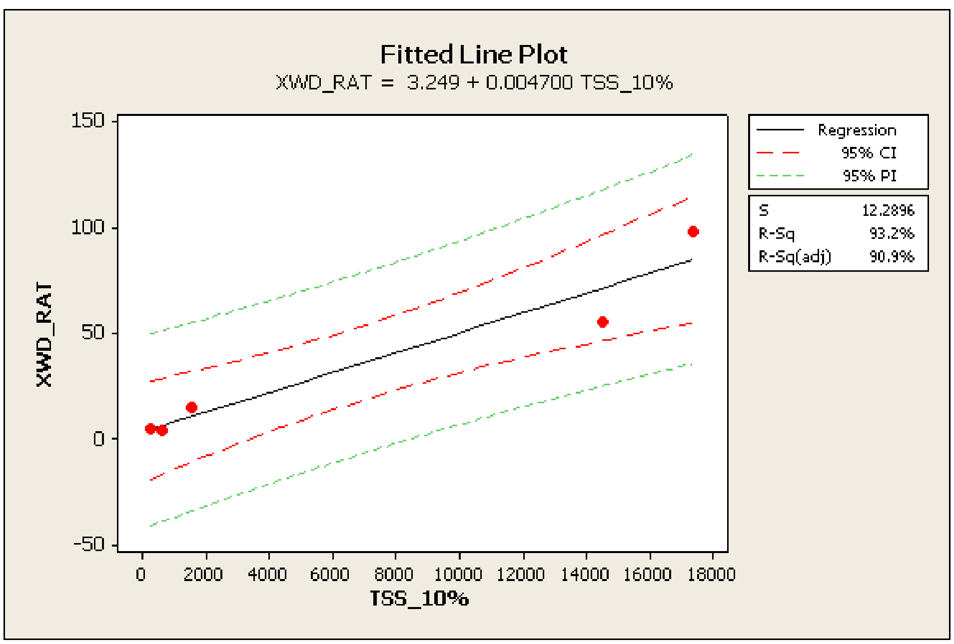


**Figure 3-25.** Width-to-Depth Ratio Versus the 10 Percent Exceedence Level for TSS.

Mean thalweg depths are negatively correlated to fecal coliform loading. Fecal loading is highest at the middle reach stations where depths are shallower. It is not clear if these variables are directly related or if both are related to watershed functions that are somehow related. For example, land use in this area is primarily rangeland with little to no dryland or irrigation farming in the river valley, which is fairly common in the upper and lower portions of the watershed. This may be part of the reason fecal loading is higher in the middle reach. The reason for lack of farming is most likely related to geology and soil types found in the watershed, which affects channel morphology and is related to the shallow depths in the middle reach. This may be a reasonable explanation as to why fecal loading and depth are negatively correlated while not being directly related.

### 3.3.5.2 Channel Cross Section Versus Water Quality

Bankfull width was the only cross-section metric correlated to water quality with high $R^2$ values. Regressions for bankfull width versus TSS metrics, as well as discharge and drainage area, appear to be highly correlated, with an $R^2$ value of 92.3 percent for bankfull width versus mean TSS values. It was discussed previously that channel cross-section morphology changed dramatically in the badlands reach. The high $R^2$ value between bankfull width and drainage area would appear to contradict this, indicating the wide channel widths may be merely a function of the increased drainage areas and the ensuing flows. However, reviewing the scatterplot of the data in Figure 3-26, it is evident that the upper stations, as well as Bear in the Lodge Creek, fall below the regression line, while the upper sites including Black Pipe Creek, with the exception of Oacoma, fall above the regression line. The largest outlier is the Oglala station, which falls outside of the 95 percent confidence interval. The jump between the Oglala station and the Rockyford station is evident in the scatterplot of the data.

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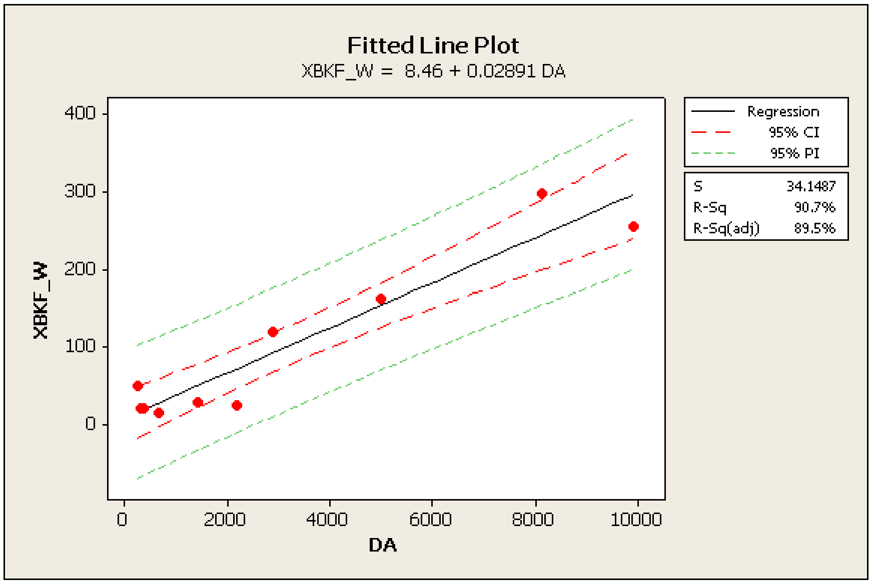


**Figure 3-26.** Bankfull Width Versus Drainage Area.

#### 3.3.5.3 Substrate Versus Water Quality

Fecal coliform loading appears to be the water-quality parameter group that is most closely related to channel substrate metrics. A positive correlation occurs between the substrate size class and fecal coliform concentrations with a negative correlation occurring between percent of fines and sands. Again, it is not clear if these are truly related or if it is a function of land use due to geology. The data may suggest that fecal coliform bacteria is attaching to suspended sediment in the system, leading to lower concentrations downstream because of settling of the suspended sediment. If this was the case, a stronger correlation might be expected between TSS concentrations, discharge, and fecal coliform concentrations than what was found at the Oacoma station. The lack of correlation may indicate fecal coliforms are also decaying after settling with the sediment.

#### 3.3.5.4 Riparian Characteristics Versus Water Quality

Riparian characteristics appear to be more closely related to TSS loading within the river when compared to other water-quality parameters. A negative correlation is found between riparian vegetation and TSS concentrations, including canopy cover, understory, and ground cover. Likewise, a positive correlation was found between TSS and the percent of bare ground. A negative correlation was also between the understory found and the fecal coliforms.

Regression analysis was performed on channel metrics versus riparian vegetation. None of the regressions performed had $R^2$ values higher than 80 percent. The strongest correlations appeared to be between the riparian vegetation and bank angles with a positive correlation. This would be expected, with the riparian vegetation stabilizing banks and leading to steeper bank angles.

### 3.3.6 Biological Sampling Results

An IBI was created for both the benthic and periphyton data. A nonparametric statistical Kruskal-Wallis test was performed on each metric, converting all the values to the same scale based on the difference from the median of the metric values. A total of seven metrics were used for the benthic IBI (BIBI). These seven metrics were chosen from seven different functional groups, with one metric selected from each functional group based on the highest range of the Kruskal-Wallis Z values. Z values for each of the sites were added for metrics that decrease with increasing disturbance and were subtracted for metrics that increase with decreasing disturbance. This created a relative ranking of each station with a high cumulative Z value reflecting less disturbance and a low Z value reflecting a high disturbance. The complete list of metrics, their functional groups, and their expected response to increasing disturbance is listed in Table 3-14.

**Table 3-14. Expected Response to Increasing Disturbances for Benthic Metrics [McLaury et al., 2005; Barbour et al., 1999] (Page 1 of 2)**

| Category | No. | 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 |
| | | Plecoptera richness | Decrease |
| | | Trichoptera richness | Decrease |
| | 10 | Oligochaeta 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 | % Oligochaeta | Increase |
| | 19 | % Ephemerellidae | Decrease |
| | 20 | % Hydropsychidae | Increase |
| | 21 | % Odonata | Increase |
| | 22 | % Simuliidae | Increase |

**Table 3-14. Expected Response to Increasing Disturbances for Benthic Metrics [McLaury et al., 2005; Barbour et al., 1999] (Page 2 of 2)**

| Category | No. | Metric | Expected Response to Increasing Disturbance |
|---|---|---|---|
| Functional Group Composition | 23 | % filterers | Increase |
| | 24 | % gatherers | Decrease |
| | 25 | % predators | Decrease |
| | 26 | % scrapers | Decrease |
| | 27 | % shredders | Decrease |
| | 28 | filterer richness | Decrease |
| | 29 | gatherer richness | Decrease |
| | 30 | predator richness | Decrease |
| | 31 | scraper richness | Decrease |
| | 32 | shredder richness | Decrease |
| Diversity/Evenness Measures | 33 | Shannon-Weaver H' (log 10) | Decrease |
| | 34 | Shannon-Weaver H' (log 2) | Decrease |
| | 35 | Shannon-Weaver H' (log e) | Decrease |
| | 36 | Hilsenhoff Biotic Index (HBI) | Increase |
| | 37 | Margalef's Richness | Decrease |
| | 38 | Metals Tolerance Index | Increase |
| | 39 | Pielou's J' | Decrease |
| | 40 | Simpson's Heterogeneity | Decrease |
| | 41 | Jaccard Similarity Index | Decrease |
| | 42 | Percent Similarity | Decrease |
| Habit Metrics | 43 | Long-lived taxa richness | Decrease |
| | 44 | Clinger richness | Decrease |
| | | % Clingers | Decrease |
| | 45 | % tolerant taxa | Increase |

Shaded metrics = White River core metrics.

Periphyton IBI (PIBI) was created using a multimetric approach based on taxonomic ecological classification metrics as well as two nontaxonomic metrics: chlorophyll *a* content and dry ash biomass [Barbour et al., 1999; Hill et al., 2000; 2001]. A total of 11 metrics were used for the PIBI following the same procedure used for BIBI. The metrics used for the PIBI are listed in Table 3-15.

**Table 3-15. Periphyton Core Metrics and Expected Response to Disturbance [Hill et al., 2000; 2001]**

| Ecological Indicator | Response to Disturbance |
|---|---|
| pH | decreases |
| Salinity | increases |
| Organic Nitrogen | increases |
| Oxygen requirement | increases |
| Saprobity | increases |
| Trophic state | increases |
| % silt tolerant taxa | increases |
| species richness | decreases |
| Chlorophyll *a* | decreases |
| biomass | decreases |
| %Dominant | increases |

Results of the IBIs based on Z values are shown in Table 3-16 listed from upstream to downstream and are displayed graphically in Figure 3-27 with sites arranged upstream to downstream on the *x*-axis from left to right. Based on the BIBI, Crawford is the highest ranking site, and the second highest ranking site is the tributary Bear in the Lodge Creek. Westover is the lowest ranking site. The general trend for the BIBI is decreasing values moving downstream. Oacoma breaks this pattern by ranking above Westover and Kadoka. However, the three sites are very closely ranked and it should be noted that the total abundance of Oacoma, Westover, and Kadoka are 11, 11, and 3, respectively. Because of this fact, it is hard to put much confidence on the exact score with the more important point being that they rank as the bottom three. Oglala received a score very similar to the bottom three, even though this site had a corrected abundance of 425. However, the community composition of the benthic macroinvertebrates was structured showing a poor biotic integrity. Oglala has low species richness, with the first dominant taxonomic group (*Caenis latipennis*-mayfly) representing a high percentage of the total abundance. There was a low percentage of gathers and a high percentage of clingers present. Lastly, the Hilsenhoff Biotic Index, a biotic tolerance/intolerance metric that is orientated toward detecting organic pollution [Barbour et al., 1999] is high, indicating a high level of disturbance when compared to the other sites.

**Table 3-16. Benthic and Periphyton IBI Scores Based on Z Values**

| Station | BIBI | Rank | PIBI | Rank |
|---|---|---|---|---|
| Crawford | 6.78 | 1 | –0.97 | 7 |
| Whitney | 0.58 | 3 | 2.72 | 2 |
| State-Line2 | 0.00 | 5 | 1.72 | 3 |
| State-Line1 | 0.19 | 4 | 1.37 | 4 |
| Oglala | –2.51 | 6 | 4.26 | 1 |
| BearLodge | 2.71 | 2 | 1.17 | 5 |
| Kadoka | –2.53 | 8 | 0.4 | 6 |
| Westover | –2.72 | 9 | –2.12 | 8 |
| Oacoma | –2.52 | 7 | –8.53 | 9 |

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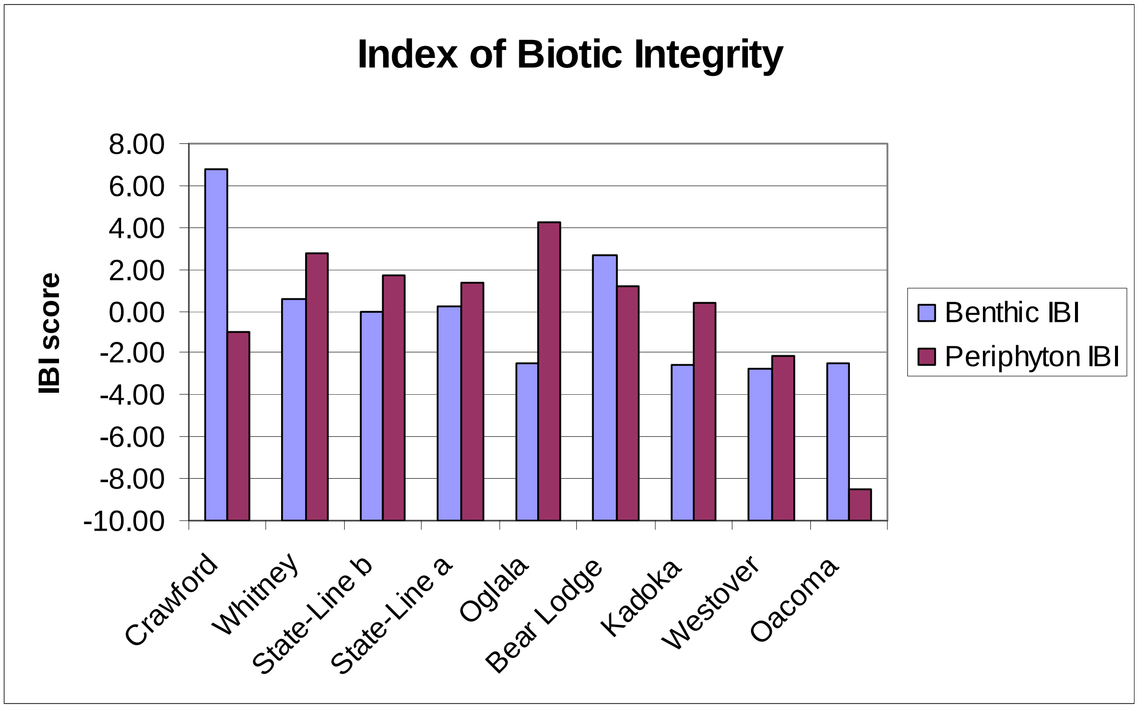


**Figure 3-27.** Index of Biotic Integrity for Benthic and Periphyton Data Based on Z Values.

Oglala had the highest periphyton IBI. Crawford drops to the seventh ranked station with Oacoma being the lowest ranked. Outside of these two sites, the PIBI shows a pattern of decreasing scores downstream. When looking at the individual metric results, Crawford is ranked low due to high organic nutrient loading and productivity. The metrics for organic nitrogen, oxygen requirements, and saprobity (sensitivity to organic pollution), and the trophic state index give a low relative ranking, indicating some sort of disturbance. This indicates that the disturbance is organic in nature and is adding to the productivity of the site. This site is located immediately downstream of the local golf course which may have an affect on the metric results.

The BIBI and PIBI for each site were normalized to a 0 to 100 scale with the highest ranking site being equal to 100 and the lowest ranking site being equal to 0. The average of the two normalized IBI scores for each site was added to create a combined IBI giving equal weight to both the BIBI and the PIPI. This creates an overall White River Index of Biotic Integrity (WR IBI) based on the biologic data collected. Combining the metrics makes it more difficult to key in on specific causes of disturbance; however, it does give a complete relative ranking based on all of the biologic data available. Results for this ranking can be seen in Table 3-17. All three IBI scores are shown on an equal scale in Figure 3-28. It becomes clear that biologic integrity degrades moving downstream in the watershed and is similar to other large river systems. It should be noted that on the bar chart, Bear in the Lodge Creek (site name BearLodge) is a tributary and is closer to the upstream sites than the sites in the lower reaches of the watershed. This can be seen as a watershed representation in Figure 3-29, with the reaches of the White River being color coded according to the combined IBI.

**Table 3-17. Combined White River IBI**

| Rank | Station | WR IBI |
|---|---|---|
| 1 | Crawford | 80 |
| 3 | Whitney | 61 |
| 4 | State-Line2 | 54 |
| 5 | State-Line1 | 54 |
| 6 | Oglala | 51 |
| 2 | BearLodge | 67 |
| 7 | Kadoka | 36 |
| 8 | Westover | 25 |
| 9 | Oacoma | 1 |

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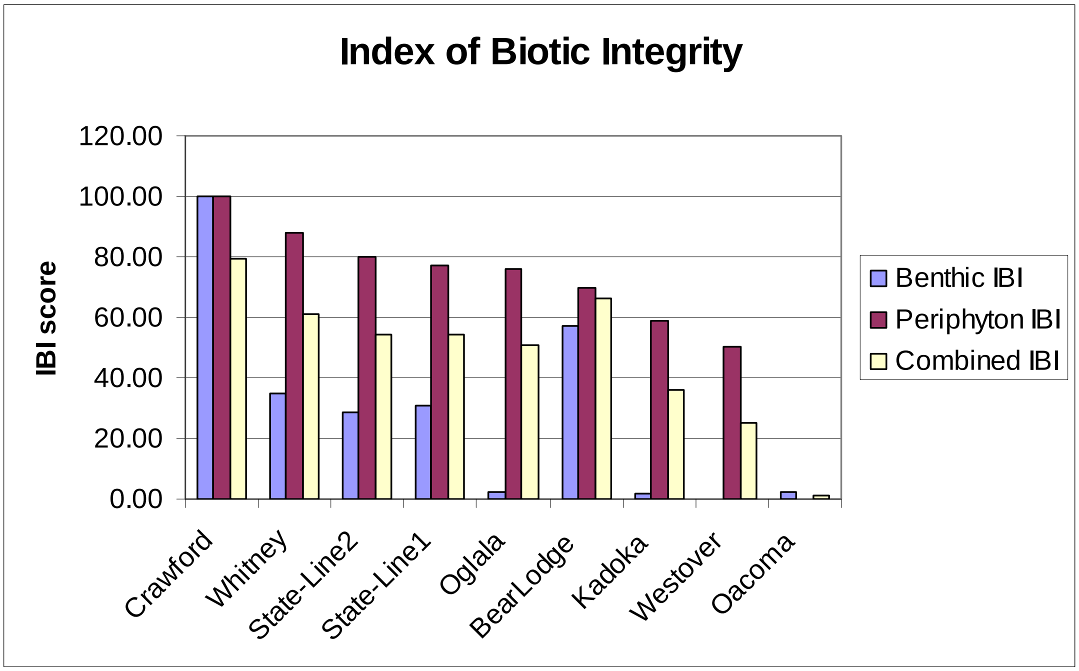


**Figure 3-28.** Bar Chart of the IBI Scores on an Equal Scale.

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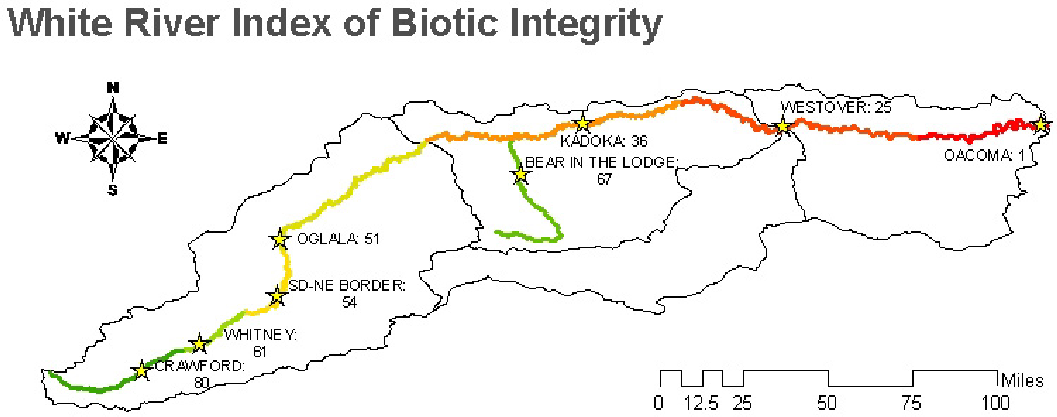


**Figure 3-29.** Graphical Representation of the White River IBI Scores for the Different Reaches of the White River.

Biologic metrics indicate lower reaches have poor biological habitat probably because of the high silt load. This is apparent with the low corrected abundances for benthic macroinvertebrates found at the three sites below the badlands. These three sites also all had negative Z values for the percent silt tolerant species metric for periphyton along with Bear in the Lodge Creek. Bear in the Lodge Creek most likely has a high silt content but offers fairly good habitat for both benthic macroinvertebrates and periphyton. The site at Oglala has good vegetative productivity but has water quality or substrate habitat that does not support biological diversity of benthic macroinvertebrates. There is some contradiction in the metrics of Oglala with the Hilsenhoff biotic index for benthic macroinvertebrates being relatively low while the saprobity metric for periphyton being relatively high. Both of these metrics are geared toward detecting organic pollution. QA/QC samples collected at the State-Line site all ranked very similar, indicating repeatability giving greater confidence in the data collection and methods used.

The IBIs for periphyton and benthic macroinvertebrate data, as well as the combined IBI, were regressed against channel metrics and water-quality data. Three regressions had $R^2$ values greater than 80 percent, while 26 regressions had $R^2$ values greater than 50 percent.

The PIBI ($R^2$=82.6) was highly correlated with median discharge at each station. In general, the PIBI scores are negatively correlated to stream width and stream discharge. BIBI is most highly correlated with median discharge normalized to drainage area, being negatively correlated, with $R^2$=80.5. Weaker correlations indicate benthic macroinvertebrates are negatively correlated with the substrate size classes, with larger substrate being associated with higher benthic integrity. The combined WR IBI had a high positive correlation with bank length. The WR IBI is the only IBI where the TSS concentrations were correlated with an $R^2$ value greater than 50 percent, with TSS concentrations being negatively correlated with the WR IBI.

### 3.3.7 Stream Classification

Classifying streams according to a consistent and reproducible classification scheme is often desirable to discuss and compare different streams. For the White River, two such systems were used to categorize the sites sampled for physical habitat. The first is Rosgen's geomorphic stream classification system and the second is Schumm's channel evolution model (CEM).

#### 3.3.7.1 Rosgen's Geomorphic Stream Classification

Rosgen's system of classification [Rosgen, 1996] is a four-level system ranging from general morphologic characterization at level one to a detailed description focusing on validation of relationships established at level four. At each level of classification, the detail and resolution of classification increases. For this project, the level two classification scheme was utilized. The focus of this level is on the stream morphological description which takes into account criteria measured at the stream cross sections such as entrenchment ratios; width-to-depth ratios; dominant channel substrate; and also the larger scale reach variables of slope, bed features, and sinuosity. The key used for stream classification is shown in Figure 3-30 [Rosgen, 1996]. The classification of each site is summarized in Table 3-18.

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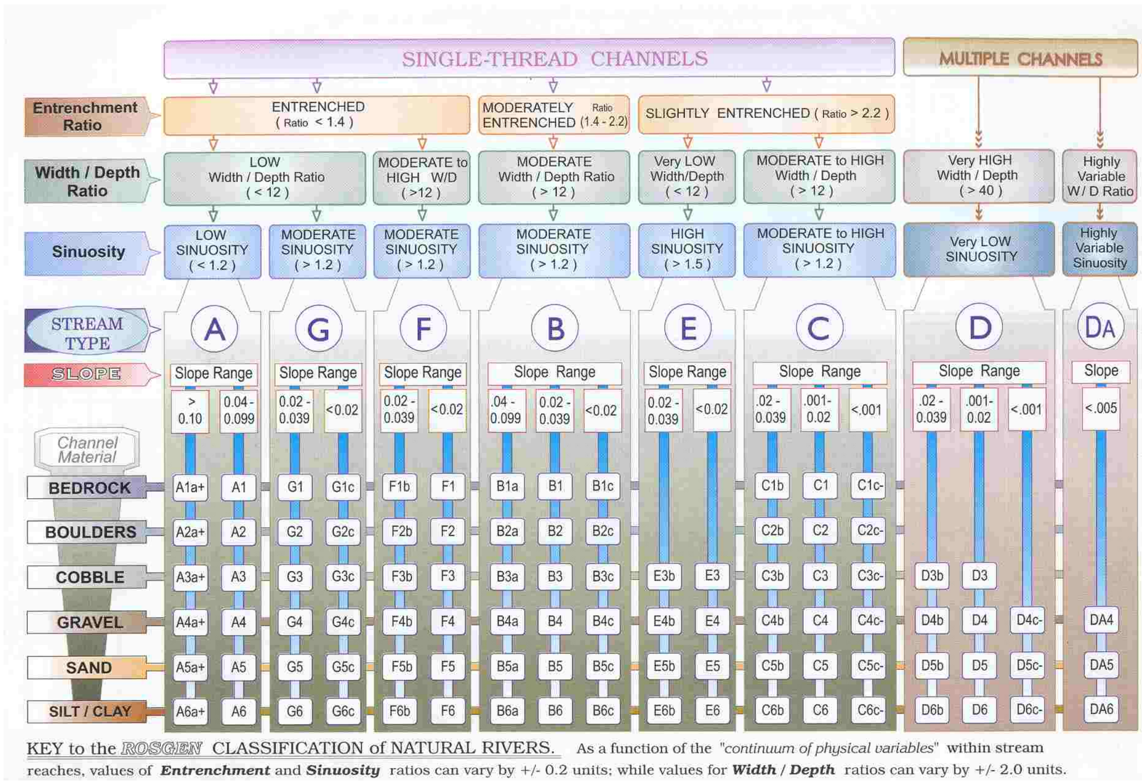


**Figure 3-30.** Rosgen Classification Key Used for Cataloging of Natural Rivers [Rosgen, 1996].

Each of the sites on the White River in the middle and lower reaches classified as F5 type streams. The F5 stream is described as a sand-dominated entrenched system, with moderate to high sediment supply and gently sloping gradients under 2 percent. The tributary site on Black Pipe Creek classified as a C4 stream. The C4 stream type is described as moderately entrenched, low gradient, and gravel dominated with a moderate to high sediment supply. Point bars and other depositional features are common in this stream type.

The upper sites and the site on Bear in the Lodge Creek are all classified as G type streams. The Crawford station is unique from all other stations on the White River, classified as a G4 stream based on a slightly higher slope and substrate dominated by gravel. G4 stream types are incised streams with moderate gradients, low width/depth ratios, and characteristic step/pool morphology. These stream types have a high sediment supply and often have high bedload transport rate, with the ratio of bedload to total sediment supply exceeding 50 percent.

Bear in the Lodge Creek is also classified as a G4 stream, being very similar to the Crawford station with higher slopes and substrate dominated by gravel and coarse material. The other sites have lower slopes and are classified as either G5c or G6c stream types distinguished by the dominant substrate. The State-Line station is classified as a G5c stream with sand being more dominate than fines, while Oglala and Whitney stations are both classified as G6c streams dominated by fines. Bedload materials tend to be lower in these stream types with bedload transport being very low in the G6c types of streams.

**Table 3-18. Stream Classifications**

| Site Name | Rosgen | CEM | F |
|---|---|---|---|
| Crawford | G4 | 4 | 7.7 |
| Whitney | G6c | 3 | 5.1 |
| State-Line | G5c | 3 | 5.5 |
| Oglala | G6c | 3 | 5.9 |
| Rockyford | F5 | 4 | 42.1 |
| Bear in the Lodge | G4 | 3 | 6.7 |
| Kadoka | F5 | 4 | 59.4 |
| Black Pipe | C4 | 4 | 8.6 |
| Westover | F5 | 4 | 99.4 |
| Oacoma | F5 | 4 | 73.3 |

#### 3.3.7.2 Schumm's Channel Evolution Model

Schumm's CEM classifies different evolutionary stages of a channel along a longitudinal profile in response to an induced disturbance event causing incision [Schumm et al., 1984]. This classification represents a spatial distribution along the profile instead of timing of the response to describe the current state of the channel. There are five stages described in the CEM ranging from initiation of the incision process (Stage I) to reestablishment of a quasi-equilibrium state (Stage V). The five stages are described as a function of their width-to-depth ratios (F) and shown graphically in Figure 3-31.

Stream incision is a function of a disturbance causing an initial nick-point creating a head cut that moves upstream as a function of discharge and sediment supply. Stage I is upstream of the active head cut and is characterized by little to no sediment storage before the active incision process caused by the passing of the active head cut. Stage II, located immediately downstream of the head cut, represents the active incision process. Stage III is dominated by widening of the stream channel, associated with bank undercutting and failure. Stage IV is associated with the widening process but at a reduced rate from Stage III. Stage IV is characterized by the formation of a sinuous thalweg with the start of alternate point bar depositions. Stage V is the final stage where quasi-equilibrium is achieved. At this stage, the alternating point bars have become stabilized by perennial vegetation such as willow growths. Bank stability has returned with bank failures being due to channel migration rather than channel widening.

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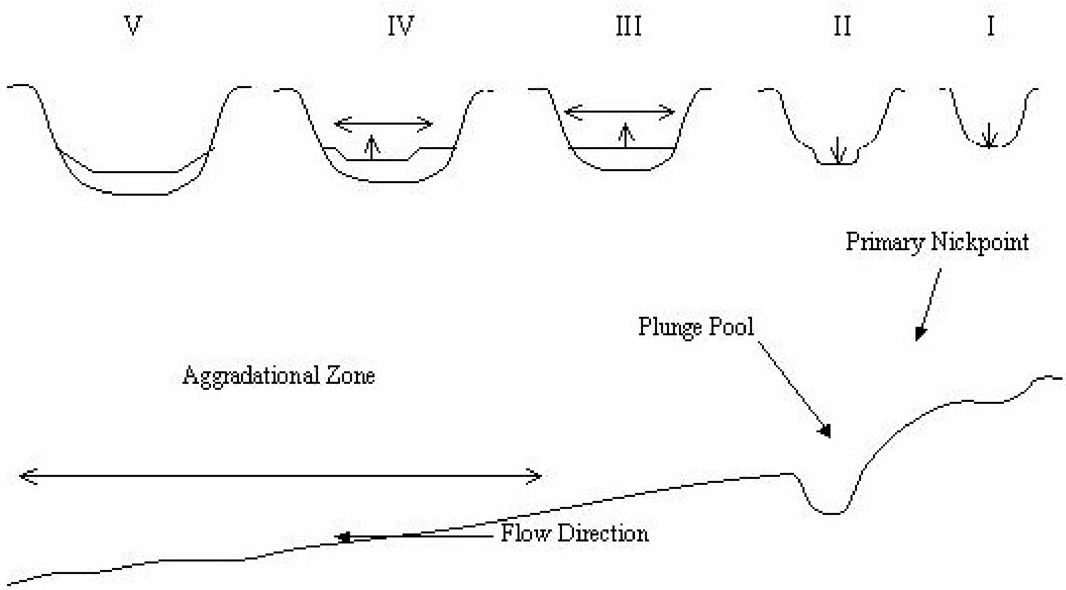


**Figure 3-31.** Schematic Longitudinal Profile of an Active Channel Depicting Evolutionary Stages as Defined by Schumm et al. [1984].

CEM classification of the river reaches as well as F values are listed in Table 3-18. The middle and lower reaches of the river were all classified as Stage IV channels, as was Black Pipe Creek. Roeser [2004] reported that the White River was most likely in a state of quasi-equilibrium based on hydraulic geometry curve analysis following procedures presented by Leopold and Maddok [1953]. The lower reaches of the White River are approaching Stage V; however, the process is not complete. F values for these stations were well above the value of eight presented by Schumm as the breaking point between Stage IV and Stage V; however, the station at Oacoma was the only station with point bar deposition above bankfull level with vegetation. Developing point bars were common throughout the reach; however, they did not appear to be permanent, with no vegetation located on most and a cut off channel along the bank still being common. Additionally, bank failures and undercutting were still common and not observed to be a function of lateral stream migration.

Part of the explanation for lack of permanent point bar deposition may be a function of bed material. The Westover station was dominated by midchannel bar deposition that appeared to be unstable and actively migrating. Properties of a sand-dominated substrate that appear to be in constant flux would affect the stabilization of point bar deposition. The sites of Oacoma and Black Pipe had the most apparent point bar deposition. Each of the sites in the lower and middle reaches has some evidence of a developing sinuous thalweg with associated point bars.

The upper stations, including Bear in the Lodge Creek with the exception of Crawford, were classified as Stage III streams. These stations were characterized by steep banks and a box-shaped cross section with bank failures being common. The Oglala station and Bear in the Lodge Creek station were further along in the progression of Stage III with the other two stations being closer to a Stage II condition. This is reflected in the physical habitat metrics for bank angle, undercut distance, and the percentage of banks containing slumpage. The Oglala station and Bear in the Lodge Creek station had lower mean bank angles and the highest percentage of banks containing slumpage. These stations were in the widening phase of the incision process. The State-Line and Whitney stations were very box-like in cross section, being closer to a Stage II. However, bank failures and undercutting were clearly occurring at both of these stations, placing these stations in the widening phase. With the exception of Bear in the Lodge Creek, $F$ values were all near the value expected for the assigned classification level as reported by Schumm et al. [1984].

Crawford was classified as a Stage IV based on the condition of the stream and the F value at the selected cross section. This station had much more gently sloping banks than the other upper stations. Undercutting and bank failures were still occurring but appeared to be mostly a function of a beaver dam that was constructed within the site reach. The later stage of evolution at this station may be due to bank modifications and stabilization that most likely took place in the Crawford City Park. The stabilization activity advanced the evolution process into the later stage by reducing the effects of widening on the bank morphology.

## 3.4 SUPPLEMENTAL DATA ANALYSIS

### 3.4.1 Watershed Soil Erosion Modeling

A Soil Erosion Susceptibility Model was created using the RUSLE. RUSLE is given as:

$$E = RKLSCP \tag{3-1}$$

where:

$E$ = erosion

$R$ = rain fall erodibility factor

$K$ = soil erodibility factor

$L$ = Slope length steepness factor normalized to 72.6 feet

$S$ = Slope normalized to 9 percent
(note, it is now common to lump $L$ and $S$ into one LS term)

$C$ = Cropping management factor

$P$ = Conservation practice factor [Julien, 2002].

The analysis was performed using tools in **ArcGIS** 8.3 [Environmental Systems Research Institute, Inc., 2002]. The layers needed for the analysis were a DEM, a soils layer, and a land use layer as well as rainfall data. The DEM for this model was a 30-meter resolution DEM with a 1-meter vertical resolution that was a product of merging several DEMs from both Nebraska and South Dakota using the mosaic map algebra function in ArcMap's Raster Calculator. It has been noted that the 10-meter DEM format with 0.1-meter vertical resolution is a more suitable DEM to use. However, at the time of this project, the availability of these DEMs was limited in South Dakota. The State Soil and Geographic Database (STATSGO) database soil data and the Anderson Level II land use came from the Basins database [U.S. Environmental Protection Agency, 2001b]. Rainfall data were assumed to be evenly distributed for this model.

At a large scale, the $LS$ factor and the $C$ factors are the most important with all other factors evening out on the watershed scale [Julien, 2002]. This was the reason that the rainfall factor, which is a function of maximum probable intensity, was neglected. It was assumed that the maximum intensity across the watershed would be nearly equal. The $P$ factor was also neglected because of its lack of importance in addition to the fact that information needed for the factor was not available in the land use layer at the scale present in the Basins data. By neglecting these factors, the results of the model will produce a relative magnitude of sediment yield based primarily on topography and soil characteristics instead of giving actual sediment yield estimates.

The $LS$ factor was computed using spatial analysis following the procedure presented by Mitasova et al. [2000]. For this procedure, the length factor was replaced by a flow accumulation factor that can be calculated in GIS using the DEM. Three main steps are needed to compute the $LS$ factor in a raster file. First, the Slope tool in Surface Analysis is used to calculate a slope grid based on the DEM. The second step is to create a flow accumulation grid based on the DEM. The final step is to combine the slope grid with the flow grid. This was done by using the following raster calculation:

$$Pow\left(\left[flowacc\right]\times resolution/22.1,0.6\right)\times Pow\left(Sin\left[slope\right]\times 0.017450/0.09,1.3\right) \qquad (3\text{-}2)$$

The resolution of the DEMs for this model was 30 meters and was placed in the proper location in the equation.

The soil factor *K* must also be a raster file in order to use the raster calculator with each pixel representing a *K* factor. The *K* factor is listed in the layers database table of the database. The layers table represents the different horizontal layers of each soil type presented in the components table. The components layer presents data associated with the many different soil types associated with each map unit identification (MUID) given in the STATSGO shapefile of soils. In the future, this one-to-many association present in the STATSGO database may be bypassed using the SSURGO database which will offer a higher resolution of soil polygons so that different components will each be their own polygon. For this analysis, the *K* factor for the surface layer was chosen for each soil type since the erosion occurs at the ground surface and not at the subsurface levels. *K* factors were spatially averaged for each MUID, using the component percents present in the component data table. This was performed by using a combination of the GIS summarize function and Microsoft Excel. A table was created in excel containing the map unit identifications as well as *K* factors and then saved as a .dbf file. This file was then added to **ArcMap** and a join was performed with the soils polygon shapefile based on the MUID field. The distribution of the *K* factors is shown in Figure 3-32.

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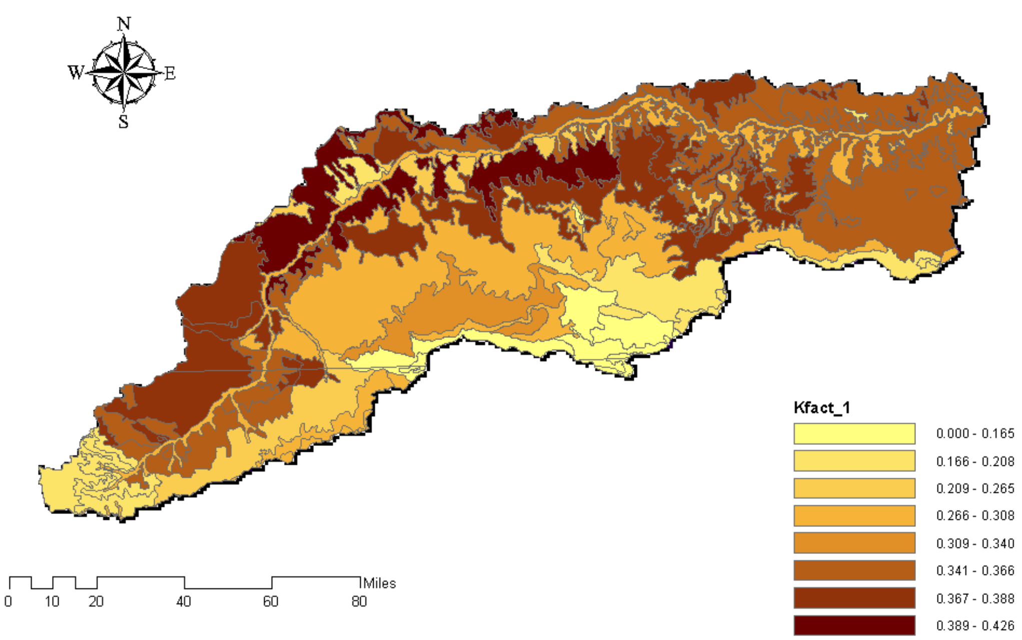


**Figure 3-32.** Soil Erodibility Factors in the White River Watershed Used for RUSLE Modeling.

The *C* factor was assigned by using values presented by Julien [2002] or by Mitasova et al. [2000]. Several categories such as urban areas were assigned NoData values since they are not representative of the types of areas that the RUSLE is applied to. These factors needed to be added to the attribute table of the landuse shapefile. This step also involved both the GIS summarize function as well as calculations in Excel. C factors used for each landuse type are listed in Table 3-19. A map of the distribution of C factors in the White River watershed is shown in Figure 3-33.

Both the soil's shapefile and landuse shapefile needed to be converted to rasters based on the *C* factors and *K* factors fields. Both files were reprojected to the same coordinate system as the DEM raster file. Once all the files are created and are in raster formats, the erosion factor *E* was calculated by multiplying the *LS*, *C* factor, and *K* factor rasters. The *R* and *P* factors were not used in this analysis. Each cell of the erosion raster was averaged using the neighborhood statistics function in spatial analyst. A circular area with a radius of 20 cells was used for this calculation. This was performed to smooth the raster visually while highlighting areas of high erosion susceptibility. The resulting sediment yield raster map can be seen in Figure 3-34.

### 3.4.2 Fisheries Data

The most recent fisheries data were collected as part of a comprehensive habitat sampling and population monitoring project through South Dakota State University as part of a graduate research project [Fryda, 2001]. The purpose of this project was to sample physical habitat throughout the watershed and to establish baseline data about fish species composition and relative abundances in the portion of the White River in South Dakota. The report from this project is summarized below with tables of the results shown in Appendix J. No new fisheries data were collected as part of this project.

The White River is classified as a semipermanent warm-water fishery in its assigned beneficial uses. A total of 11 sites were sampled by South Dakota State University personnel in the White River watershed; 4 sites in the upper White River Basin, 4 sites in the middle White River Basin, and 3 sites in the lower White River Basin. Seining multiple habitat types within each reach was the main sampling technique; however, in an attempt to increase the efficiency of sampling channel catfish (*Ictalurus punctatus*), soybean-baited trap nets and hoop nets were also used. Twenty species of fish representing five different families were sampled in the White River. Cyprinidae (74 percent) and Ictaluridae (23 percent) represented the dominant families in the White River with Clupiedae (herring family), Catostomidae (suckers family), Centrarcidae (sunfish family), and Percidae (perch family) comprising the remaining 3 percent of the sample. The results of this study show that the White River is typical of western South Dakota streams dominated by species that are adapted to the adverse conditions found in an arid region [Fryda, 2001]. The report suggests that it is likely the White River's species composition has changed very little from its historic condition, finding only one nonnative

**Table 3-19. List of *C* Factors Used for the RUSLE**

| Land Use Category | *C* Factor |
|---|---|
| Bare Exposed Rock | 0 |
| Commercial and Services | NoData |
| Commercial Services | NoData |
| Confined Feeding Ops | 0.4 |
| Cropland and Pasture | 0.5 |
| Deciduous Forest Land | 0.005 |
| Evergreen Forest Land | 0.005 |
| Forested Wetlands | 0 |
| Herbaceous Rangeland | 0.1 |
| Industrial | NoData |
| Lakes | 0 |
| Mixed Forest Land | 0.005 |
| Mixed Rangeland | 0.1 |
| Mixed Urban or Built-up | NoData |
| Nonforested Wetlands | 0 |
| Other Agricultural Land | 0.5 |
| Other Urban or Built-up | NoData |
| Reservoirs | 0 |
| Sandy Area (Nonbeach) | 0.45 |
| Shrub and Brush Rangeland | 0.18 |
| Strip Mines | NoData |
| Strip Mines, Quarries | NoData |
| Trans, Communication, Utilities | NoData |
| Transportation, Communication | NoData |
| Shrub and Brush Rangeland | 0.18 |
| Residential | NoData |

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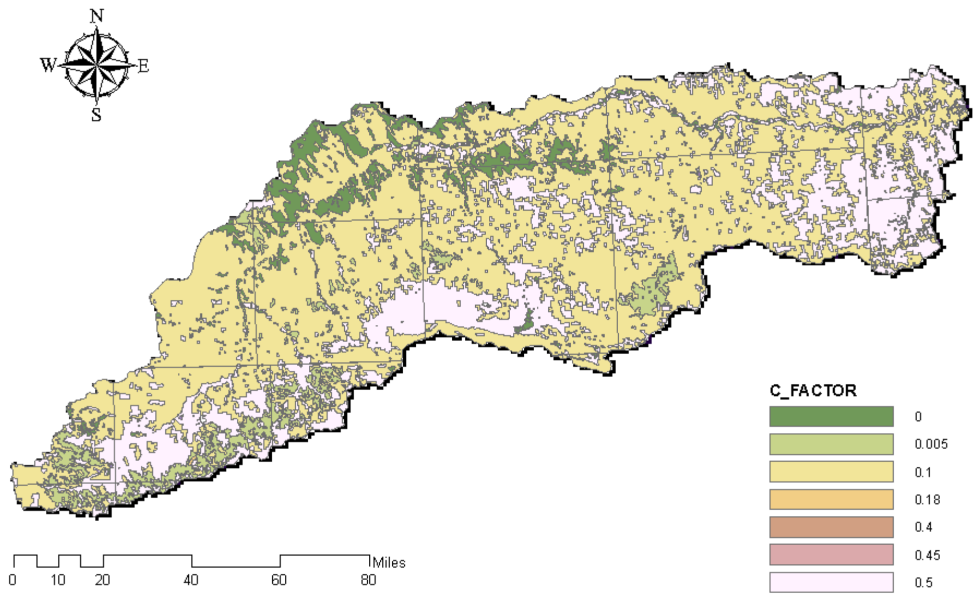


**Figure 3-33.** Cropping Management Factors in the White River Watershed Used for RUSLE Modeling.

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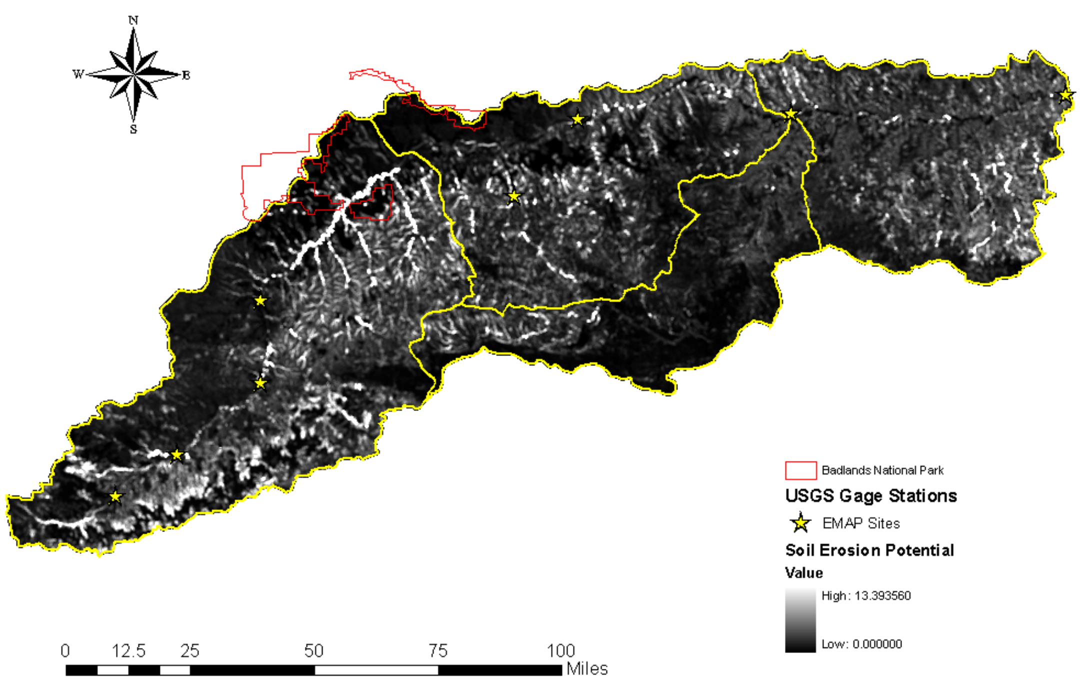


**Figure 3-34.** Soil Erosion Potential for the White River Watershed.

species, the common carp (*Cyprinus carpio*), along with several species of special concern representing a large percentage of the fish community. The sturgeon chub (*Macrhybopsis gelida*), the plains minnow (*Hybognathus placitus*) and the flathead chub (*Platygobio gracilis*) are all species of special concern; however, they comprised a cumulative of 61 percent of the fishes sampled. Contrary to the expected pattern, as reported by Vannote et al. [1980], species richness declined in the downstream reaches of the watershed. This corresponds to the general trend found in this TMDL project's index of biotic integrity based on both the periphyton and benthic macroinvertebrate communities. Channel catfish represented the only abundant sport fish found in the river; however, the abundance of relatively small, immature fish led researchers to conclude that the White River is mostly a nursery and staging area for spawning activities with adults migrating into the river in the spring high flow months from Lewis and Clark Reservoir on the Missouri River and returning in the fall.

Future management of the White River as a sport fishery is limited due to the limited abundance of sport fish. The report [Fryda, 2001] suggests that the White River may be a critical area for the protection of rare and threatened species, citing *Rivers of Life*, a publication by the Nature Conservancy that identified the White River as a watershed critical to protecting freshwater biodiversity and at-risk fish species. The researchers recommended future fish community monitoring using the Morisita-Horn index of community similarity, stating that good baseline data were collected for future fisheries work on the White River.

### 3.4.3 Endangered Species

The South Dakota Natural Heritage Database [2004] identified four species, the whooping crane (*Grus Americana*), black-footed ferret (*Mustela nigripes*), pallid sturgeon (*Scaphirhynchus albus*), and american burying beetle (*Nicrophorus americanus*), as endangered on the federal endangered species list in the White River Watershed. The state of South Dakota lists the whooping crane as SZN, nonbreeding, and no definable occurrences for conservation purposes. This category is usually assigned to migrants. The black-footed ferret is currently part of a National Recovery Plan in which the Conata Basin is identified as one of six nonessential experimental population centers where ferret reintroduction is underway. The most recent introduction in the Conata Basin took place in 1999 [National Park Service, 2004]. The black-footed ferret, the pallid sturgeon, and the american burying beetle are listed as S1, critically imperiled because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.

Additionally, there is one species, the lynx (*Lynx canadensis*), listed as threatened on the federal list and three species, the sturgeon chub (*Macrhybopsis gelida*), the swift fox (*Vulpes velox*), and the pearl dace (*Margariscus margarita*), listed as threatened on the South Dakota endangered species list. The complete list of rare, threatened, and endangered species is listed in Appendix K. A total of 11 bird species, 8 mammal species, 7 fish species, 5 reptile species, 1 amphibian species, 1 insect specie, and 14 plant species are identified as rare, threatened, or endangered occurring in the White River Watershed. None of these species were encountered during this study. Special care should be taken when implementing BMPs in the White River Watershed.

### 3.4.4 Conceptual Sediment Budget

Based on the available historic data for the White River Watershed along with the sediment erosion modeling and stream physical habitat assessment, a conceptual sediment budget was created outlining source areas of sediment while distinguishing between natural background and man-induced sediment in the watershed. The budget is displayed graphically in Figure 3-35.

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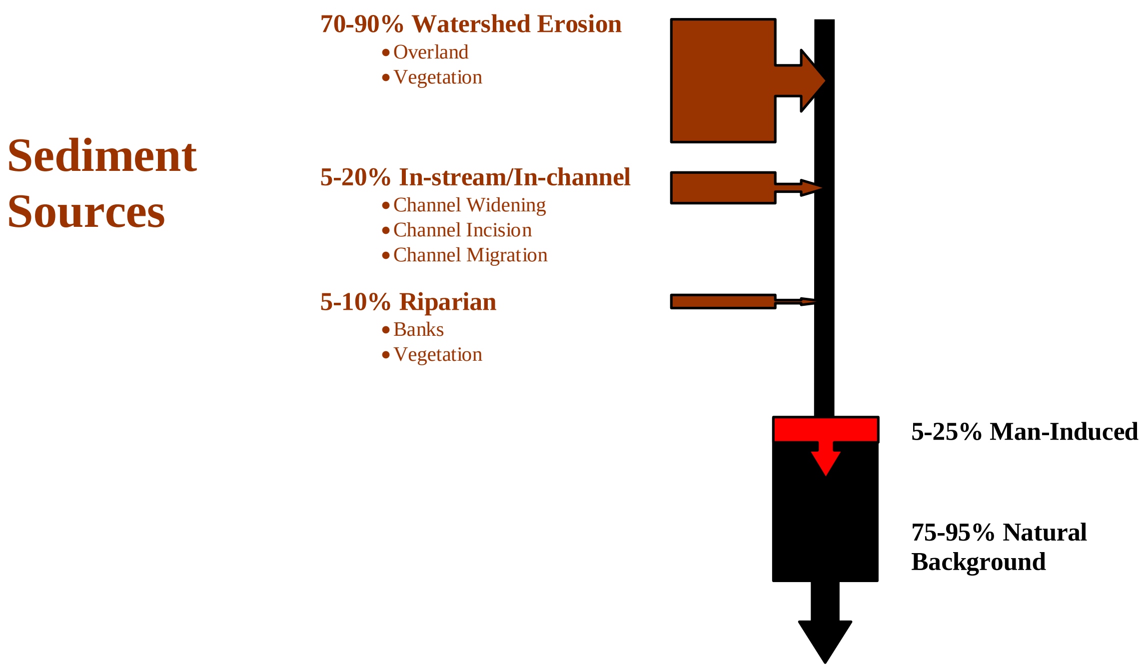


**Figure 3-35.** Conceptual Sediment Budget Outlining Sediment Erosion by Source Areas Along With Man-Made and Natural Background of the System.

Most of the sediment in the White River is caused by watershed erosion from overland flow. It is clear that the bulk of this originates in the Badlands area and is a function of the steep sided bluffs with virtually no vegetation. It was estimated that 70 to 90 percent is from this area. Approximately 5 to 20 percent of the sediment is estimated to come from in-stream/in-channel sources. This includes channel widening, channel incision, and channel migration. These processes have a larger impact on the lower reaches of the watershed where widening and channel migration are more prominent than in the upper watersheds. This corresponds to the addition of water from the Little White River as well as a change in geology where the Pierre Shale Groups are more prominent. This portion of the watershed is similar to the Bad River Watershed where channel incision was found to be the larger contributor to sediment loading. However, this contribution is only a small portion of the sediment in the White River, when compared to the contribution added by the Badlands. The final area of sediment contribution comes from the riparian zone. This is the smallest area of contribution to sediment loading and comes from bank failures and erosion due to a lack of riparian vegetation which holds sediment in place. This is a natural vegetative state in some areas, while over grazing of the riparian zone is a contributor in others.

The sediment load in the White River is largely natural, with an estimated 75 to 95 percent being considered natural background. Only 5 to 25 percent is estimated to be man-induced. Most of the sediment in the system originates in the Badlands area, which is a natural geologic phenomenon. Other natural processes will be included in the natural sediment loading, such as wildlife grazing impacts. One example of natural wildlife that may contribute to the natural sediment loading is prairie dog towns. However, the magnitude of these impacts to sediment loading is small compared to the large background coming from the Badlands.

The fact that the White River has a large natural background for sediment loading is supported by the previously collected fisheries data, where a large abundance of native, threatened, and endangered species were found in the White River [Fryda, 2001]. This fact makes it clear that the White River has not been highly impacted by anthropogenic influences, with conditions found today being very similar to the historic condition of the river.

## 3.5 QUALITY ASSURANCE REPORTING

Replicate QA/QC samples were collected for the biologic sampling at one station during the fall of 2003. A replicate composite sample was collected for both periphyton and benthic macroinvertebrate analysis at the State-Line physical habitat sampling location, immediately following the collection of the original sample. The same transect locations were used for the original and the replicate samples. IBI scores were calculated for both samples and the relative percent error was calculated by dividing the difference between the two samples by the total difference of all the samples collected. The results are summarized in Table 3-20.

A total of 360 data sheets were recoded in the field and transferred to electronic forms after sampling was complete. Each sheet contains between 11 and 106 individual recorded field observations with an average number of 71. In order to verify the quality of the data entered into the electronic forms, 10.2 percent of all the data sheets, or 37 sheets, were checked for data entry errors. Of the sheets verified, one mistake was found on one observation. That represents an estimated error rate of .03 percent, assuming 71 data entry locations on each sheet.

**Table 3-20. Biologic Sampling Quality Assurance/Quality Control Samples Collected in the White River in the Fall 2003**

| | BIBI | PIBI |
|---|---|---|
| Routine | 0.19 | 1.37 |
| Replicate | 0.00 | 1.72 |
| Relative % Error | 2% | 3% |

## 3.6 WATERSHED ANALYSIS SUMMARY AND RECOMMENDATIONS

Based on physical habitat classification and analyses of historical discharge and water-quality data, three unique reaches were identified on the White River. The breaks of these reaches were determined by geology of the watershed and hydrology of the system. The reaches are as follows: (1) from the headwaters to the confluence of Willow Creek 5 miles north of the gage station identified as the White River near Oglala; (2) Willow Creek to the confluence of the Little White River; and (3) the confluence of the Little White River to the mouth of the river near Oacoma, South Dakota (Figure 3-36).

The upper reach is the least impaired of the three reaches. It is currently impaired due to high TSS loading with a median value of 139 mg/l. The river at this station needs a 90 percent reduction in TSS concentrations in order to comply with current water-quality standards. This reach is not impaired due to fecal coliform loading, meeting the water-quality standard.

The middle reach is the critical reach of the White River for both TSS and fecal coliform bacteria. The station near Kadoka has a median TSS value of 1,118 mg/l and a median fecal coliform bacteria value of 200 cfu/100 ml. The river at this station needs a 99 percent reduction in TSS concentrations and a 78 percent reduction in fecal coliforms in order to comply with current water-quality standards.

The lower reach of the river sees improvements in water quality for TSS concentrations and fecal coliform concentrations. The station near Oacoma has a median TSS value of 1,075. This site has a higher annual TSS load than the station at Kadoka. The lower concentrations for TSS in the lower reach can be attributed to dilution effects, mainly from the confluence of the Little White River. The median value for fecal coliforms is 120 cfu/100 ml. The river at this station needs a 99 percent reduction in TSS concentrations and a 20 percent reduction in fecal coliforms in order to comply with current water-quality standards.

The TSS water-quality standard is unattainable in this system. It is estimated that between 70 and 90 percent of the TSS loading of the White River comes from natural background of the system. Much of the load is coming from areas in and around the Badlands National Parks where the geology of the area causes steep sided bluffs with little to no vegetation. This causes low infiltration rates with high runoff and erosion rates. BMPs in these areas would be ineffective. Improvements in the TSS concentrations for the upper reach of the watershed would be possible. Much of the watershed for the upper reach of the river is in Nebraska. It is not known how much of the load for the upper reach originates upstream of the Nebraska/South Dakota border. The addition of a water-quality monitoring station at this location may be beneficial. BMPs possible for the upper reach watershed could include conservation cover (Practice Code 327), rotational grazing (Practice Code 528A), stream bank protection (Practice Code 580), and upland wildlife habitat management (Practice Code 645). The BMPs implemented in the upper portion will not cause a sizable reduction in the TSS loading in the middle and lower reaches of the White River. Therefore, the implementation of BMPs in the upper watershed may not be cost effective when dealing with water quality on a watershed scale.

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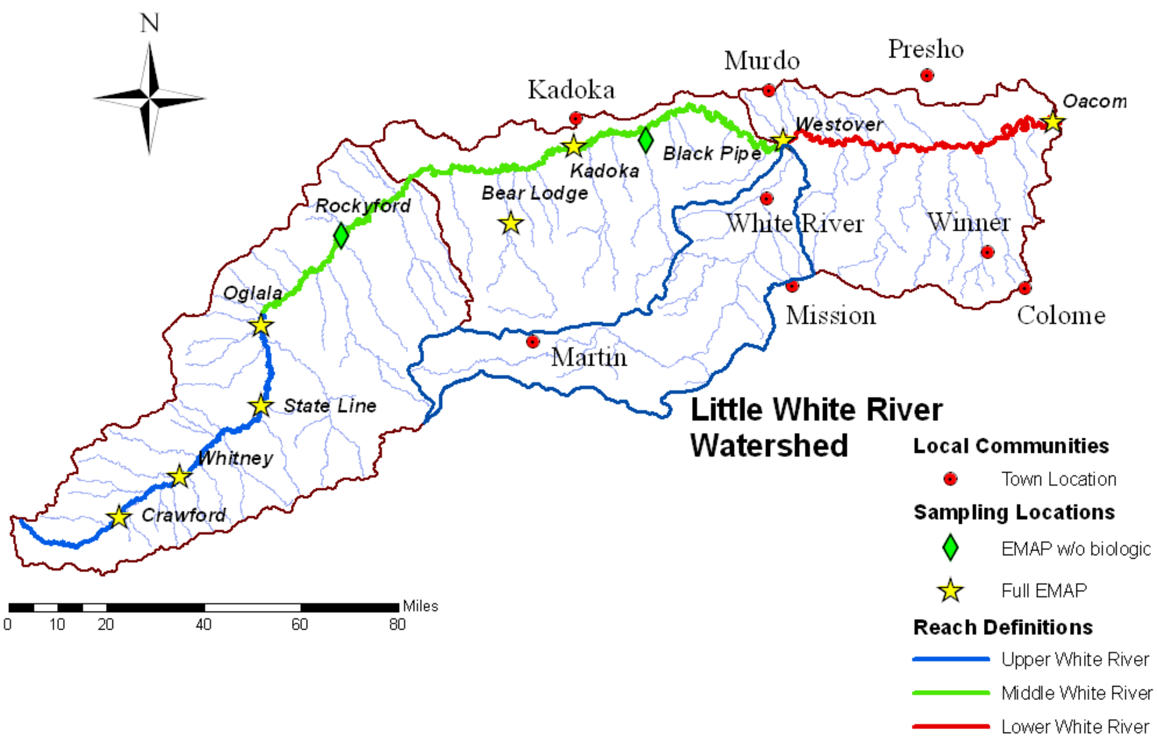


**Figure 3-36.** Distinct Reaches of the White River, Based on Stream Hydrology, Water Quality, and Geology.

Site-specific standards for the White River based on the 95 percent exceedence level should be implemented for TSS in the White River. The 95 percent exceedence levels for Oglala, Kadoka, and Oacoma are approximately 4,425 mg/l, 24,300 mg/l, and 21,550 mg/l, respectively. Site-specific standards based on these concentrations would be conservative and protective of the beneficial uses for the White River. Biological data collected as part of this project, along with previously collected data, show that the White River is currently a healthy and natural system. Major alterations to the system; specifically, reducing the TSS loading, could be potentially harmful to native fish species that have evolved in high sediment systems such as the White River.

The water-quality standard for fecal coliform bacteria is attainable for the White River. The focus of the fecal coliform BMPs should be, but not limited to, the watershed for the middle reach of the White River. Possible BMPs for implementation should include conservation cover (Practice Code 327), rotational grazing (Practice Code 528A), stream bank protection (Practice Code 580), filter strips (Practice Code 393A), and upland wildlife habitat management (Practice Code 645). A slight decrease in the TSS loading of the White River is expected with the implementation of these BMPs. This is especially true of the lower reach of the river, where the additional TSS contributions from the river are more influenced by channel incision. Additional work may be needed to clearly identify the contributions of sediment load due to watershed erosion and channel incision of tributaries.

The implementations of BMPs recommended in this report are not likely to have an adverse effect on the endangered species in the White River Watershed [South Dakota Technical Guide, 2004]. However, because several endangered species are found in the White River and the White River Watershed, special attention and care needs to take place when implementing BMPs to ensure that endangered species are not negatively affected in the White River Watershed.

# 4.0 PUBLIC INVOLVEMENT AND COORDINATION

Public involvement and coordination was organized primary through the South-Central Resources, Conservation and Development (RC&D) and Badlands RC&D offices located in White River and Martin, South Dakota, respectively. Two public meetings were held (the first in Kadoka, South Dakota, and the second in White River, South Dakota) to gain public insight about the White River Watershed while informing the public of the project goals, results and conclusions. A complete list of the organizations the public meeting announcement was sent to as well as the announcement as it appeared in the local newspaper is listed below, as prepared by Ms. Geri Livermont with the Badlands RC&D. Besides the organizations listed below, personal invitations were extended to personnel with the USGS, the SD DENR, the Bureau of Indian Affairs (BIA), and the South Dakota School of Mines and Technology (SDSM&T).

Public Service Announcements (PSAs) and news releases were sent out by Badlands RC&D for White River Watershed public meetings held in Kadoka on September 21, 2004, and White River on September 23, 2004.

Public Service Announcements:

| Station | Town | Fax |
|---|---|---|
| KCCR Radio | Pierre, SD | 605.224.0095 |
| KGFX/FOX Radio | Pierre, SD | 605.224.8984 |
| KINI Radio | Rosebud, SD | 605.747.5791 |
| KOTA Radio & TV | Rapid City, SD | 605.342.7305 |
| KSDZ Radio | Gordon, NE | 308.282.0061 |
| KCSR 610 AM | | 308.432.5545 |
| KILI | Porcupine, SD | 605.867.5634 |
| KBHB | Sturgis, SD | 605.347.5120 |
| Rapid City Radio Stations (6) | | 605.343.9012 |
| KQKY | | 605.236.6465 |
| KAAQ | Alliance, NE | 308.762.7804 |
| KWYR | | 605.842.3875 |

Meeting announcements for the White River Watershed meetings were sent to the following newspapers:

***Bennett County Booster II***, Martin, South Dakot. The announcement was also forwarded to the papers owned by Tim Huether, editor.

***Pioneer Review***, Philip, South Dakota

***Kadoka Press***, Kadoka, South Dakota.

**Public Service Announcement and News Release**

**White River Watershed Public Meeting Notice**

All persons interested in the White River Watershed, especially those who have working knowledge of the White River Watershed and its current management, are invited to attend either of two public meetings:

| September 23, 2004 | September 21, 2004 |
|---|---|
| Mellette County Courthouse<br>White River, South Dakota | Club 27<br>Kadoka, South Dakota |
| 7 p.m. (CST) | 7 p.m. (MST) |

At the meeting, personnel working on the project will provide a short presentation followed by a public forum. For further information, please contact Theresa Benda, South Central RC&D at 605.259.3547.

*— Programs and services are available on a nondiscriminatory basis. —*

## 4.1 STATE AGENCIES

The SD DENR is the statewide pollution control agency and was, therefore, the overseeing state agency for this project. They provided funding for this project in the form of administering the 319 funds as well as the state 319 matching dollars. Their involvement was in the form of, but not limited to, input on methods and techniques used in the field, supplying field assistance when needed, and data analysis expertise near the end of the project. Much of the data were supplied by the SD DENR from WQM stations on the White River in South Dakota. Their input was sought to ensure the complete data set available was being used.

SDSM&T, as a leading research organization and education facility involved in water resources in South Dakota, was directly responsible for much of the work that took place on this project. A water resources graduate student oversaw the activities for this project, including the associated field work, the data analysis, and the public involvement. Much of the field work was performed by various graduate and undergraduate students attending the school. The water resources faculty aided the students in their work and provided guidance and leadership where it was required.

## 4.2 FEDERAL AGENCIES

The US EPA provided financial assistance in the form of 319 funds for this project. The US EPA provided $48,000 of Section 319 funds to cover various project costs. They will also review and approve this assessment and TMDL.

Much of the data used came from the USGS on-line network of stream flow gage stations. Input from local personnel was used to ensure the complete data were downloaded and no data were available that was overlooked. Also, feedback on the White River system was acquired from personnel that had a working knowledge of the system.

Much of the land in the White River Watershed is part of the tribal reservation system, which the BIA administers. Some of the field work was conducted within the reservation borders. Insight was provided by the BIA hydrologist on local hydrology of the river system.

## 4.3 LOCAL GOVERNMENTS

The South Central RC&D and Badlands RC&D were essential in organizing public meetings held for the White River Watershed assessment. They were in charge of both the advertising that took place before the meetings and the press coverage of the meetings after they were held. Their help and support will be essential in the future of the watershed work that needs to be conducted, especially in the implementation stage where support of local landowners is required.

# 5.0 ASPECTS OF THE PROJECT THAT DID NOT WORK WELL

Field sampling was an area of difficulty for this project. The EMAP protocols developed for wadeable streams worked well for the upper portions of the watershed and the tributaries. However, subtle alterations needed to be made for the methods in which certain measurements were collected. This was the case for some of the larger sites in the lower portions of the watersheds where larger widths and depths made accurate sampling difficult. This was compounded by a tight schedule that required sampling to be performed during the late fall and early spring when cold, winter weather was encountered frequently.

Often these larger sites in the lower portions of the watershed were monotonous in stream habitat with very little clear pool/riffle formations occurring. It was often difficult to clearly identify riffle habitats using the same criteria that were used for identifying riffle habitats in the upper portions of the watershed. This made confidence in certain measurements and the subsequent metrics based of the habitat types difficult to achieve. However, most of the watershed displayed a lack of pool/riffle formation. Therefore, these metrics were not used in distinguishing differences between stations.

Regression between water-quality variables was performed to establish relationships and augment data sets where TSS and fecal coliform data were missing. Regressions between TSS and fecal coliforms versus discharge were also performed for the same reason. However, no significant correlations were established between these variables. The White River has a relatively large data set for both discharge and water quality when compared to other western South Dakota watersheds. This fact made augmenting data sets with estimated concentrations unnecessary for the analysis.

# 6.0 FUTURE ACTIVITY RECOMMENDATIONS

This project identified the reach of the White River between the gage station near Oglala and the gage station near Kadoka as the critical reach for TSS and fecal coliform bacteria. It is not clear the exact locations of the source of the loading for either variable. It is clear that the White River geological group, which is prevalent in Badlands National Park, is a major contributor to the TSS loading of the river. A large percentage of the TSS loading comes from natural background and is not man-induced by watershed activities. Conversely, the specific contributing source or area of origination is not known for fecal coliform bacteria. Much of the loading is likely a function of landuse and agricultural practices in the area between Oglala and Kadoka. However, contributions from wildlife are a large source of loading, especially in the lower reaches of the river. Direct man-made sources of fecal coliform loading, such as septic systems and urbanization, have little impact on the White River Watershed.

The reach definitions of the White River should be redefined to match the physical conditions found in the watershed with three reach segments being defined as: (1) the Nebraska border to the confluence of Willow Creek approximately 5 miles north of the gage station near Oglala, (2) from Willow Creek to the confluence of the Little White River, and (3) from the confluence of the Little White River to the mouth of the River near Oacoma. The current criterion of 158 mg/l for TSS is unattainable in the White River in South Dakota. Site-specific antidegredation standards for TSS based on the 95 percent exceedence level should be implemented for the defined reaches of the White River. The 95 percent exceedence levels for the three reaches of the White River are given in Table 6-1. It is clear based on the physical, chemical, and biological data that these standards would reflect the natural condition of the river, and that these standards would be protective of the beneficial uses of the White River. The criterion for fecal coliforms is attainable with the implementation of BMPs with a specific focus on the area between Oglala and Kadoka. BMPs should be implemented for each reach of the river individually based on the goals set forth for that reach.

**Table 6-1. Ninety-Five Percent Exceedence Concentrations (mg/l) for the White River, South Dakota**

| | 95 % Exceedence Concentrations |
|---|---|
| State-Line to Willow Creek | 4,525 |
| Willow Creek to Little White River | 24,300 |
| Little White River to Mouth | 21,550 |

An implementation project should be initiated for the White River Watershed. This project should include implementation of the recommended BMPs. Additional monitoring on major tributaries is needed to identify specific areas of loading for both TSS and fecal coliforms and to ensure compliance with current water-quality standards. One goal of the additional monitoring would be to separate the sediment contributions from overland erosion from in-channel processes. The project should include additional modeling and monitoring of the White River to identify the specific sources of fecal coliform loading. Part of this research should include an investigation into the life span of fecal coliforms in the White River Watershed. It is unknown how much of the fecal loading originating between Oglala and Kadoka is being transported to the lower reaches of the river and reaching the mouth. The potential exists for long life spans due to low light penetration and storage in the substrate. This aspect of fecal coliforms is important in understanding how critical the lower reaches are in reducing the fecal coliform loading in the watershed. Lastly, the current monitoring stations need to be continued into the future to monitor the effectiveness of BMP implementation that will occur in the future.

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# APPENDIX A

# HYDROLOGY ANALYSIS

RSI-1465-04-092

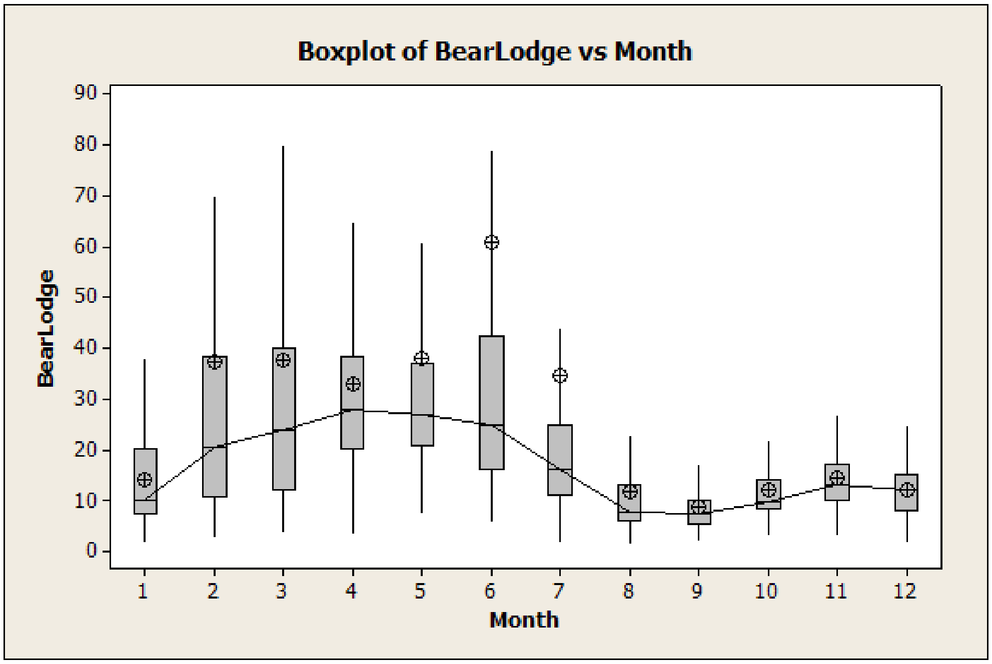



**Figure A-1.** Box Plot of BearLodge Versus Month.

RSI-1465-04-093

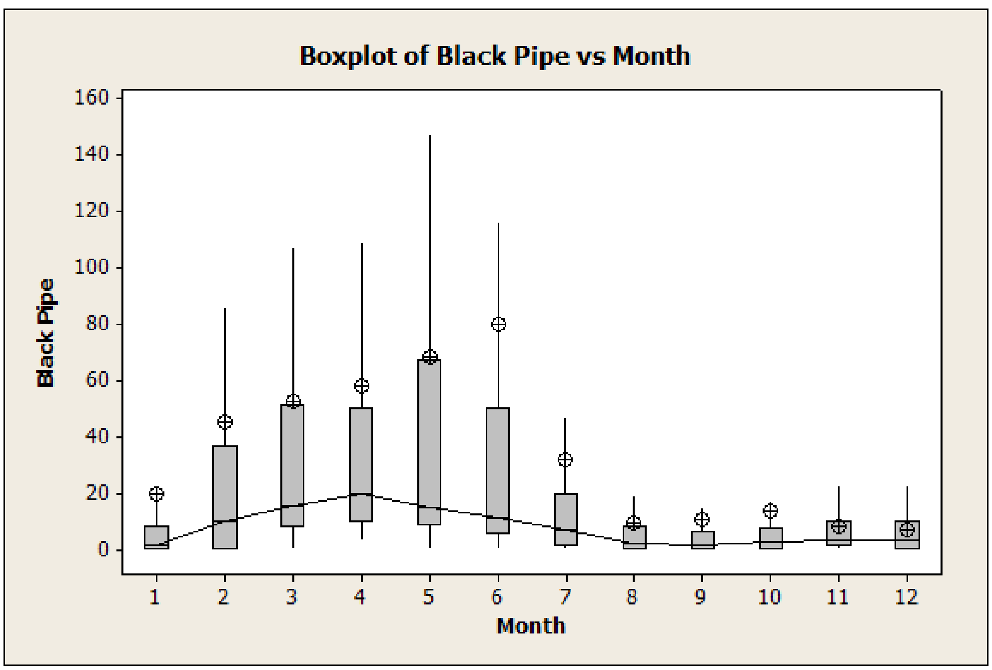



**Figure A-2.** Box Plot of Black Pipe Versus Month.

RSI-1465-04-094

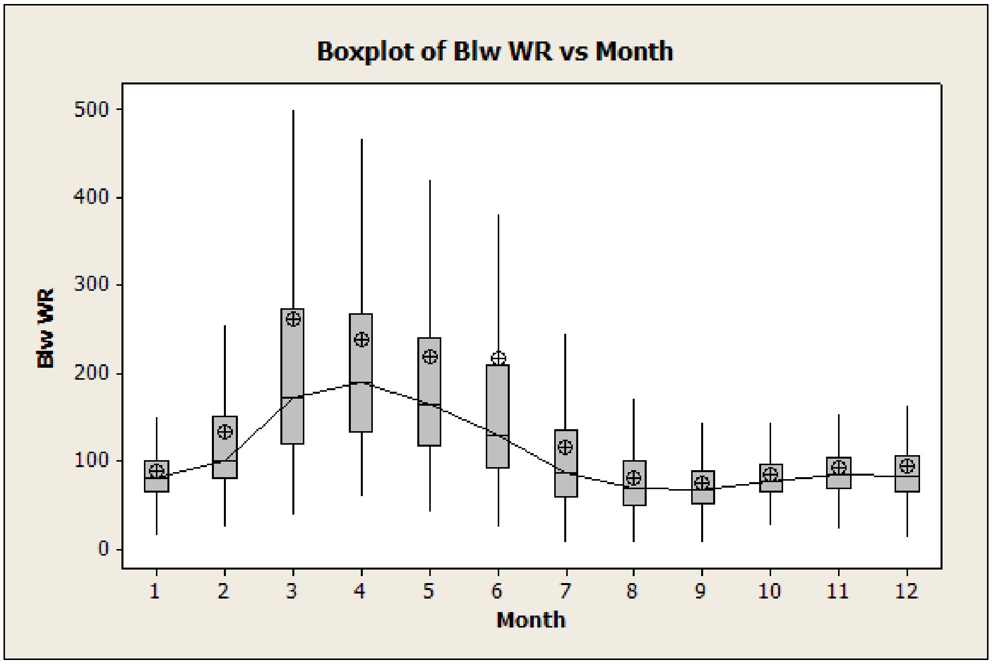



**Figure A-3.** Box Plot of Little White River Below White River Versus Month.

RSI-1465-04-095

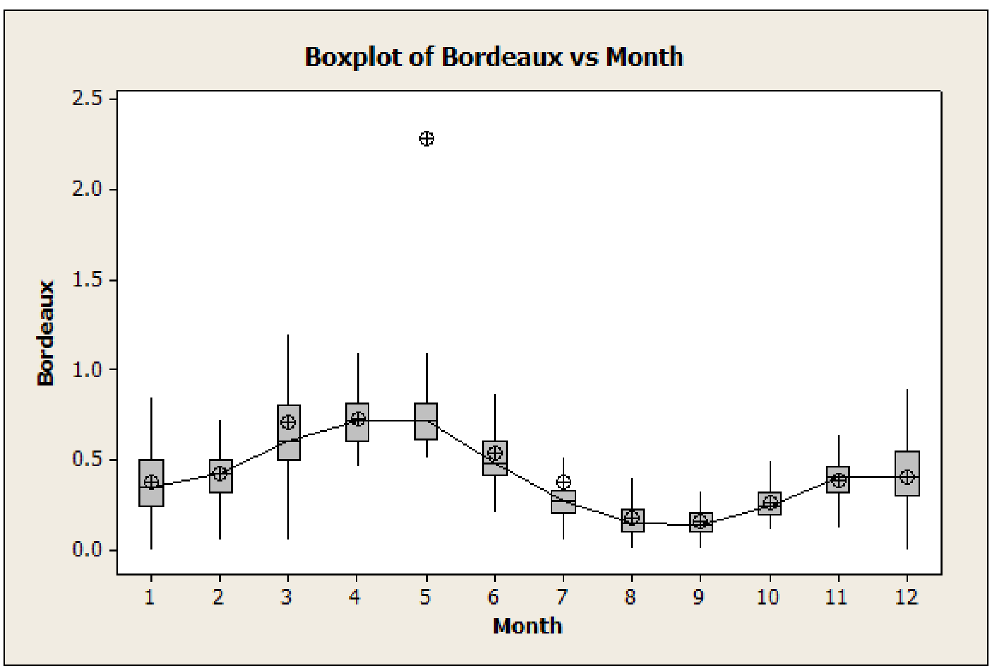



**Figure A-4.** Box Plot of Bordeaux Versus Month.

RSI-1465-04-096

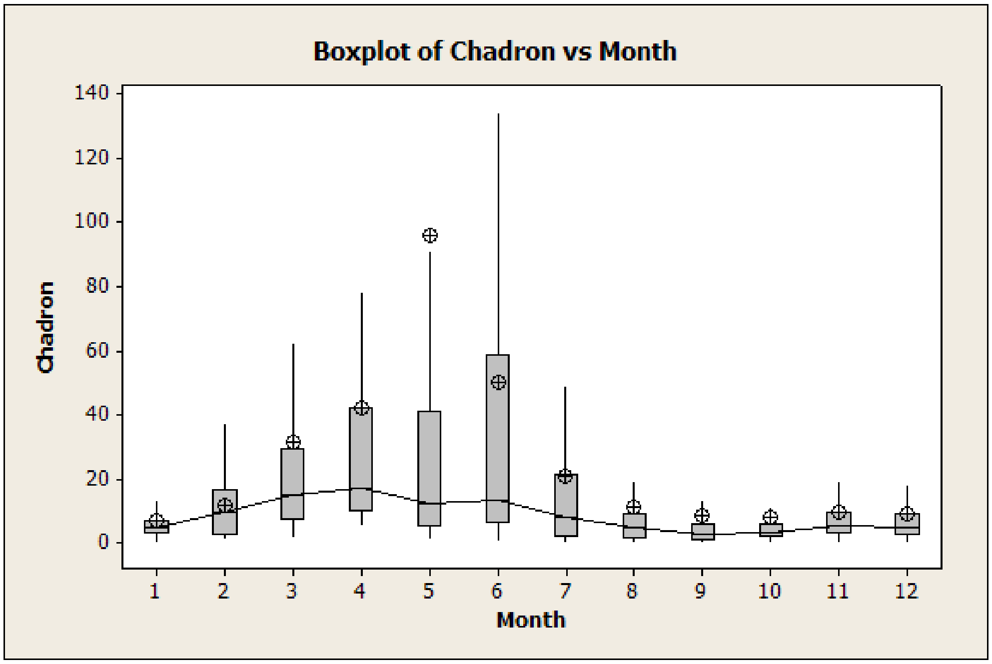



**Figure A-5.** Box Plot of Chadron Versus Month.

RSI-1465-04-097

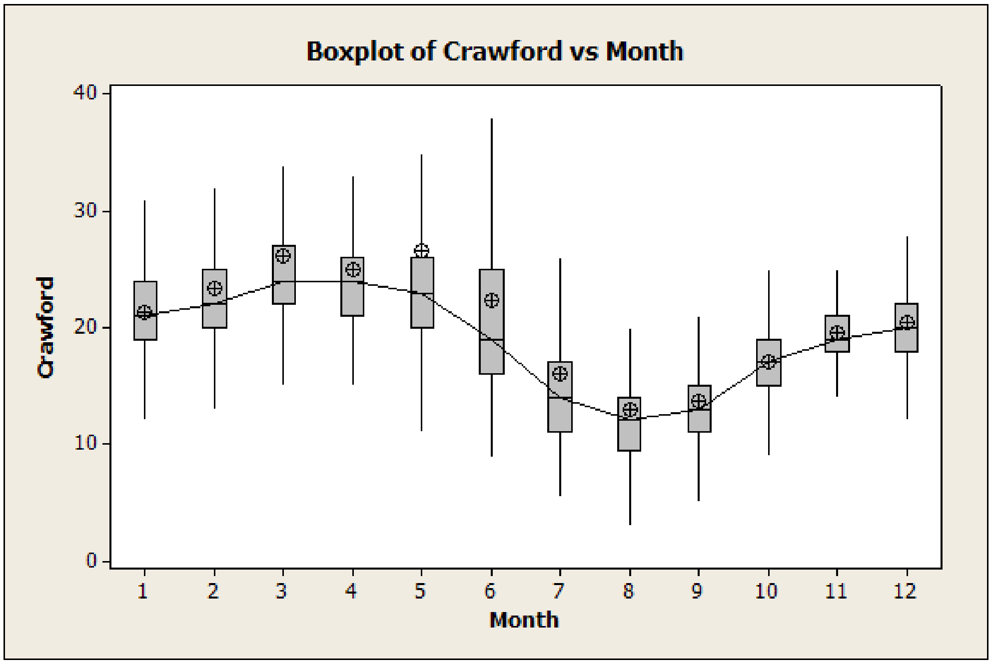



**Figure A-6.** Box Plot of Crawford Versus Month.

RSI-1465-04-098

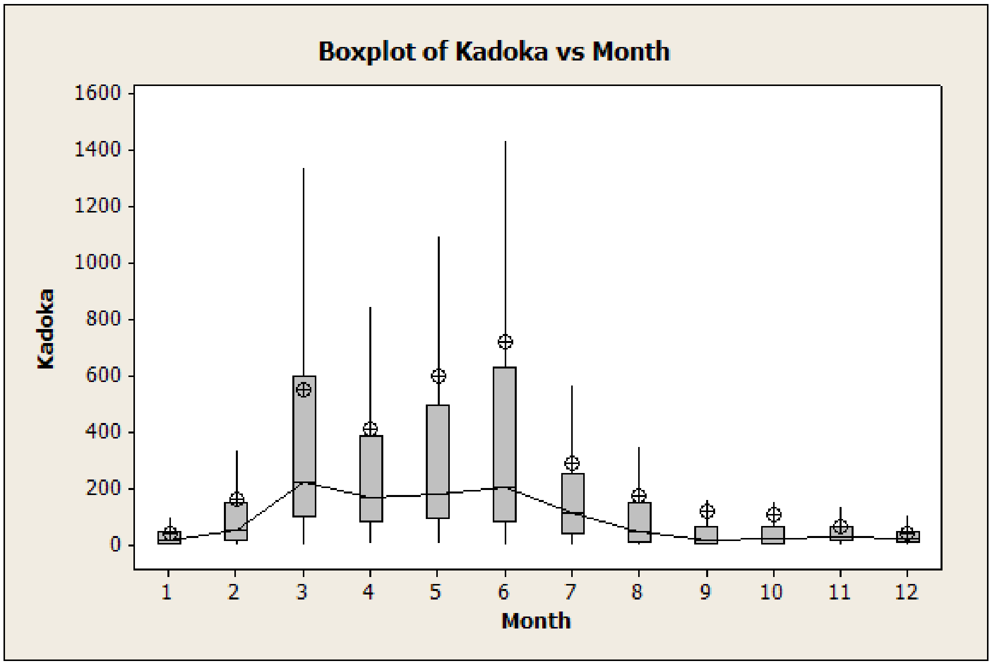



**Figure A-7.** Box Plot of Kadoka Versus Month.

RSI-1465-04-099

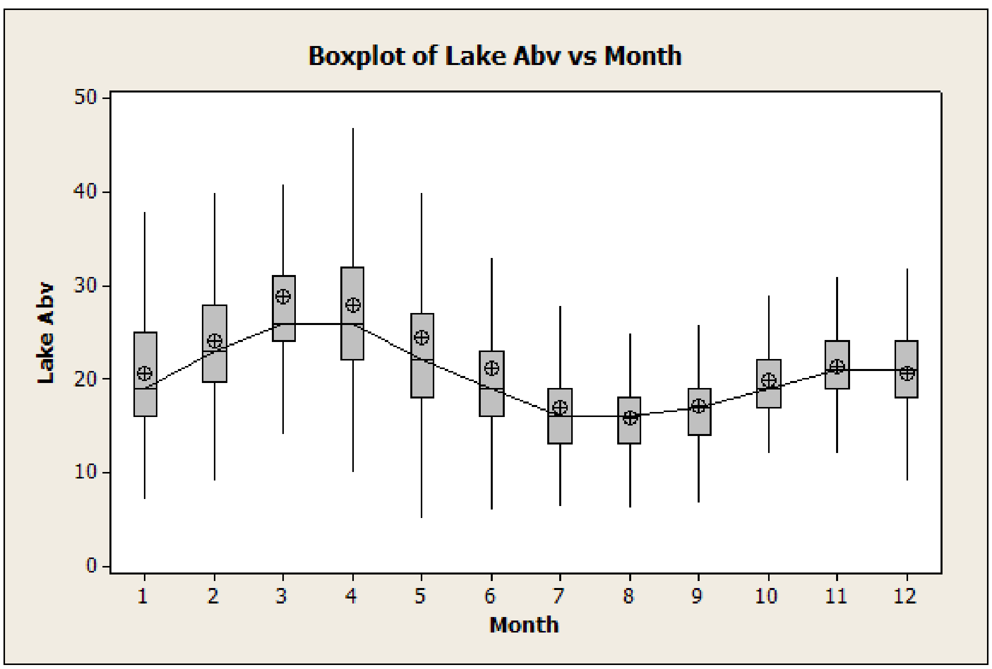



**Figure A-8.** Box Plot of Lake Creek Above Refuge Versus Month.

RSI-1465-04-100

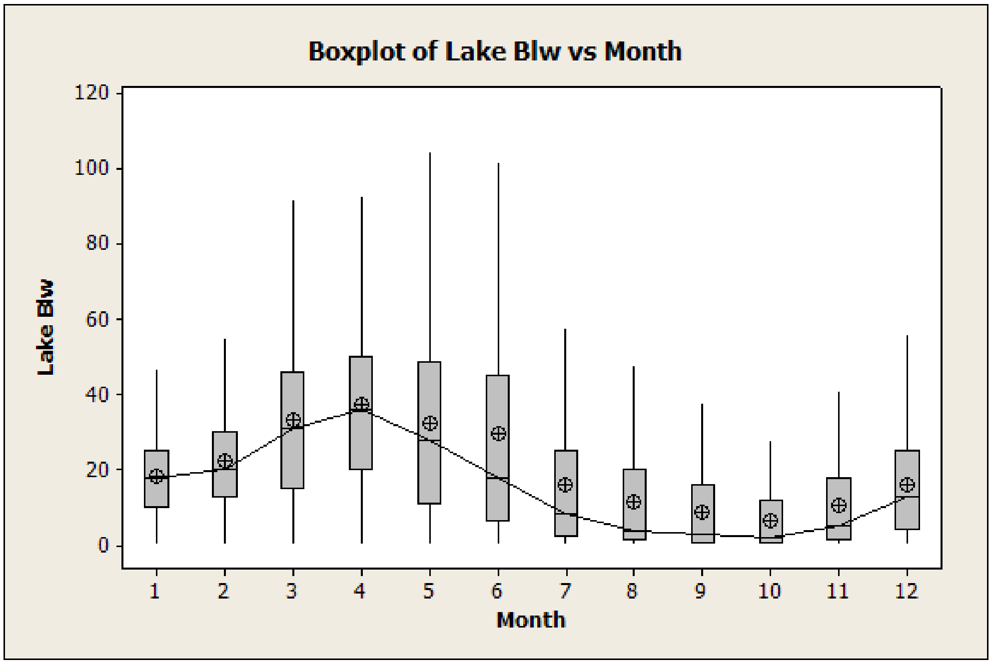



**Figure A-9.** Box Plot of Lake Creek Below Refuge Versus Month.

RSI-1465-04-101

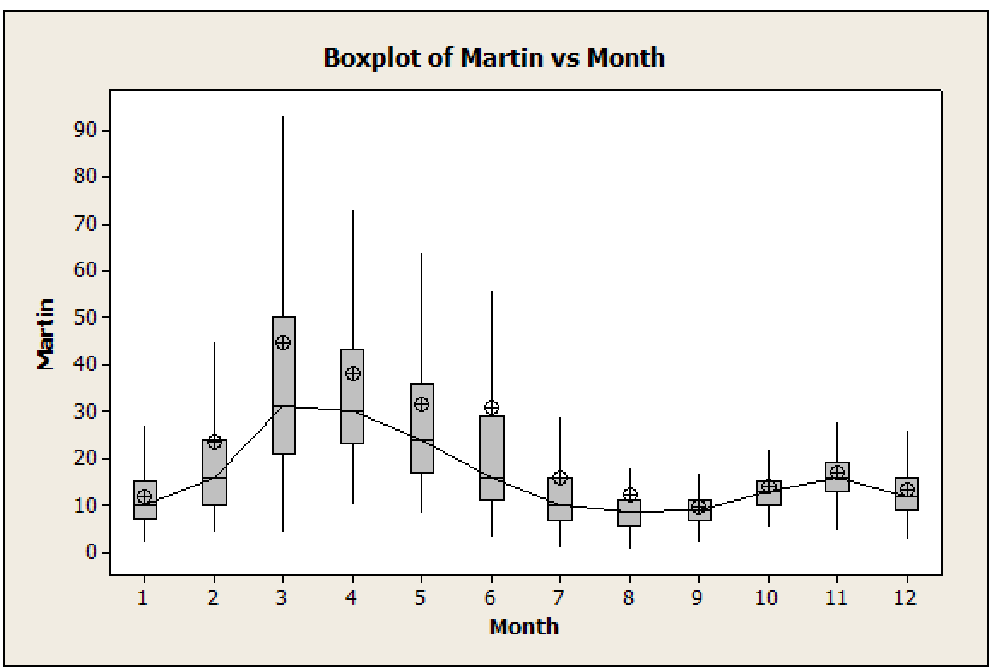



**Figure A-10.** Box Plot of Martin Versus Month.

RSI-1465-04-102

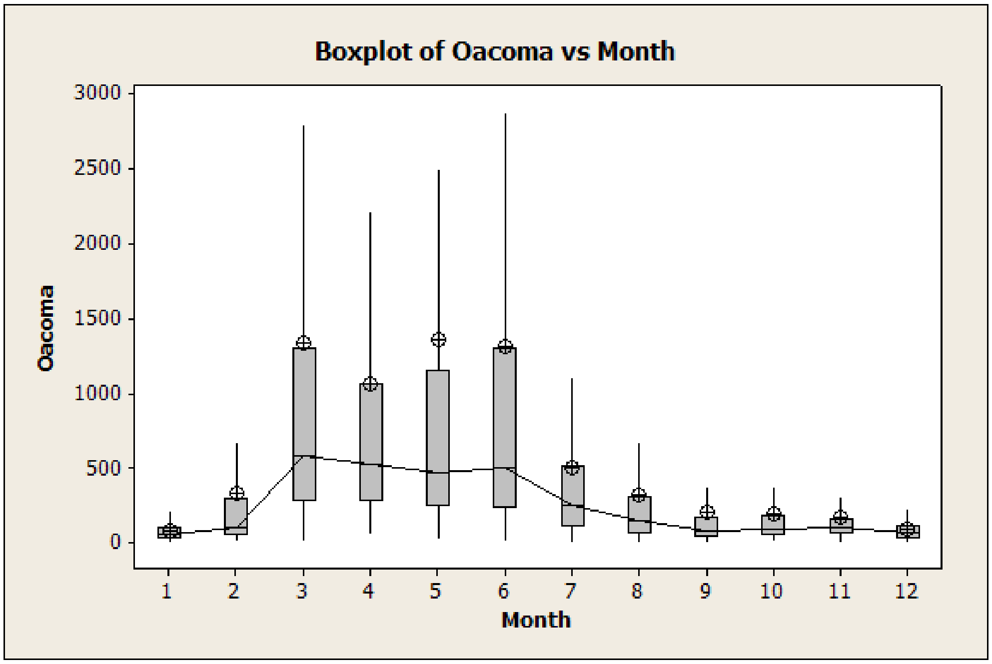



**Figure A-11.** Box Plot of Oacoma Versus Month.

RSI-1465-04-103

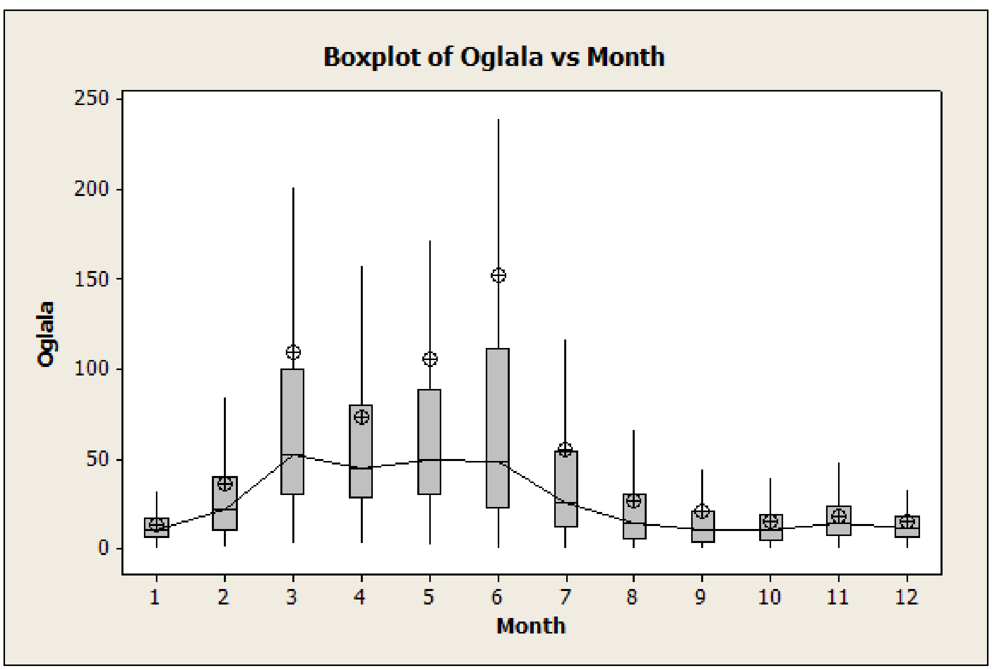



**Figure A-12.** Box Plot of Oglala Versus Month.

RSI-1465-04-104

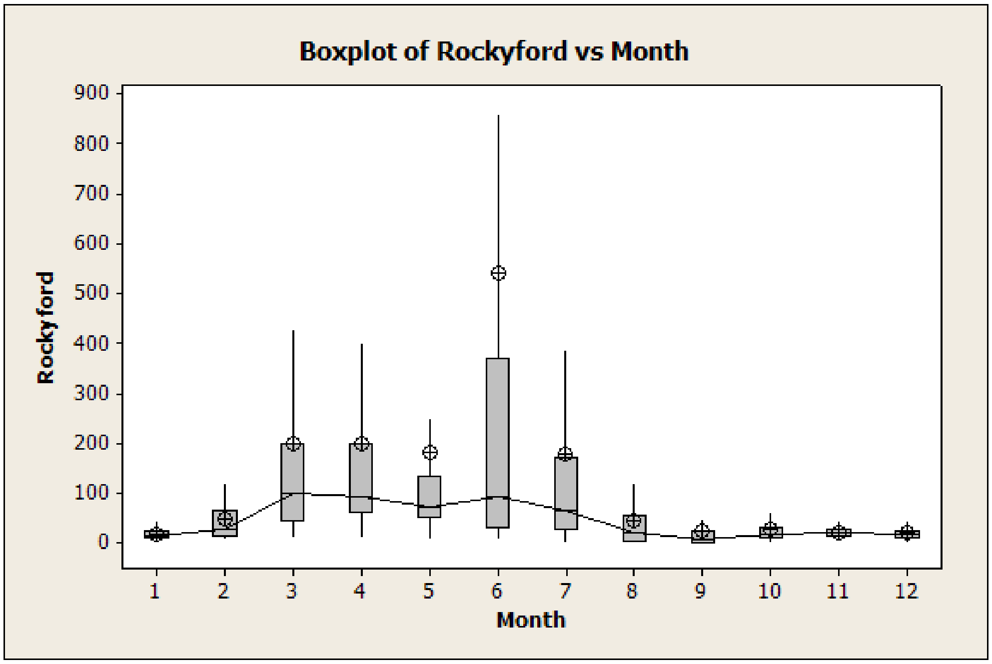



**Figure A-13.** Box Plot of Rockyford Versus Month.

RSI-1465-04-105

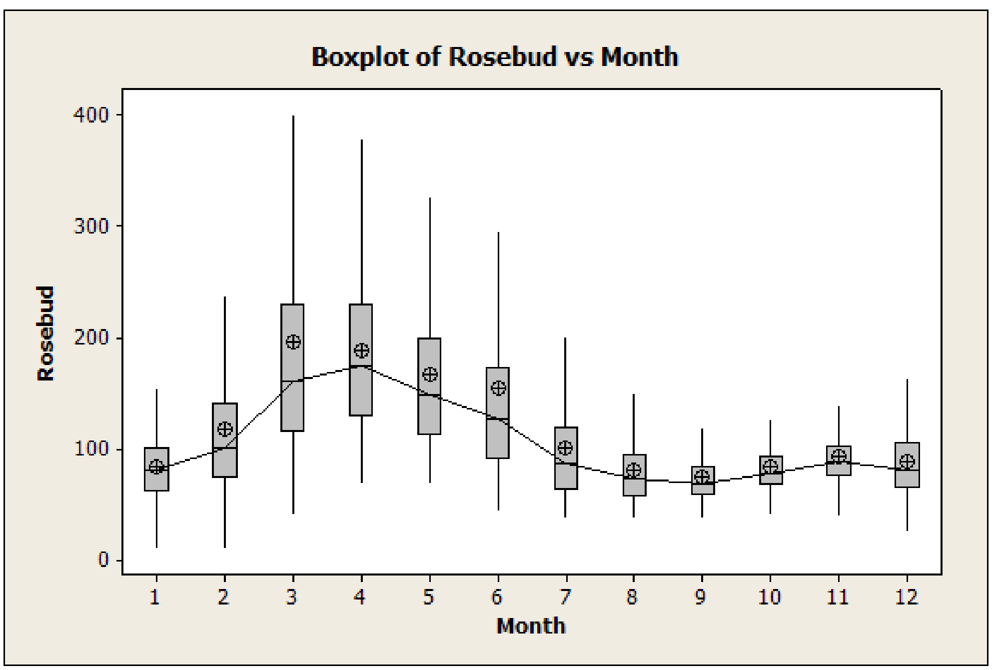



**Figure A-14.** Box Plot of Rosebud Versus Month.

RSI-1465-04-106

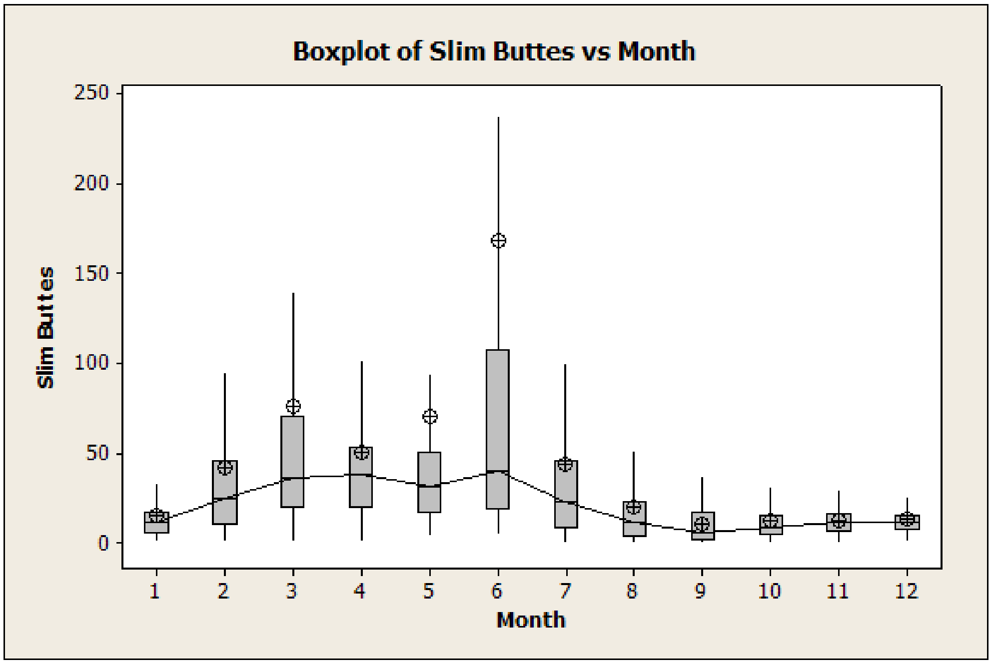



**Figure A-15.** Box Plot of Slim Buttes Versus Month.

RSI-1465-04-107

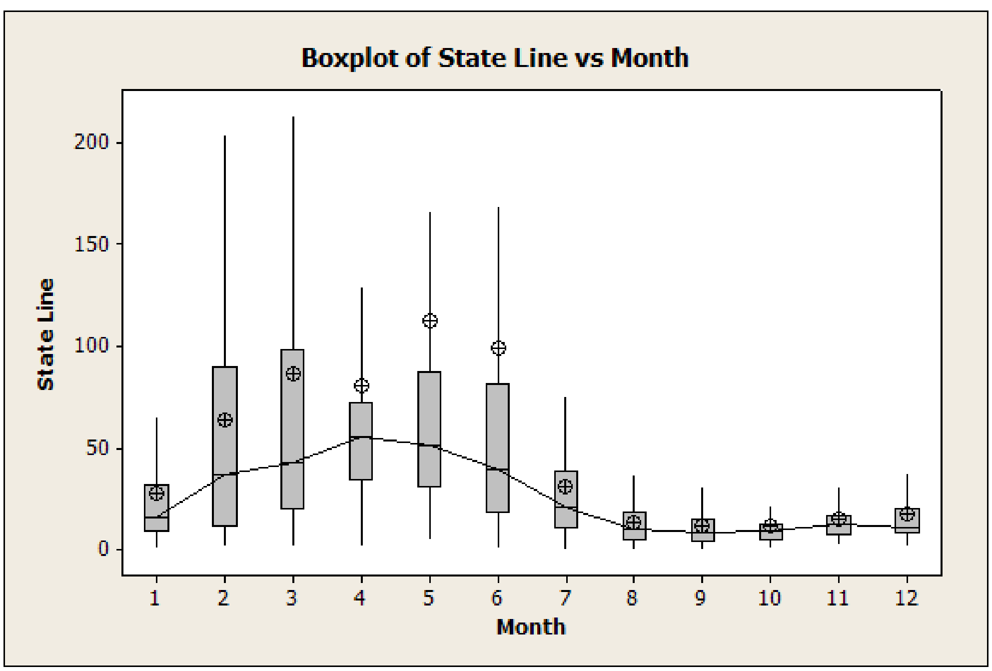



**Figure A-16.** Box Plot of State Line Versus Month.

RSI-1465-04-108

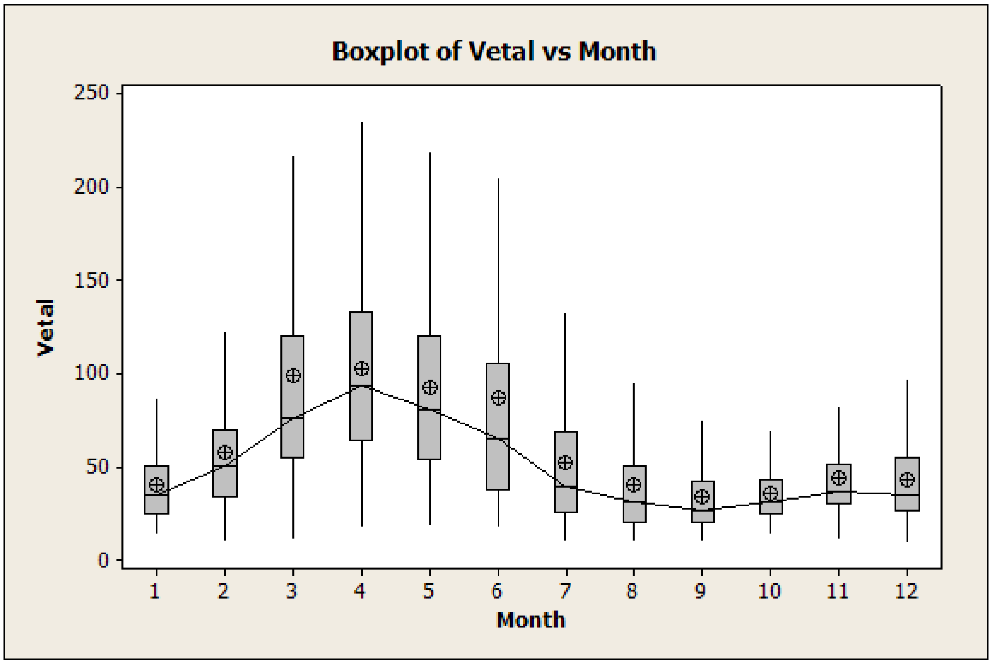



**Figure A-17.** Box Plot of Vetal Versus Month.

RSI-1465-04-109

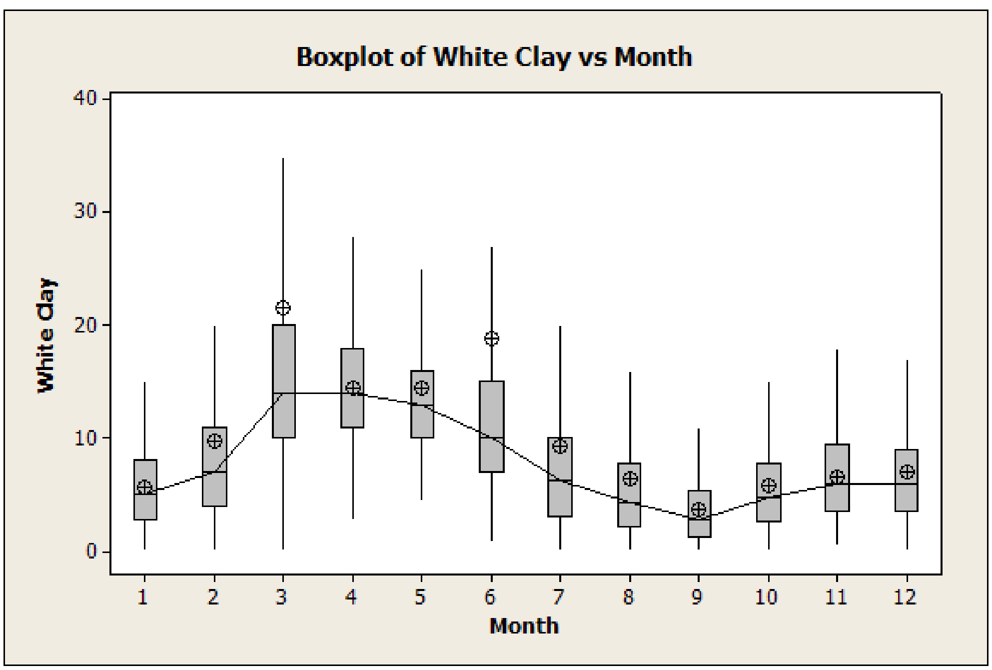



**Figure A-18.** Box Plot of White Clay Versus Month.

RSI-1465-04-110

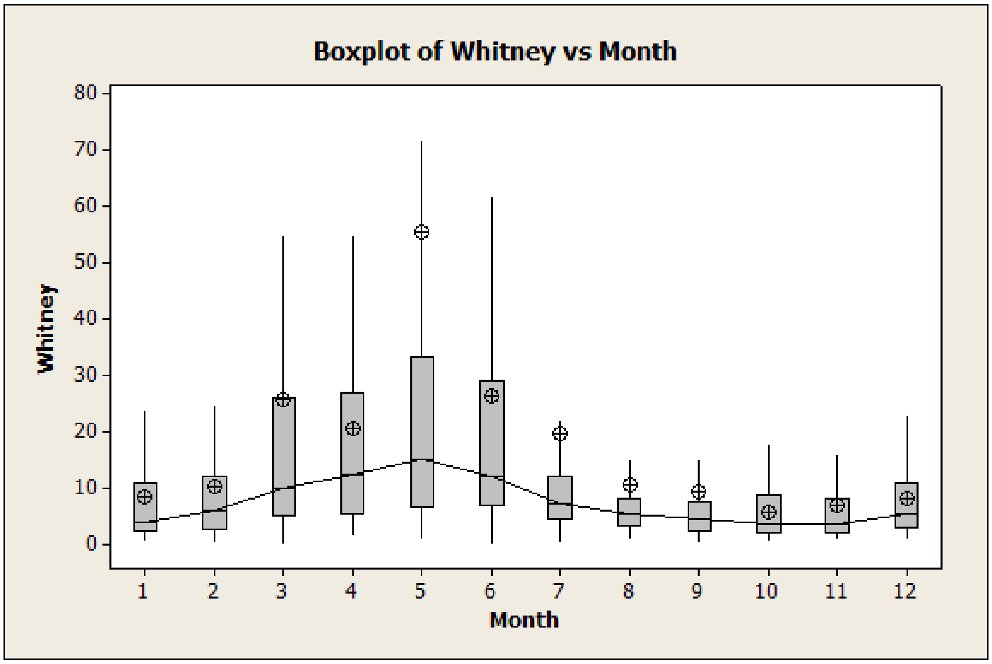



**Figure A-19.** Box Plot of Whitney Versus Month.

RSI-1465-04-111

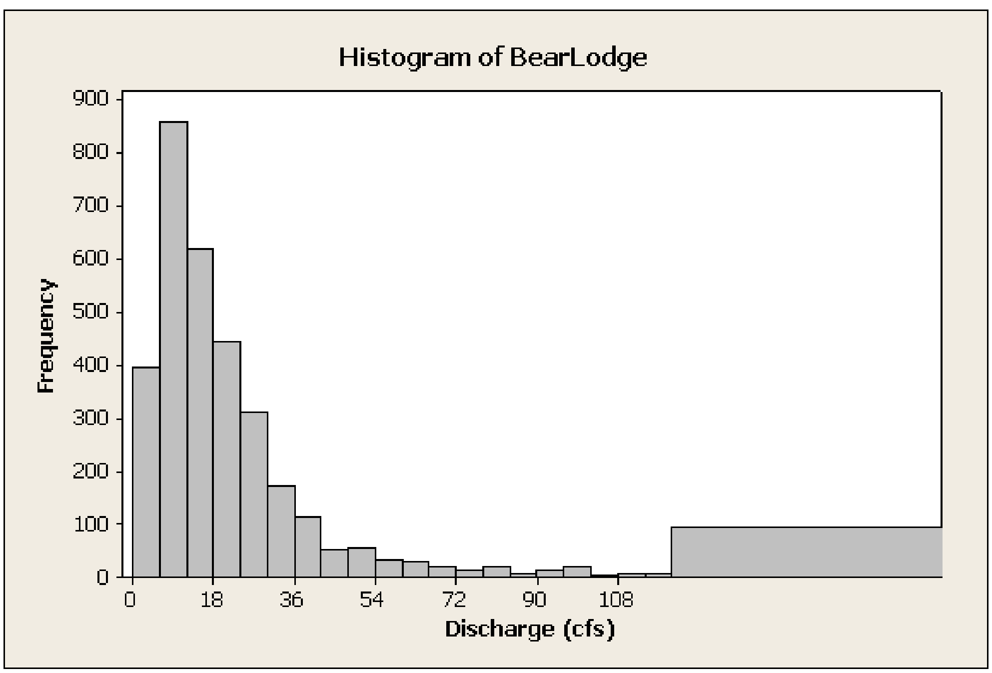



**Figure A-20.** Histogram of BearLodge.

RSI-1465-04-112

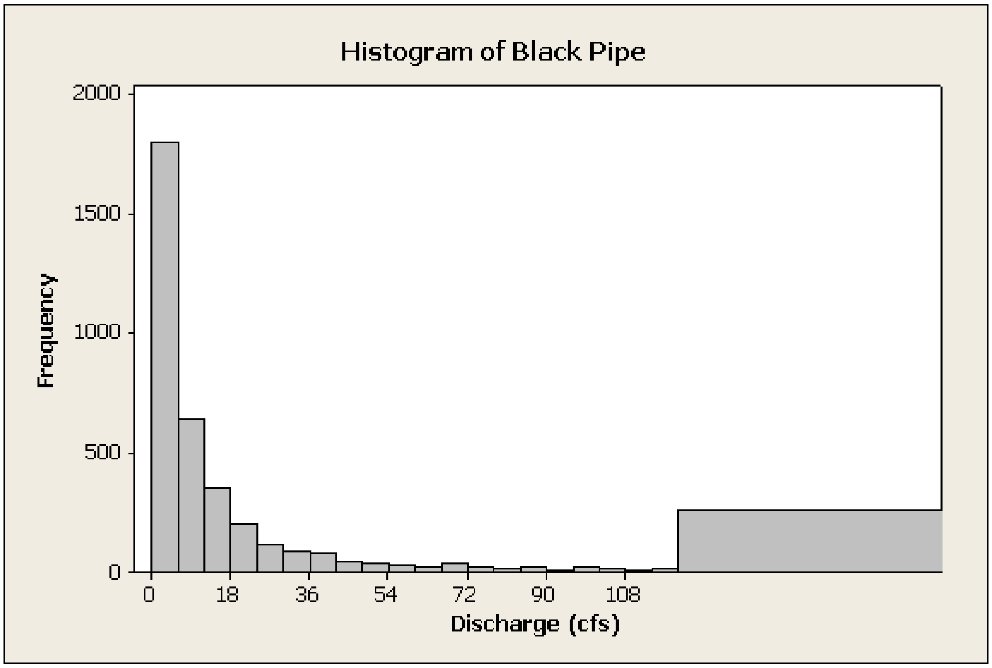



**Figure A-21.** Histogram of Black Pipe.

RSI-1465-04-113

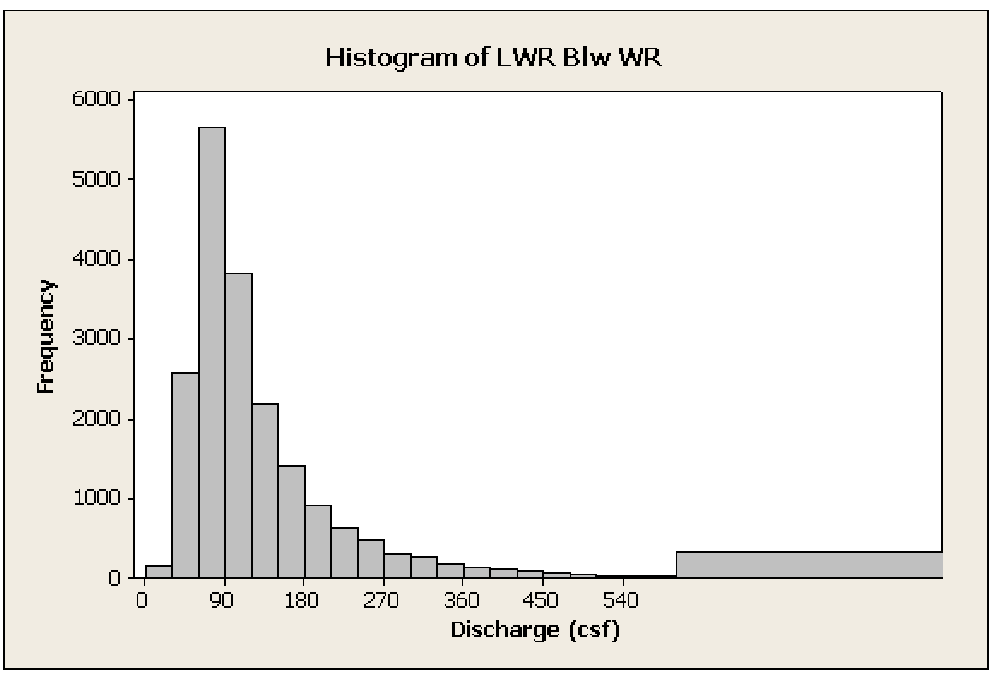



**Figure A-22.** Histogram of Little White River Below White River.

RSI-1465-04-114

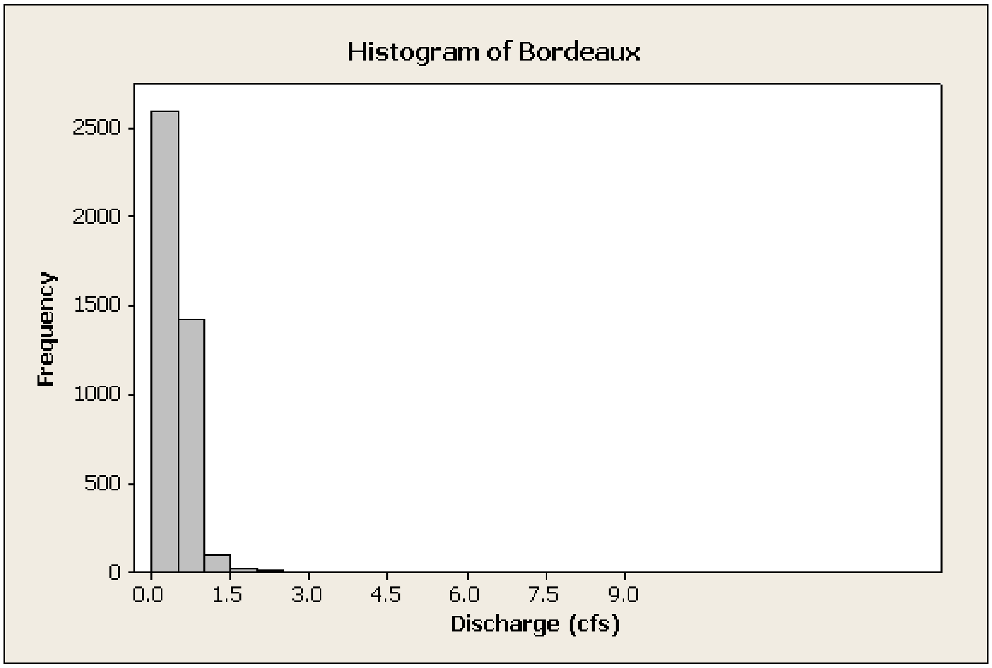



**Figure A-23.** Histogram of Bordeaux.

RSI-1465-04-115

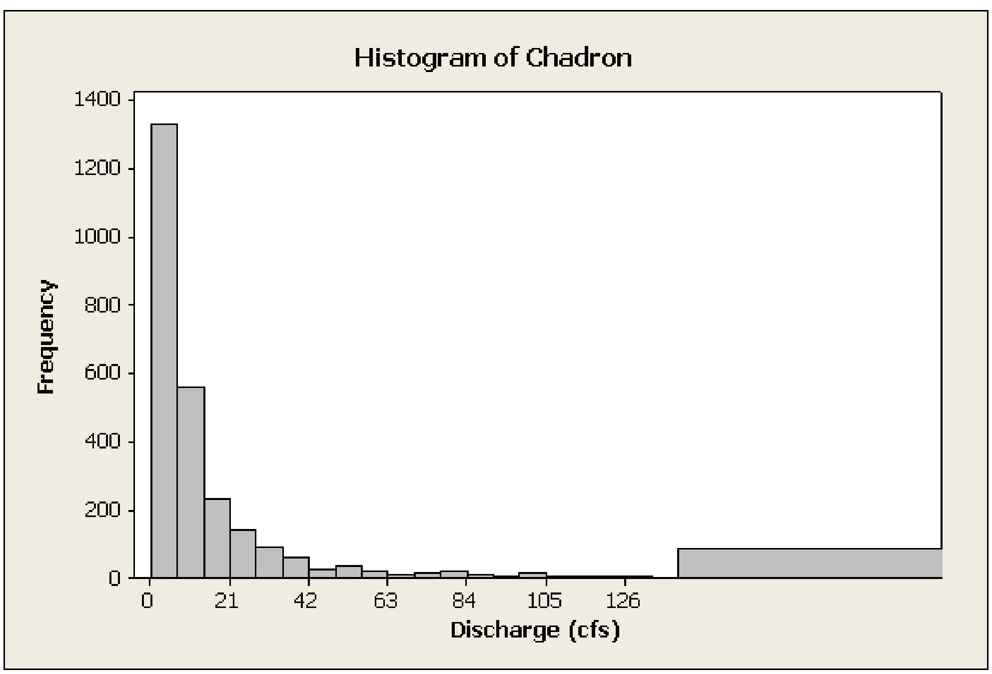



**Figure A-24.** Histogram of Chadron.

RSI-1465-04-116

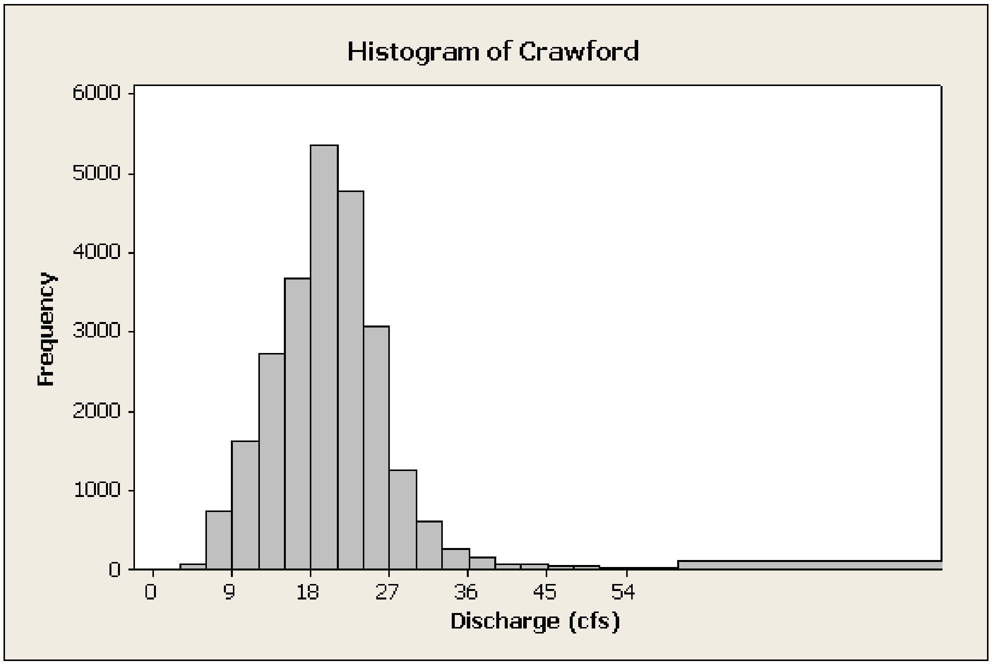



**Figure A-25.** Histogram of Crawford.

RSI-1465-04-117

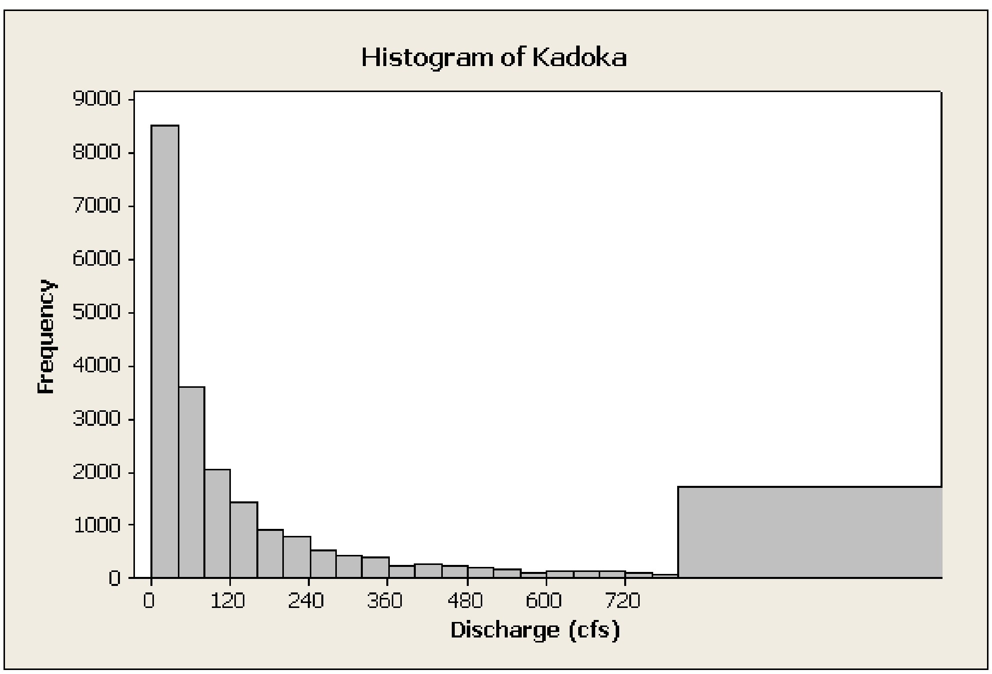



**Figure A-26.** Histogram of Kadoka.

RSI-1465-04-118

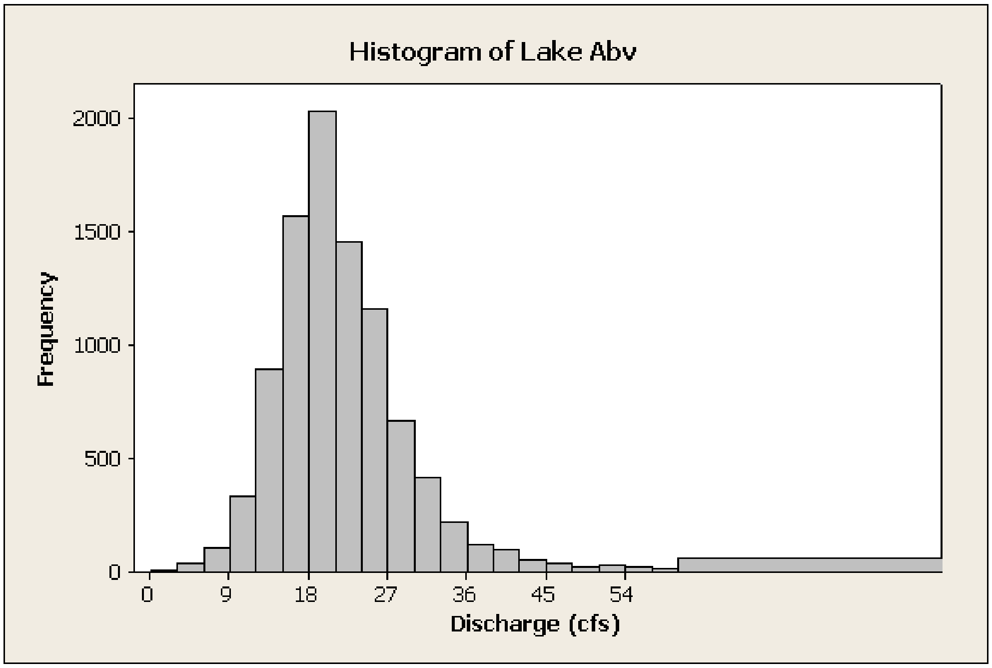



**Figure A-27.** Histogram of Lake Creek Above Refuge.

RSI-1465-04-119

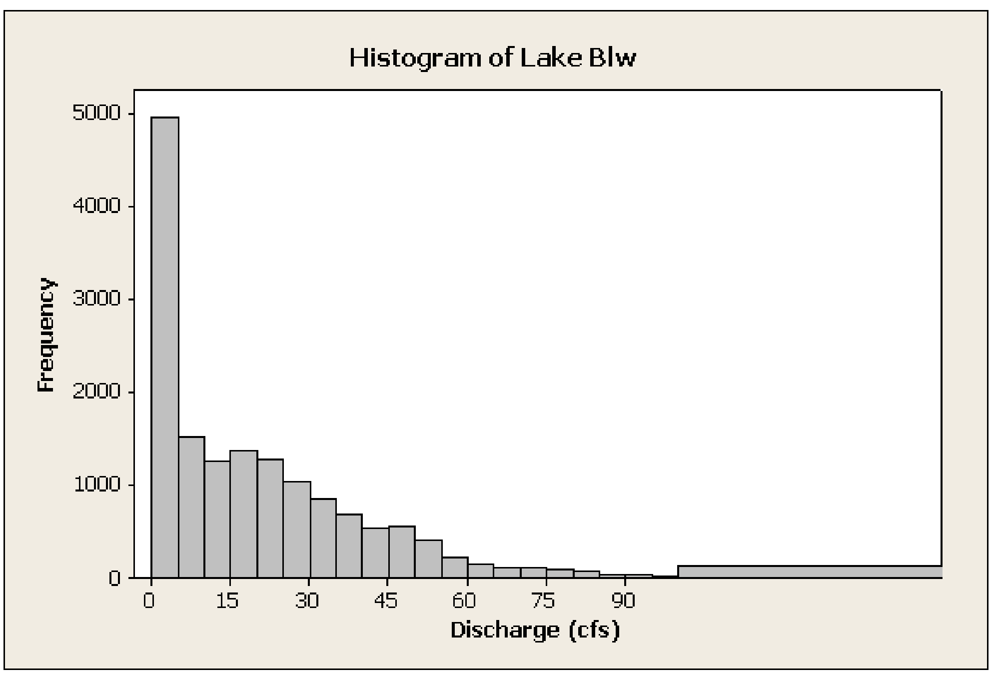



**Figure A-28.** Histogram of Lake Creek Below Refuge.

RSI-1465-04-120

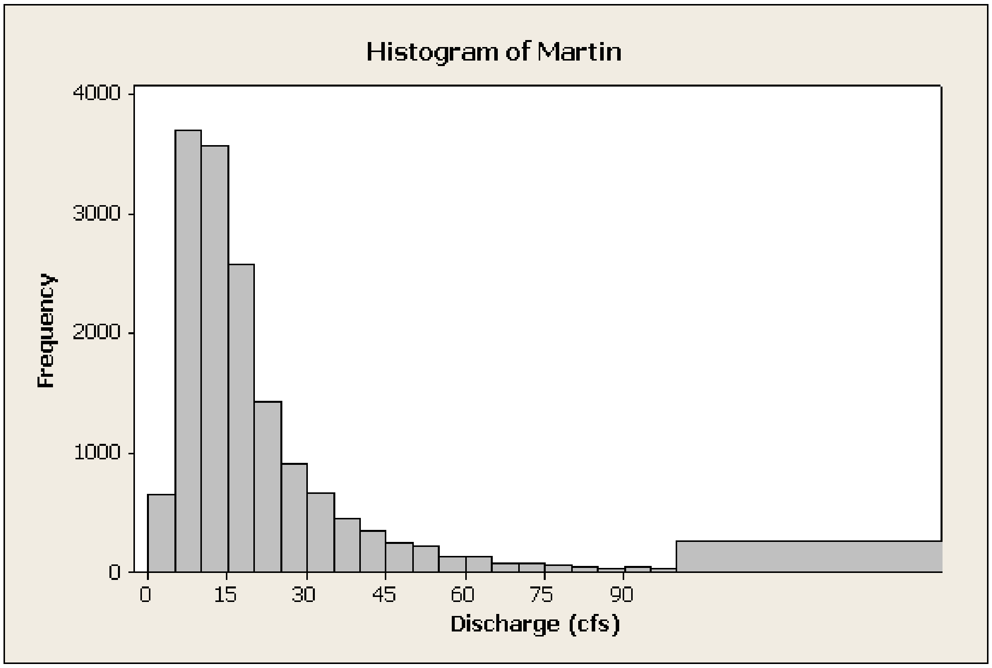



**Figure A-29.** Histogram of Martin.

RSI-1465-04-121

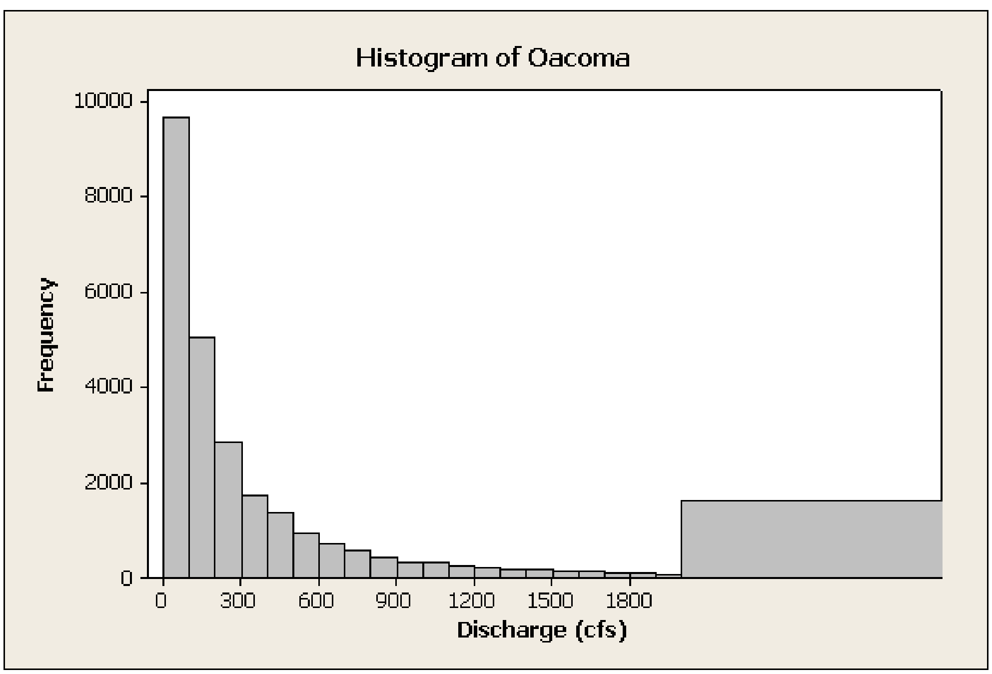



**Figure A-30.** Histogram of Oacoma.

RSI-1465-04-122

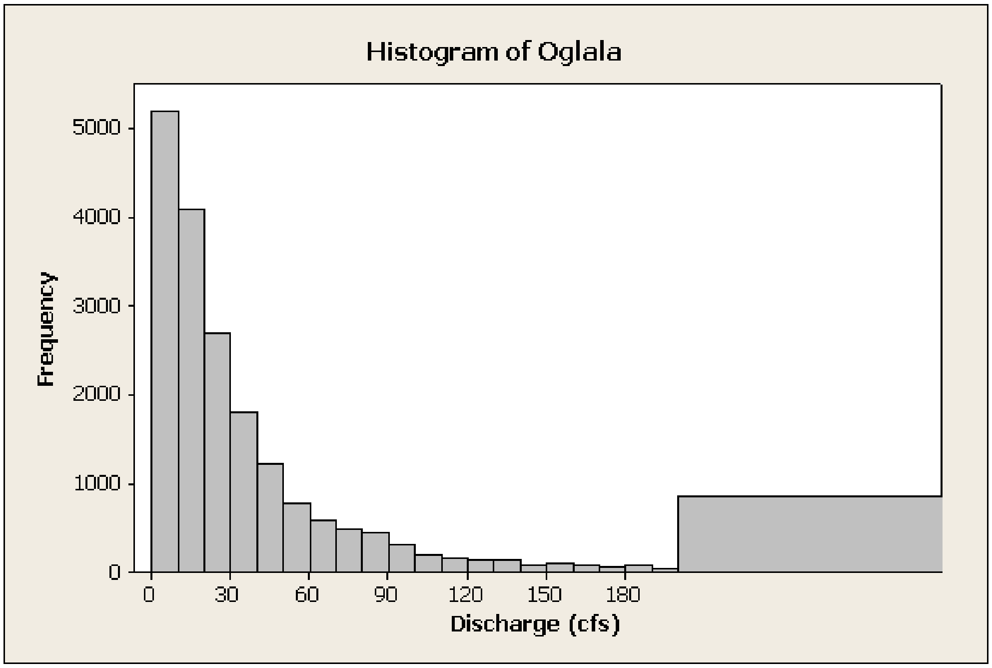



**Figure A-31.** Histogram of Oglala.

RSI-1465-04-123

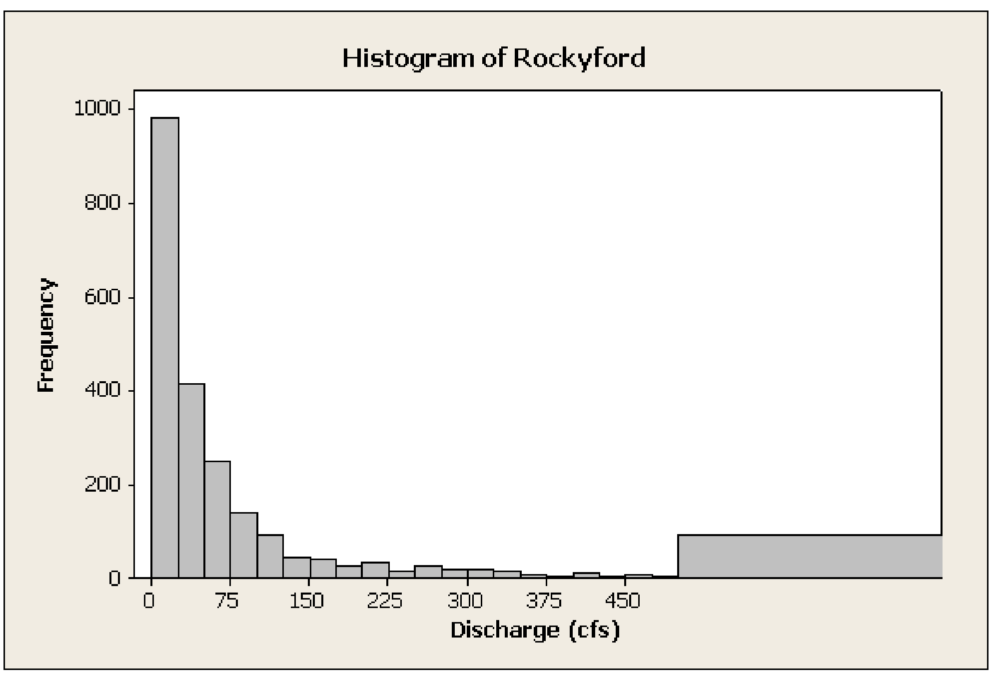



**Figure A-32.** Histogram of Rockyford.

RSI-1465-04-124

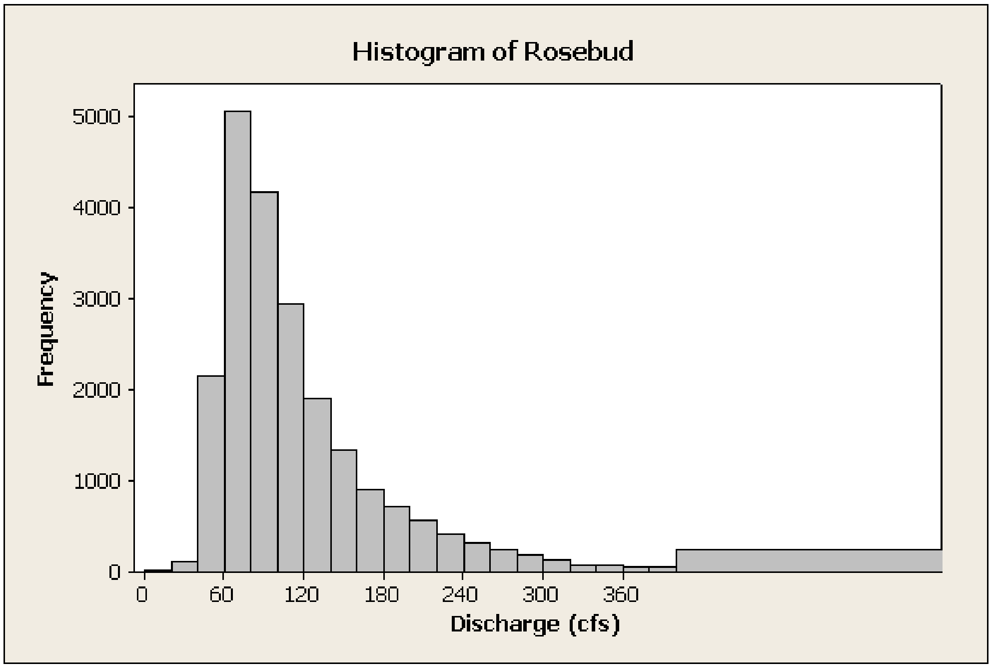



**Figure A-33.** Histogram of Rosebud.

RSI-1465-04-125

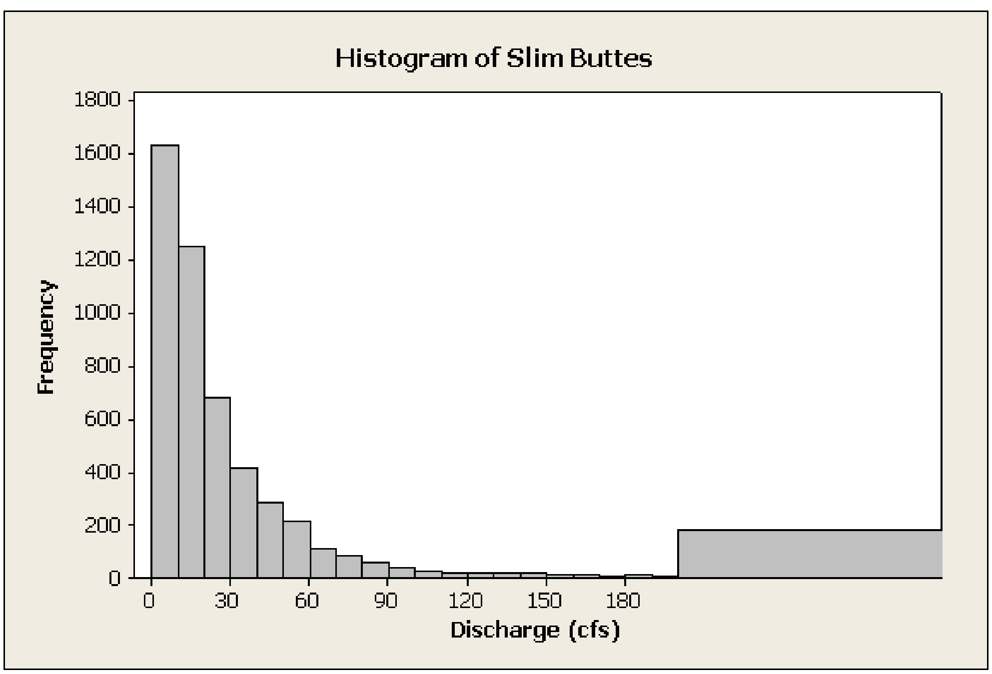



**Figure A-34.** Histogram of Slim Buttes.

RSI-1465-04-126

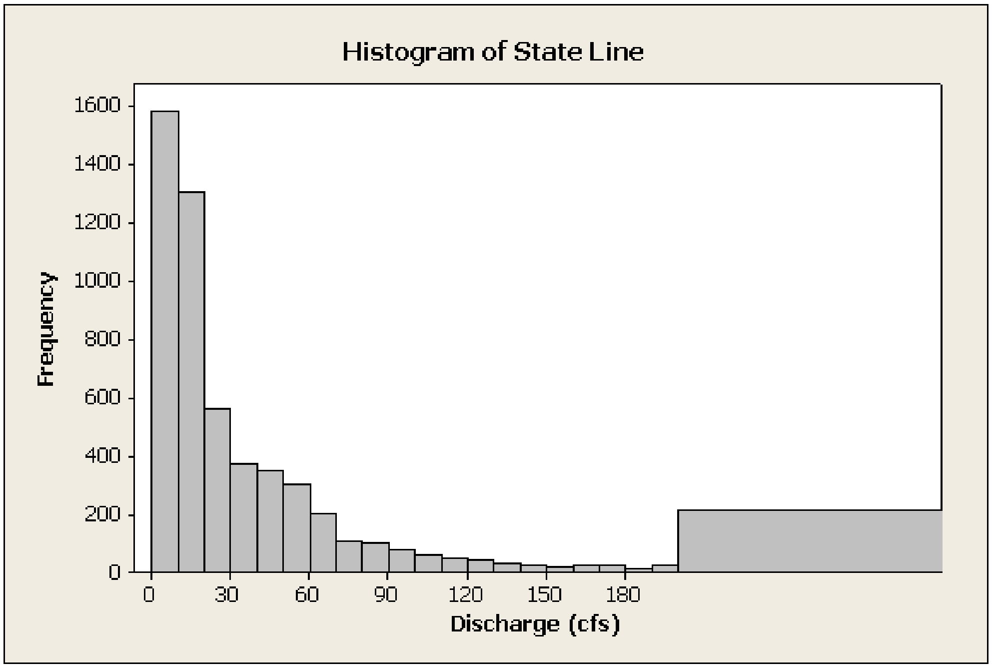



**Figure A-35.** Histogram of State Line.

RSI-1465-04-127

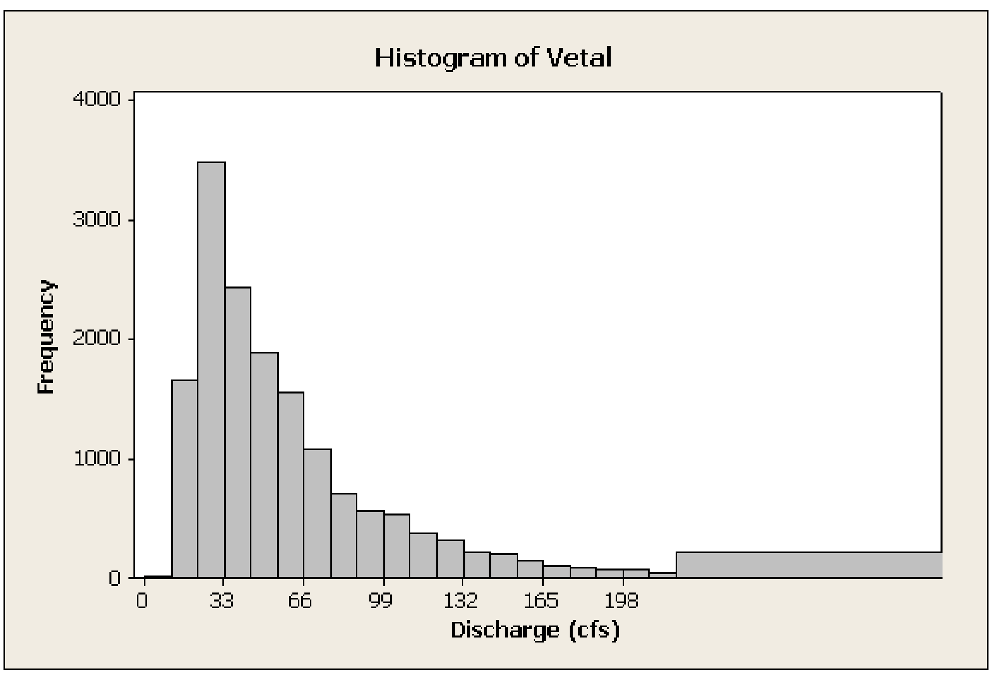



**Figure A-36.** Histogram of Vetal.

RSI-1465-04-128

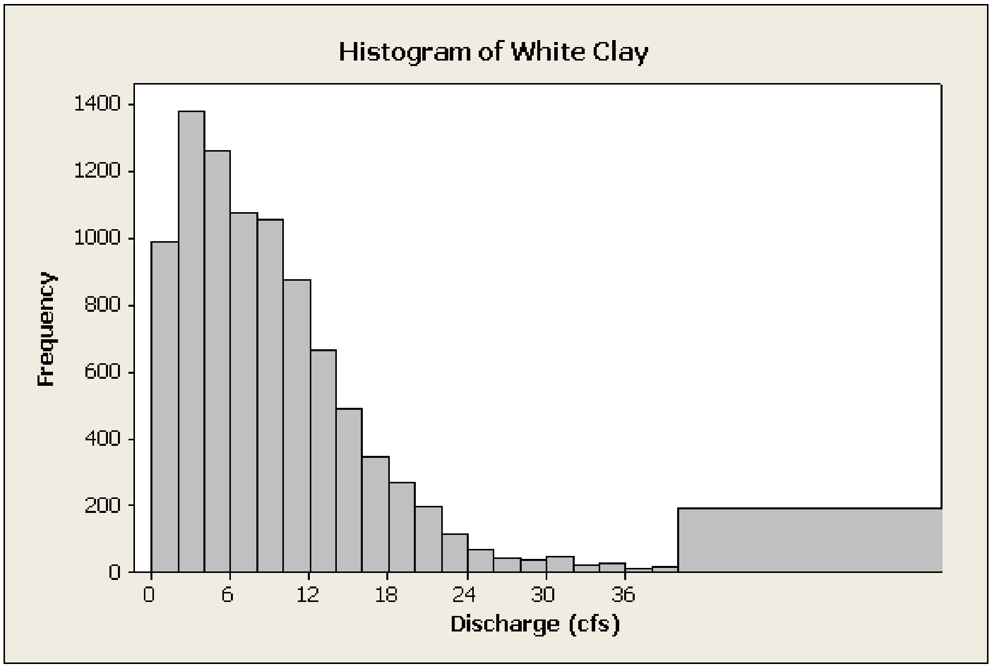



**Figure A-37.** Histogram of White Clay.

RSI-1465-04-129

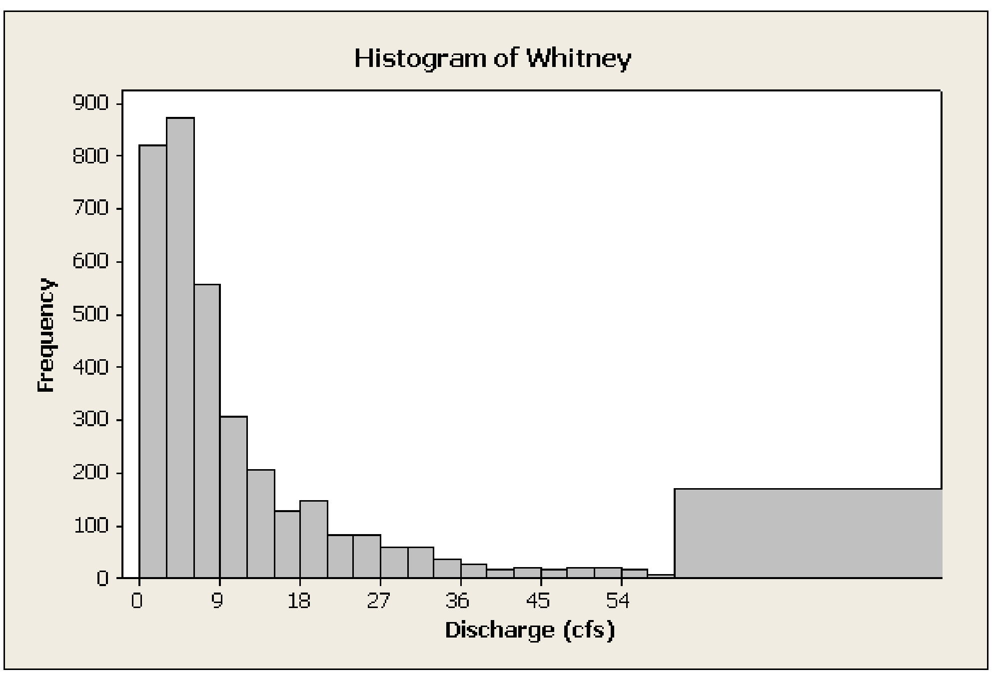



**Figure A-38.** Histogram of Whitney.

RSI-1465-04-130

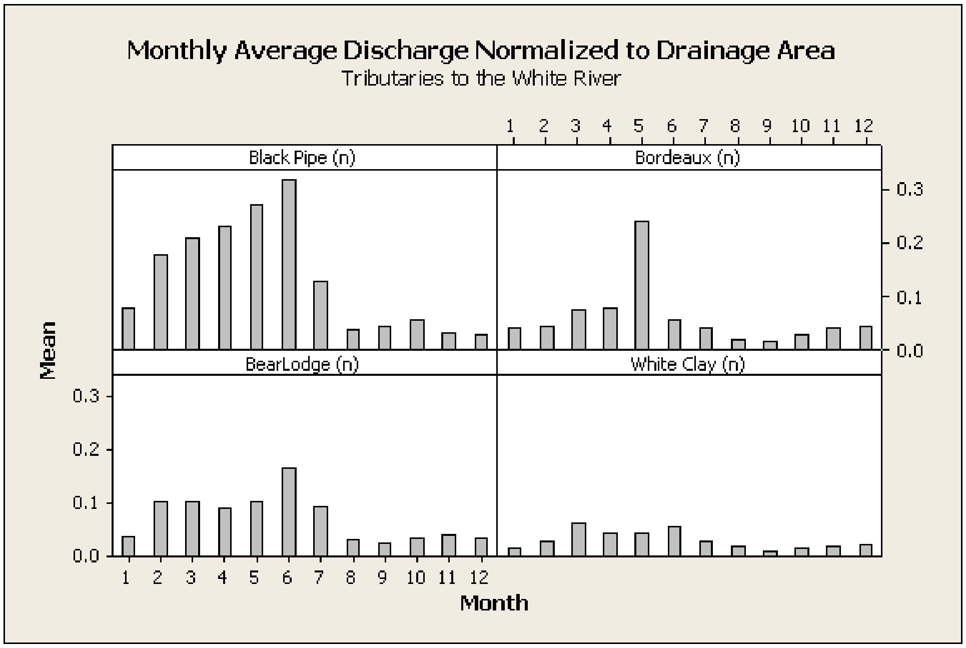



**Figure A-39.** Monthly Average Discharge Normalized to Drainage Area for Tributaries to the White River.

RSI-1465-04-131

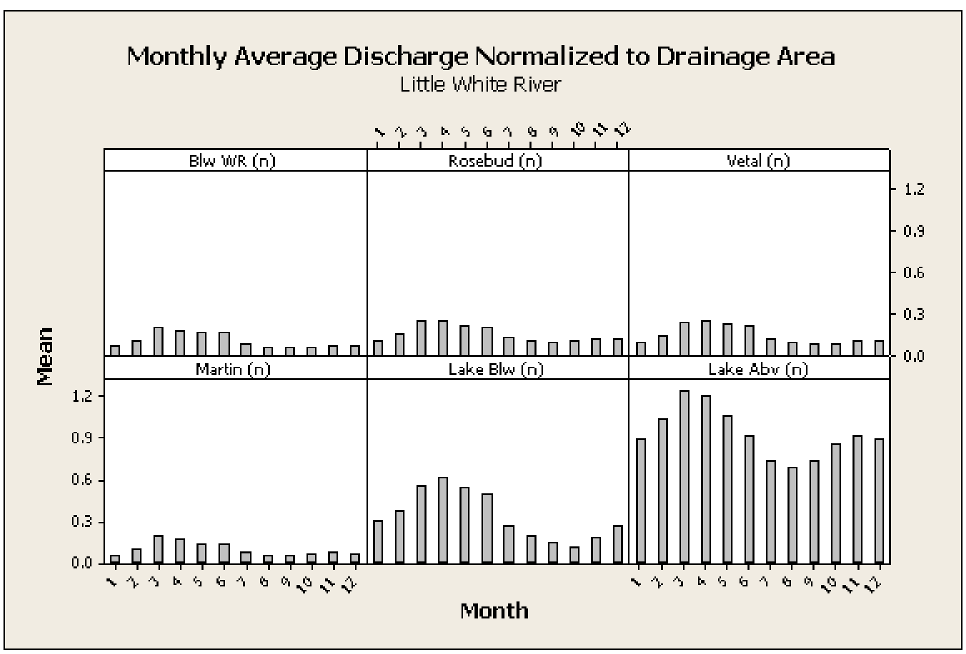



**Figure A-40.** Monthly Average Discharge Normalized to Drainage Area for Little White River.

RSI-1465-04-132

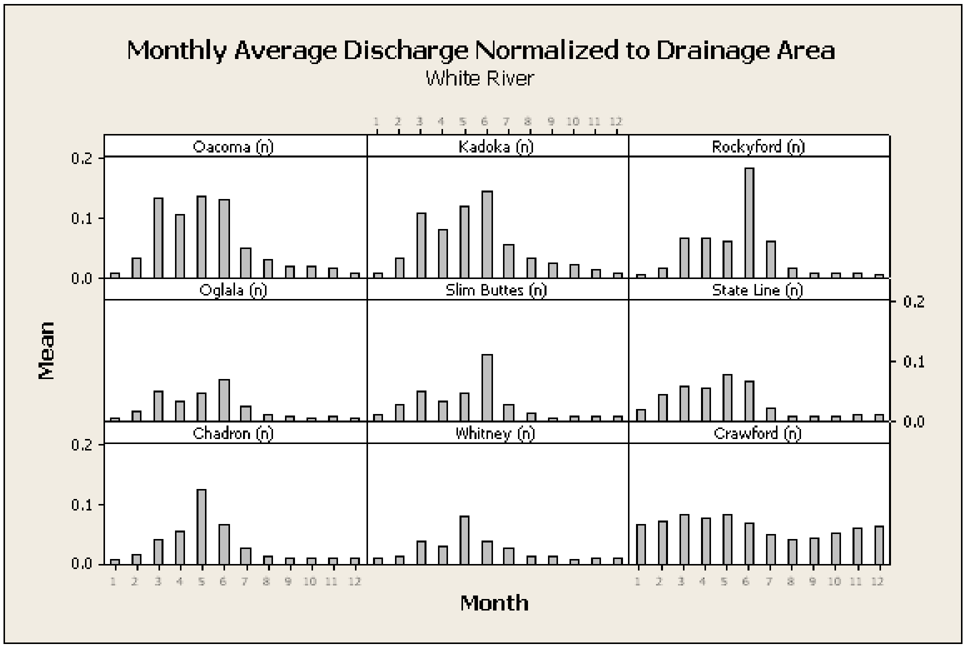



**Figure A-41.** Monthly Average Discharge Normalized to Drainage Area for Oacoma, Little White River Below White River, and Kadoka.

RSI-1465-04-133

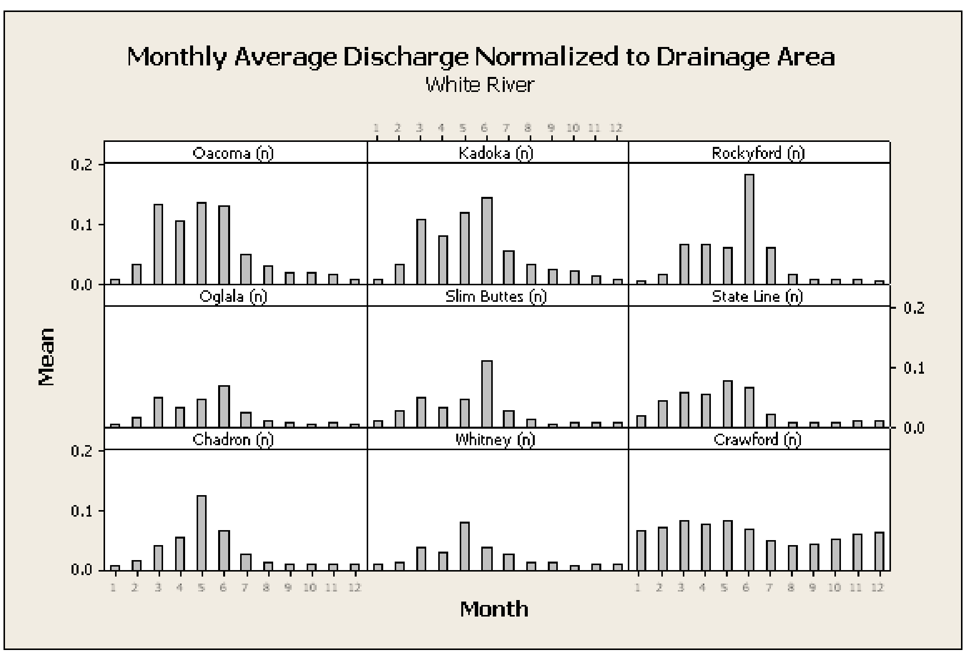



**Figure A-42.** Monthly Average Discharge Normalized to Drainage Area for White River.

RSI-1465-04-134

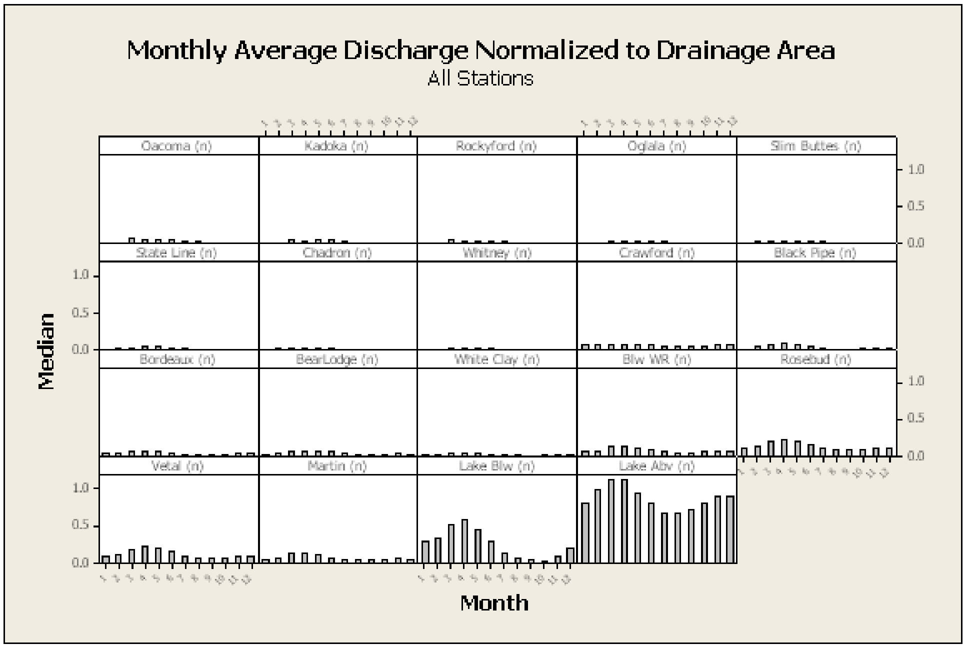



**Figure A-43.** Monthly Average Discharge Normalized to Drainage Area for All Stations.

RSI-1465-04-135

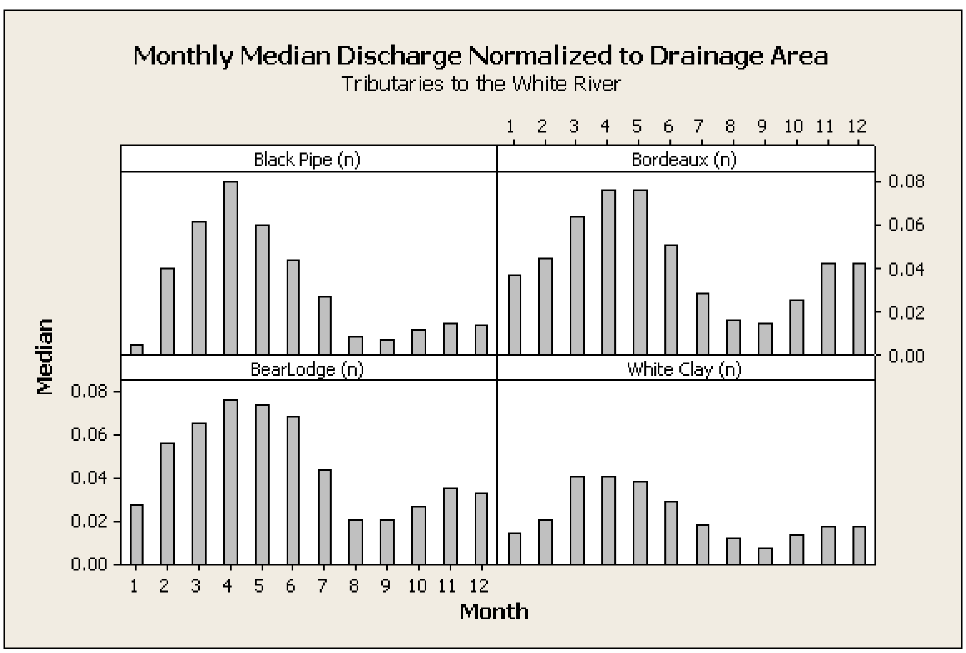



**Figure A-44.** Monthly Median Discharge Normalized to Drainage Area for Tributaries to the White River.

RSI-1465-04-136

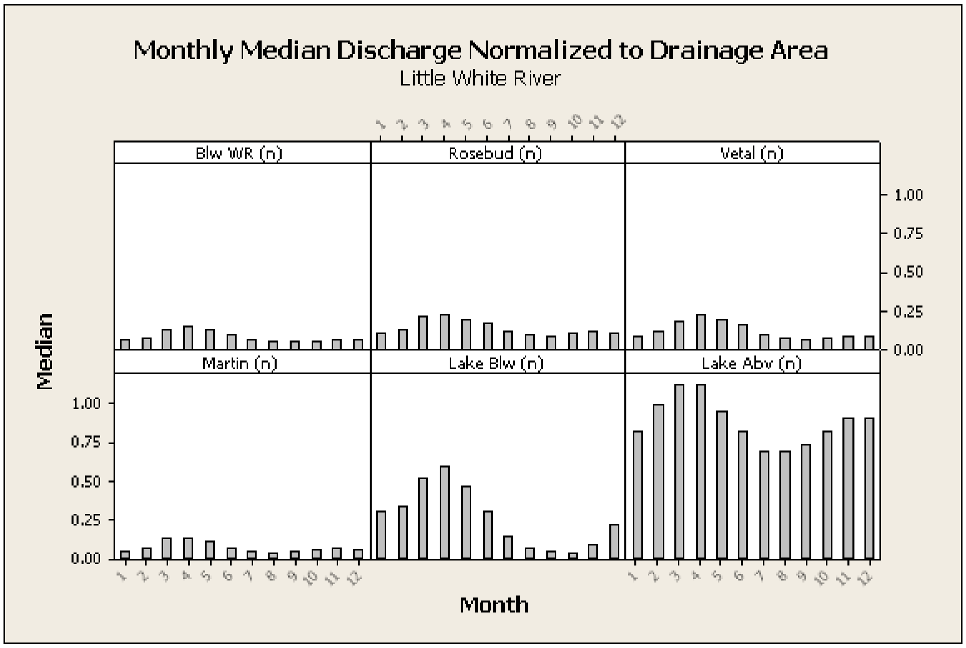



**Figure A-45.** Monthly Median Discharge Normalized to Drainage Area for Little White River.

RSI-1465-04-137

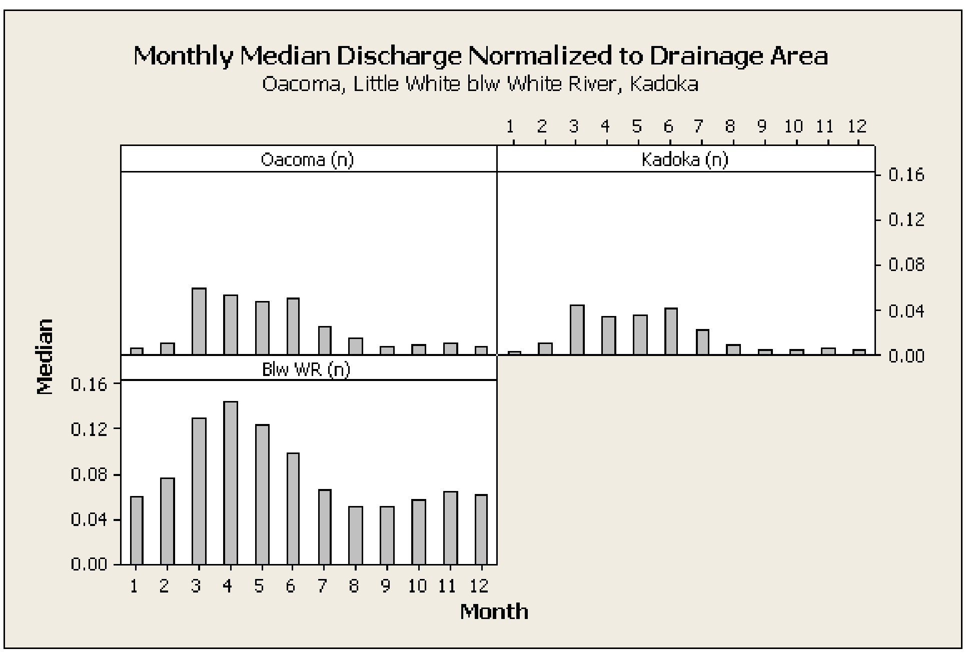



**Figure A-46.** Monthly Median Discharge Normalized to Drainage Area for Oacoma, Little White River Below White River, and Kadoka.

RSI-1465-04-138

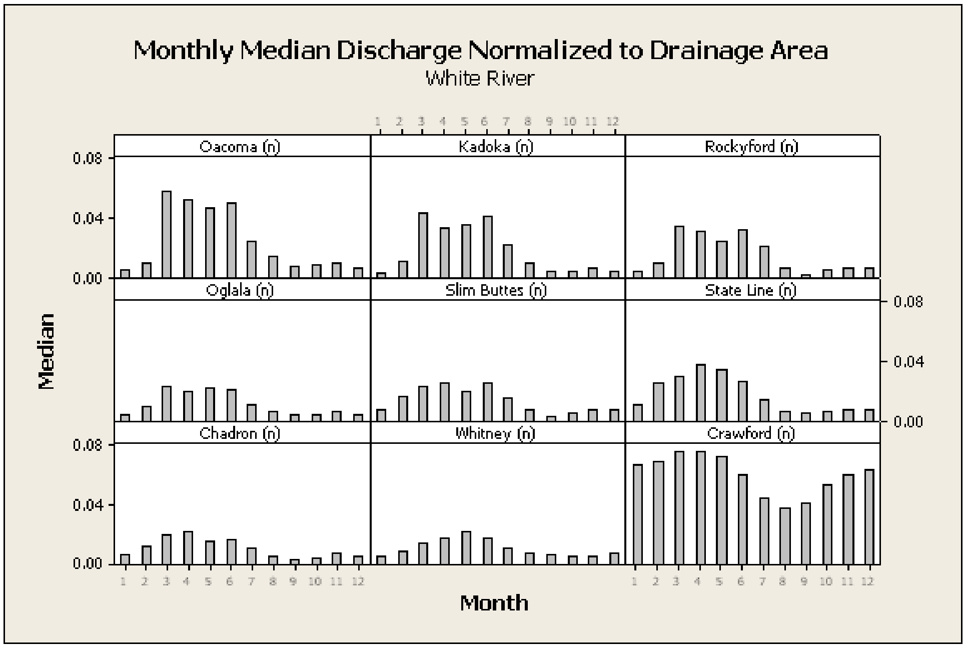



**Figure A-47.** Monthly Median Discharge Normalized to Drainage Area for White River.

RSI-1465-04-139

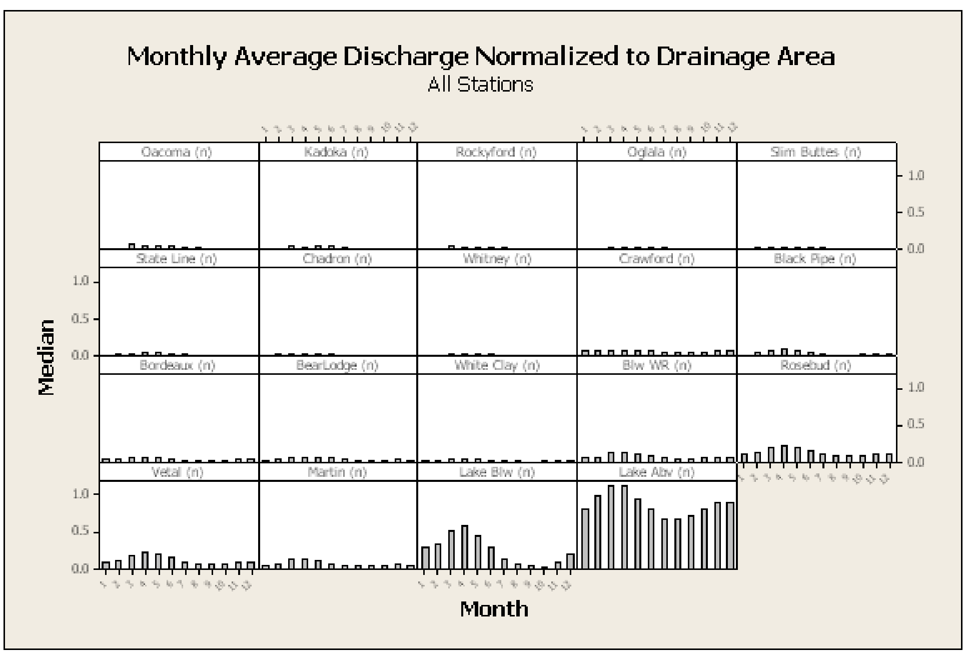



**Figure A-48.** Monthly Median Discharge Normalized to Drainage Area for All Stations.

# APPENDIX B

# WATER-QUALITY ANALYSIS

RSI-1465-04-141

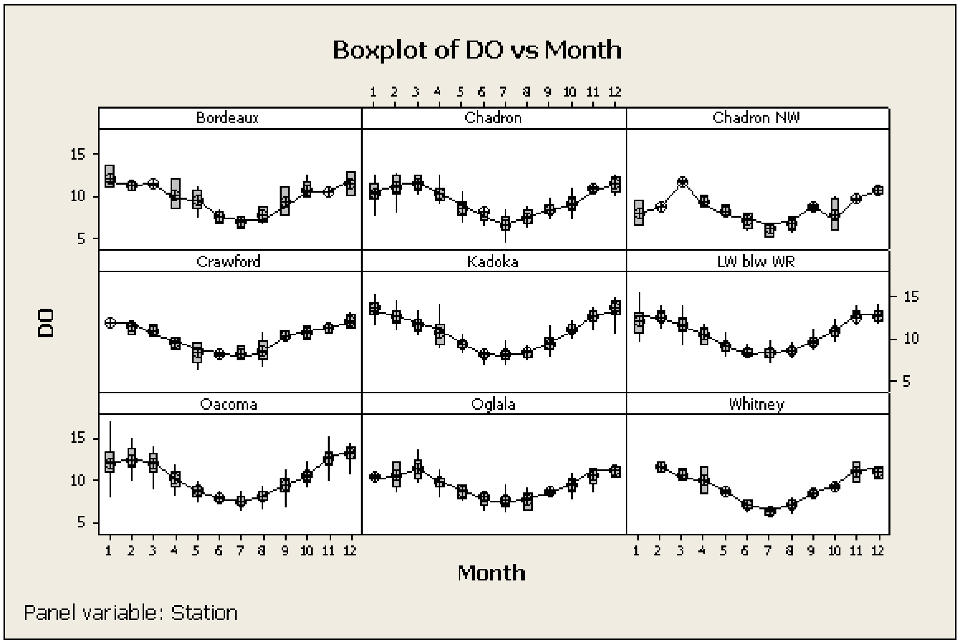



**Figure B-1.** Box Plot of Dissolved Oxygen Versus Month for All Stations.

RSI-1465-04-142

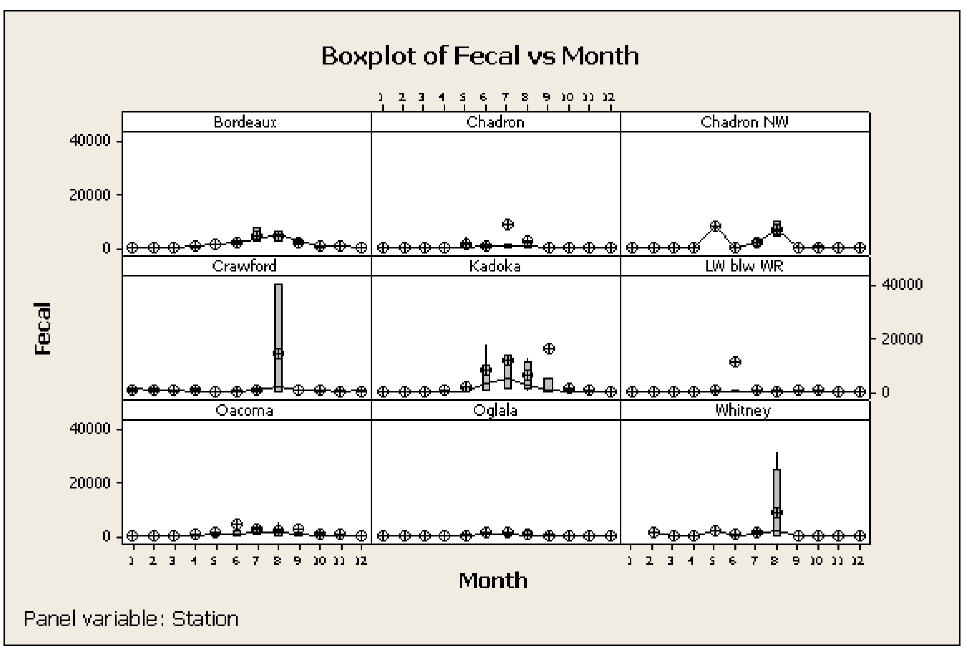



**Figure B-2.** Box Plot of Fecal Coliforms Versus Month for All Stations.

RSI-1465-04-143

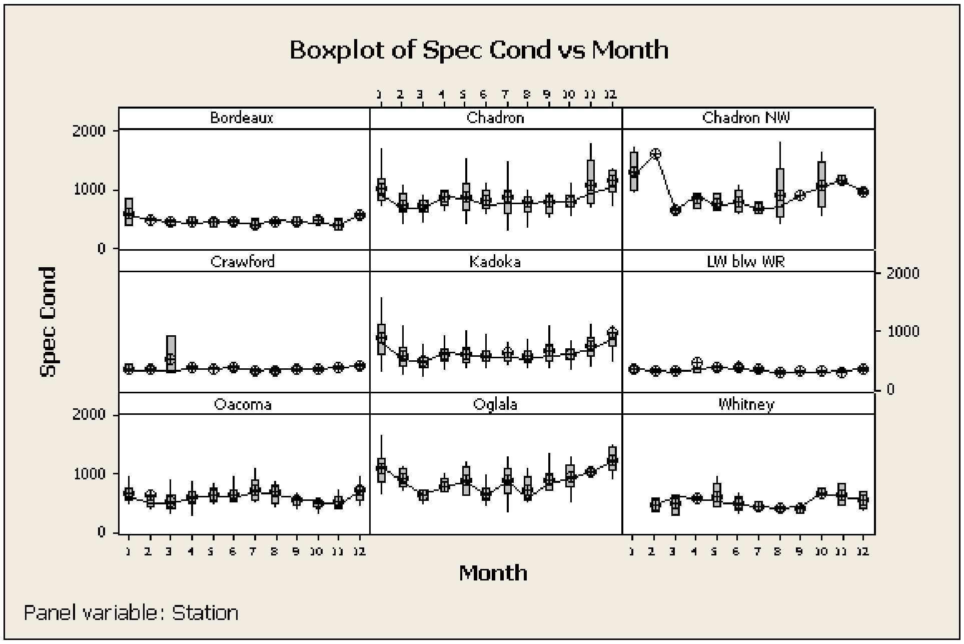



**Figure B-3.** Box Plot of Specific Conductivity Versus Month for All Stations.

RSI-1465-04-144

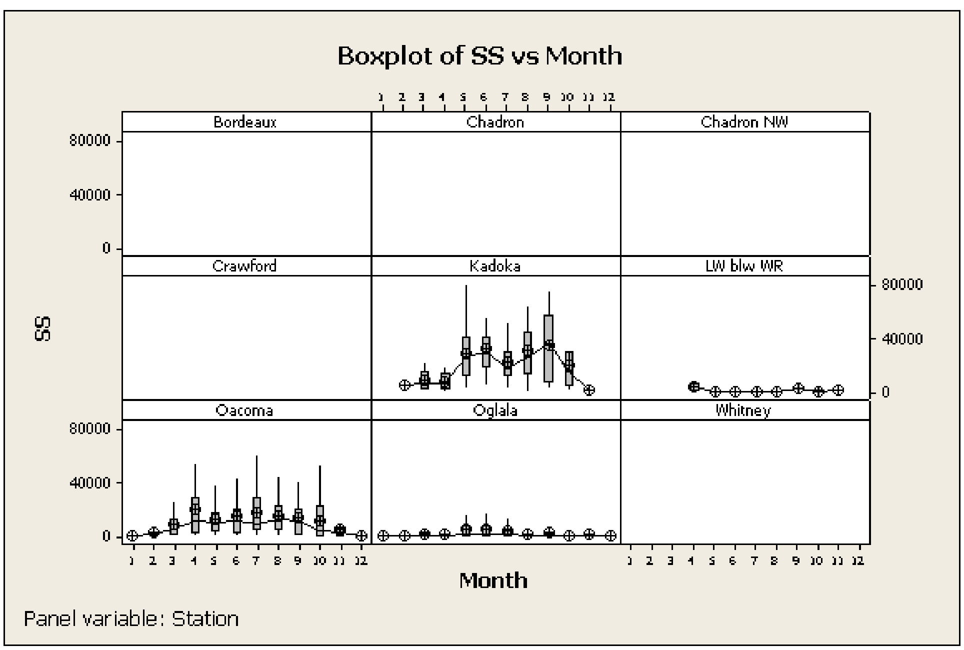



**Figure B-4.** Box Plot of Suspended Sediment Versus Month for All Stations.

RSI-1465-04-145

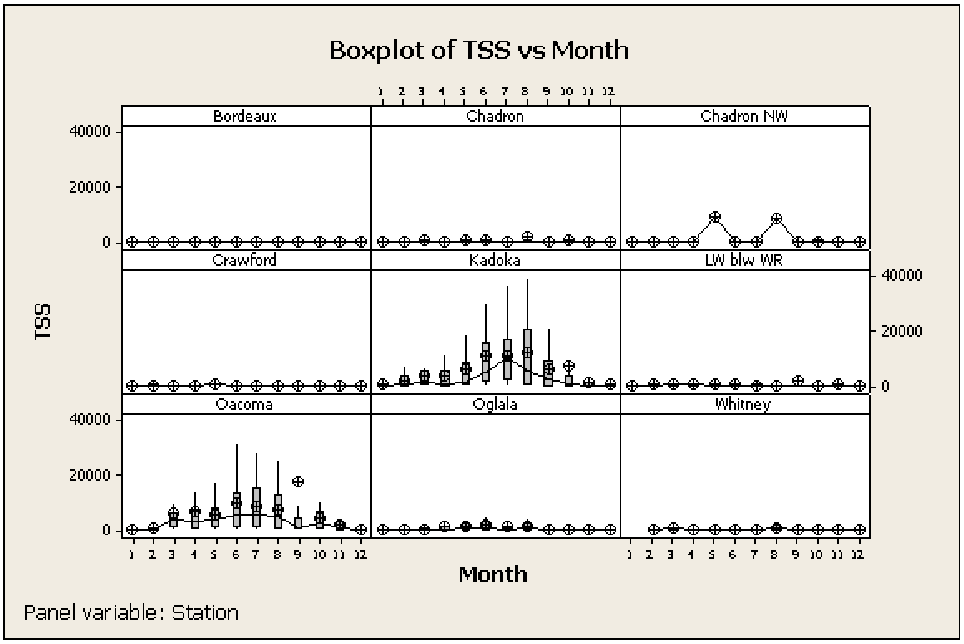



**Figure B-5.** Box Plot of Total Suspended Solids Versus Month for All Stations.

RSI-1465-04-146

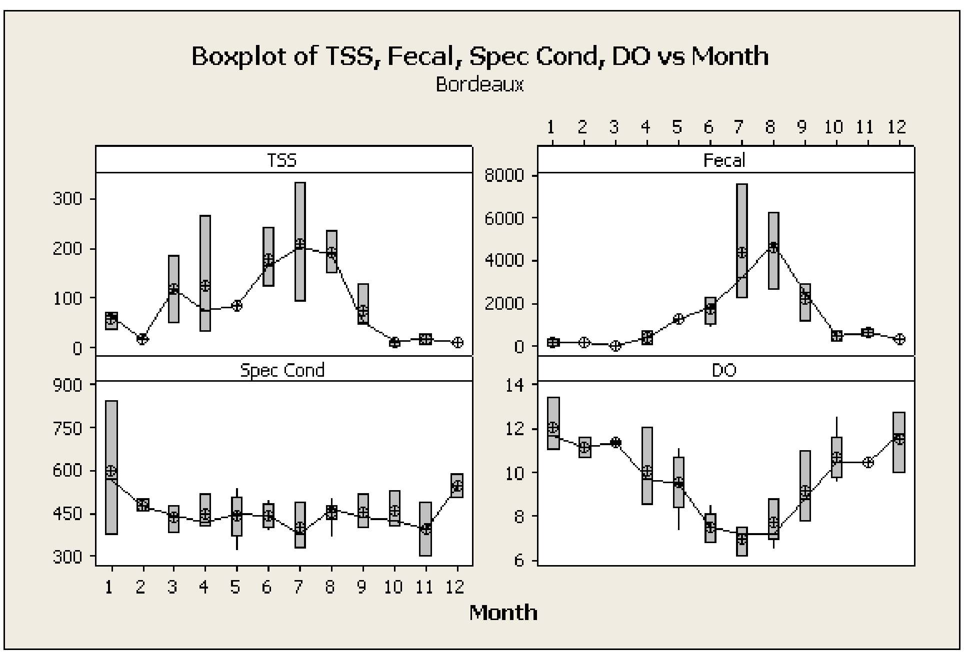



**Figure B-6.** Box Plot of Total Suspended Solids, Fecal Coliforms, Specific Conductivity, and Dissolved Oxygen Versus Month for Bordeaux.

RSI-1465-04-147

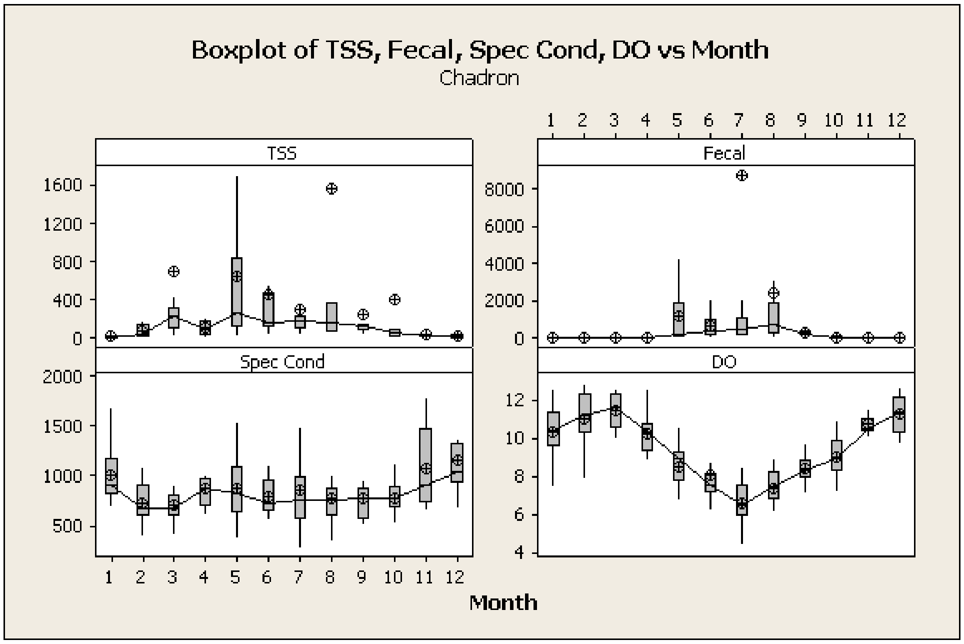



**Figure B-7.** Box Plot of Total Suspended Solids, Fecal Coliforms, Specific Conductivity, and Dissolved Oxygen Versus Month for Chadron.

RSI-1465-04-148

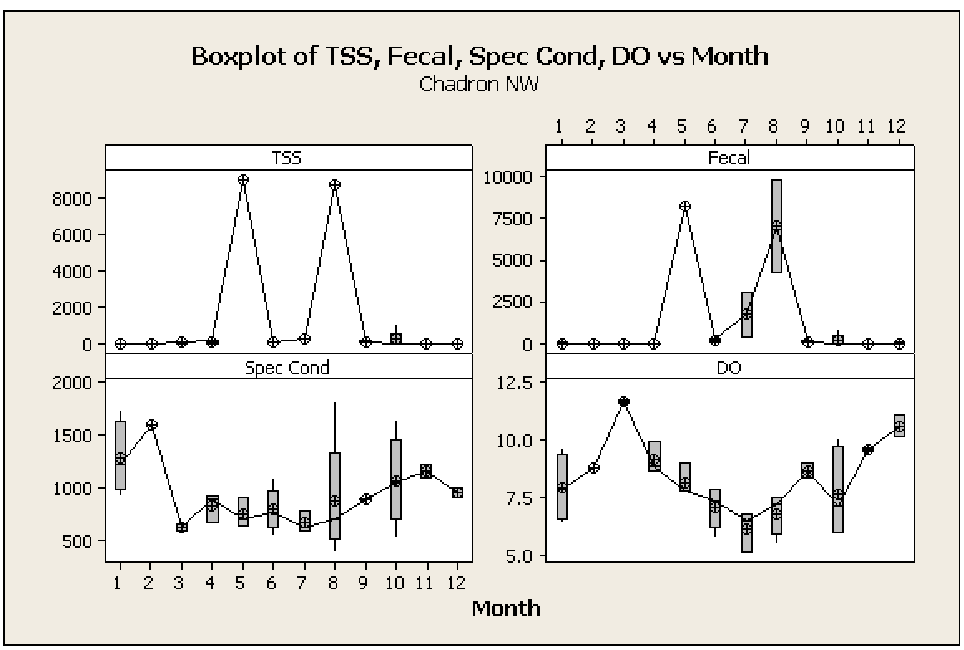



**Figure B-8.** Box Plot of Total Suspended Solids, Fecal Coliforms, Specific Conductivity, and Dissolved Oxygen Versus Month for Chadron NW.

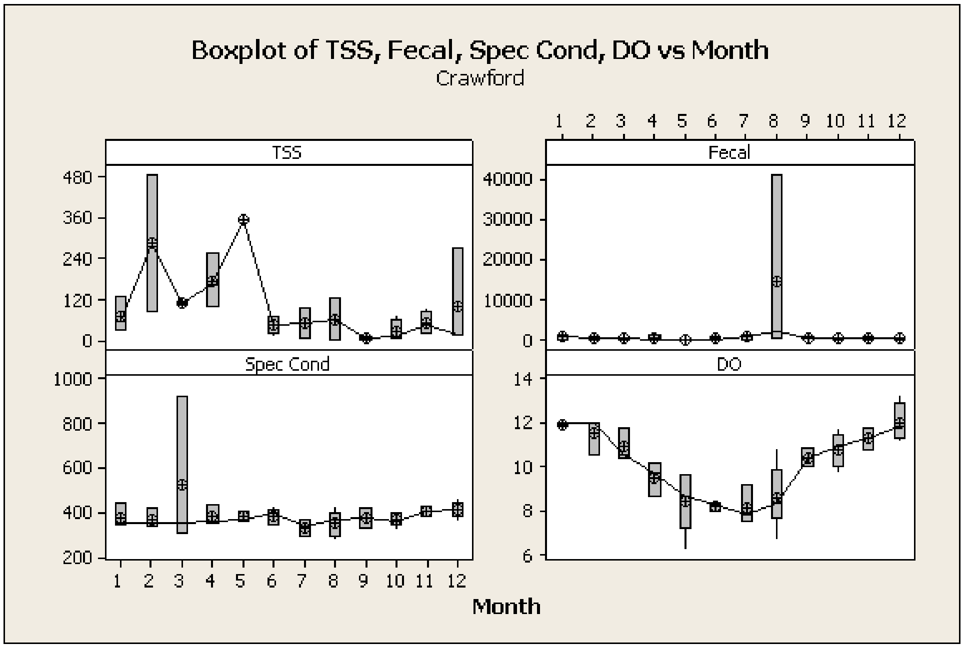



**Figure B-9.** Box Plot of Total Suspended Solids, Fecal Coliforms, Specific Conductivity, and Dissolved Oxygen Versus Month for Crawford.

RSI-1465-04-150

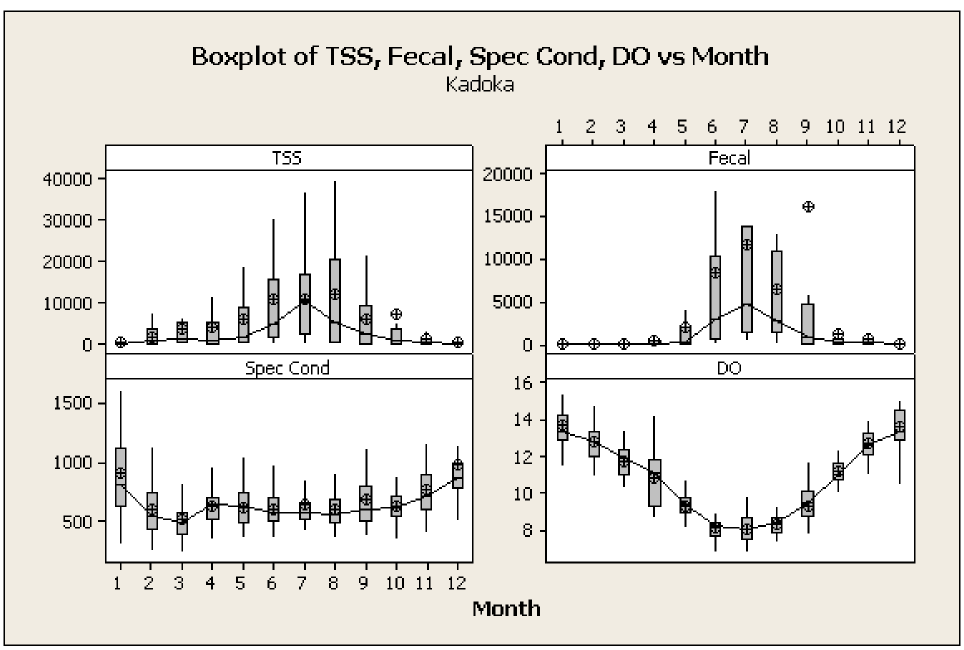



**Figure B-10.** Box Plot of Total Suspended Solids, Fecal Coliforms, Specific Conductivity, and Dissolved Oxygen Versus Month for Kadoka.

RSI-1465-04-151

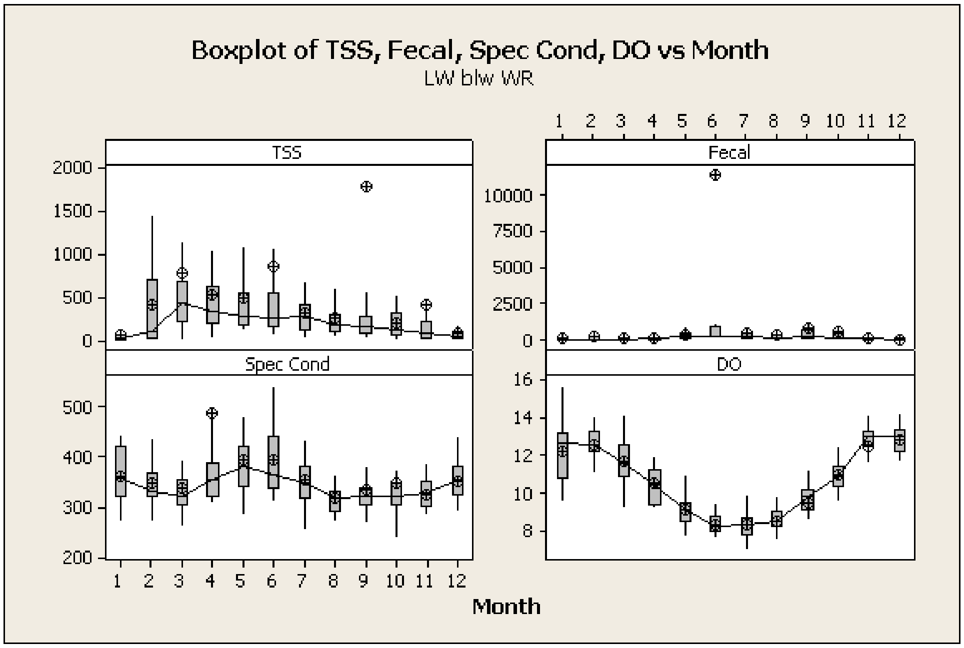



**Figure B-11.** Box Plot of Total Suspended Solids, Fecal Coliforms, Specific Conductivity, and Dissolved Oxygen Versus Month for Little White River Below White River.

RSI-1465-04-152

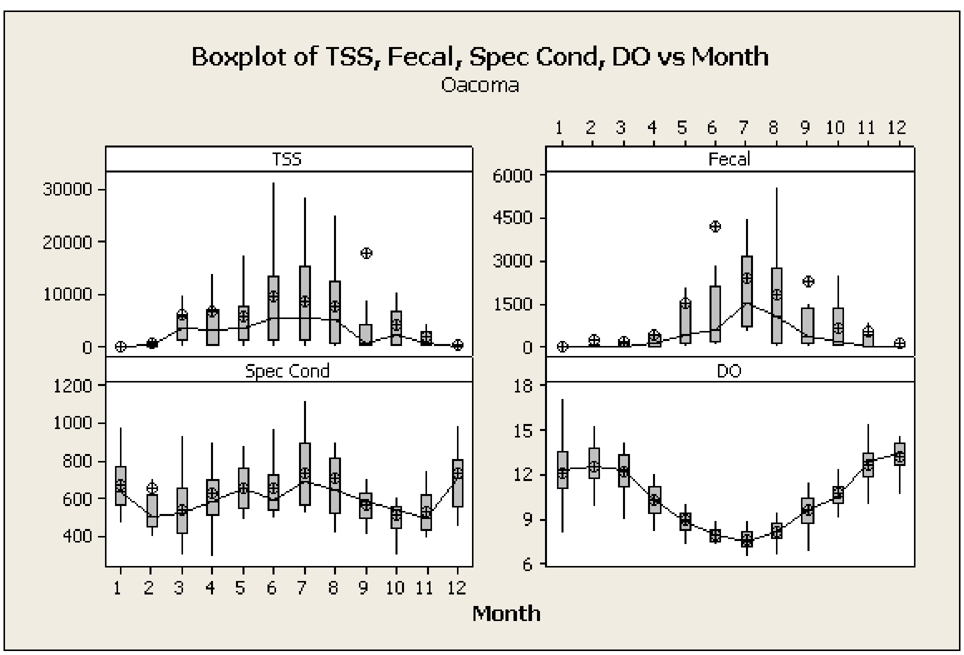



**Figure B-12.** Box Plot of Total Suspended Solids, Fecal Coliforms, Specific Conductivity, and Dissolved Oxygen Versus Month for Oacoma.

RSI-1465-04-153

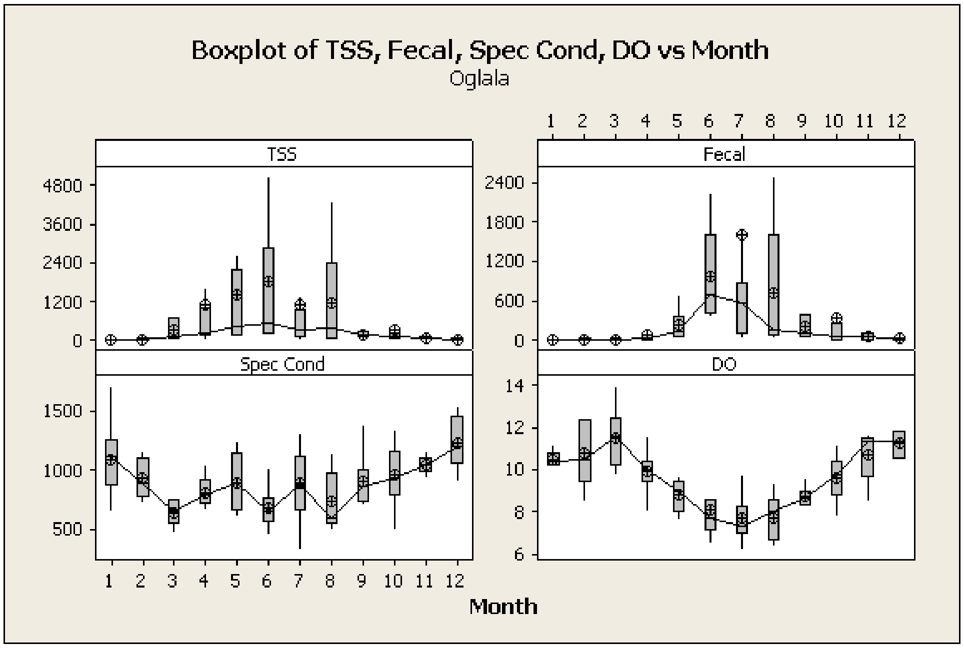



**Figure B-13.** Box Plot of Total Suspended Solids, Fecal Coliforms, Specific Conductivity, and Dissolved Oxygen Versus Month for Oglala.

RSI-1465-04-154

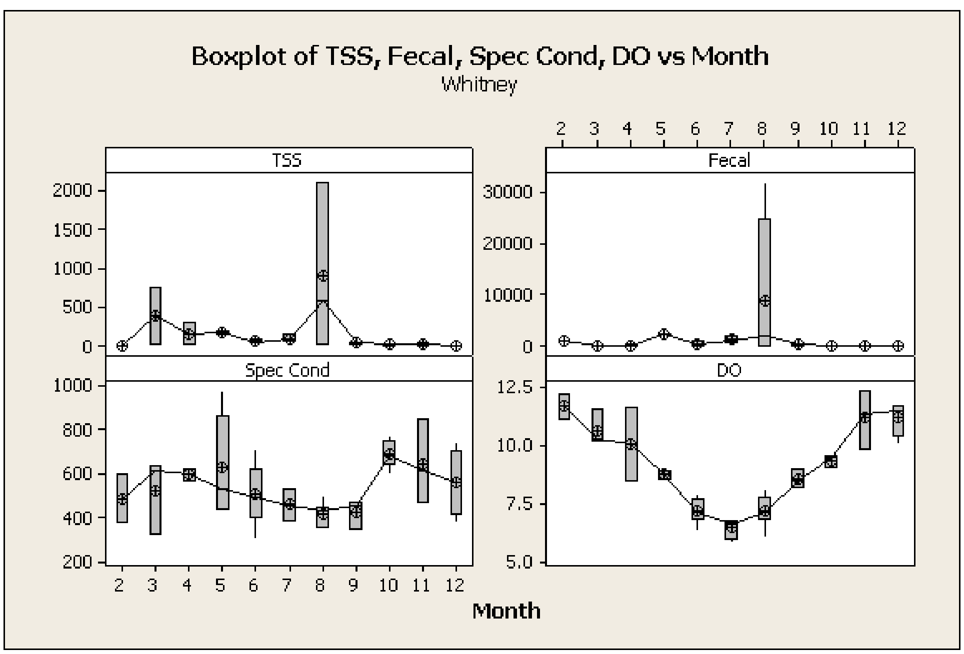



**Figure B-14.** Box Plot of Total Suspended Solids, Fecal Coliforms, Specific Conductivity, and Dissolved Oxygen Versus Month for Whitney.

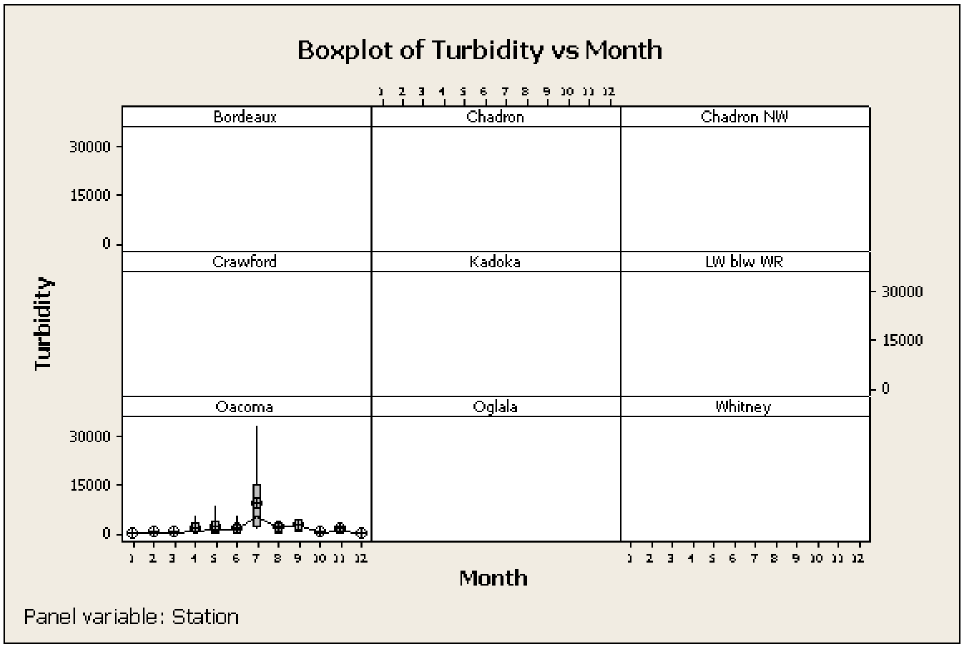



**Figure B-15.** Box Plot of Turbidity Versus Month for All Stations.

RSI-1465-04-156

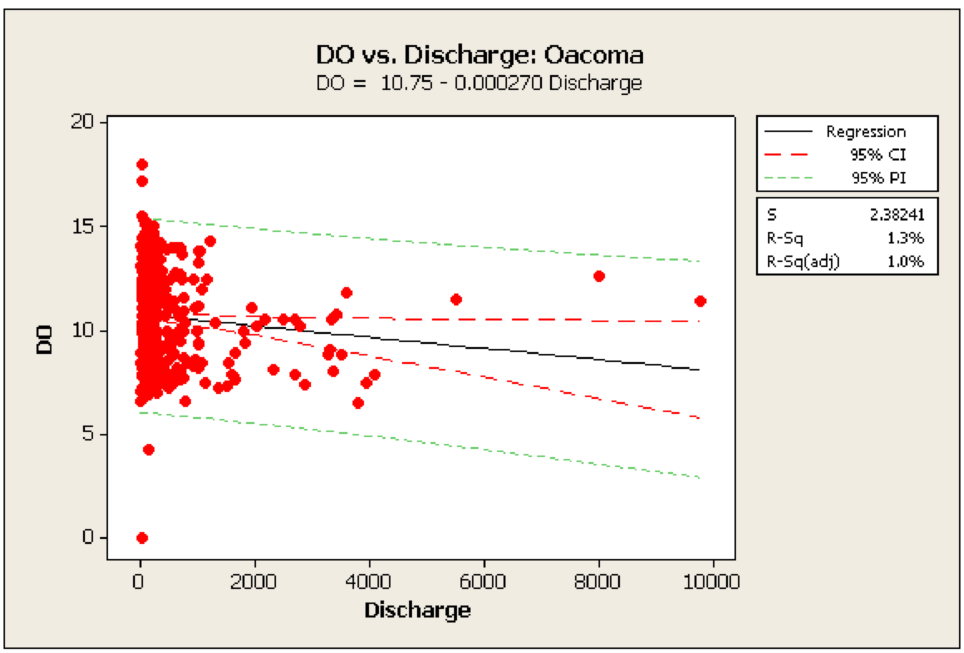



**Figure B-16.** Box Plot of Dissolved Oxygen Versus Discharge for Oacoma.

RSI-1465-04-157

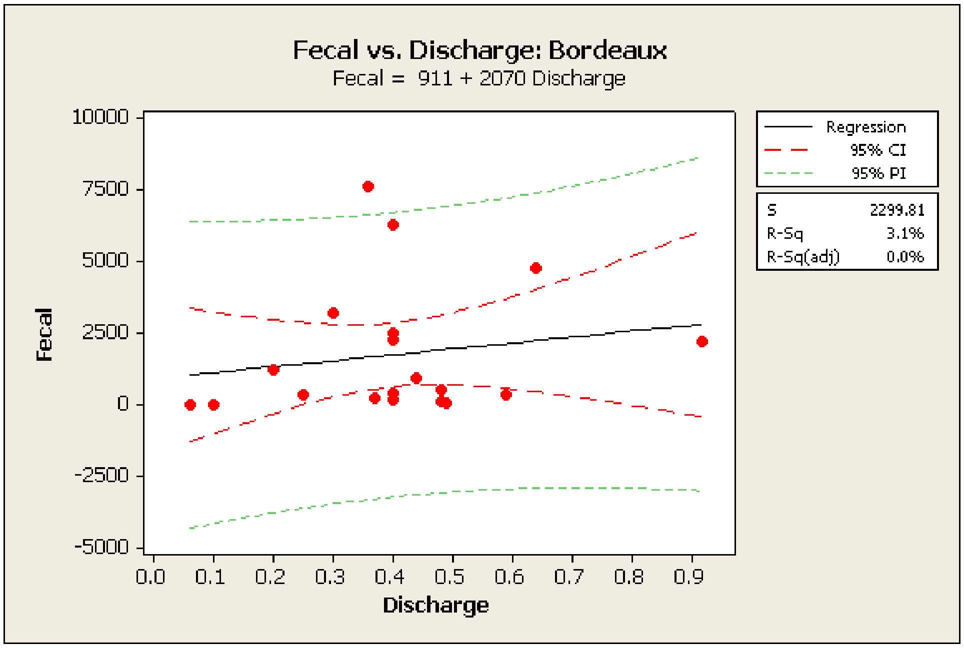



**Figure B-17.** Box Plot of Fecal Coliforms Versus Discharge for Bordeaux.

RSI-1465-04-158

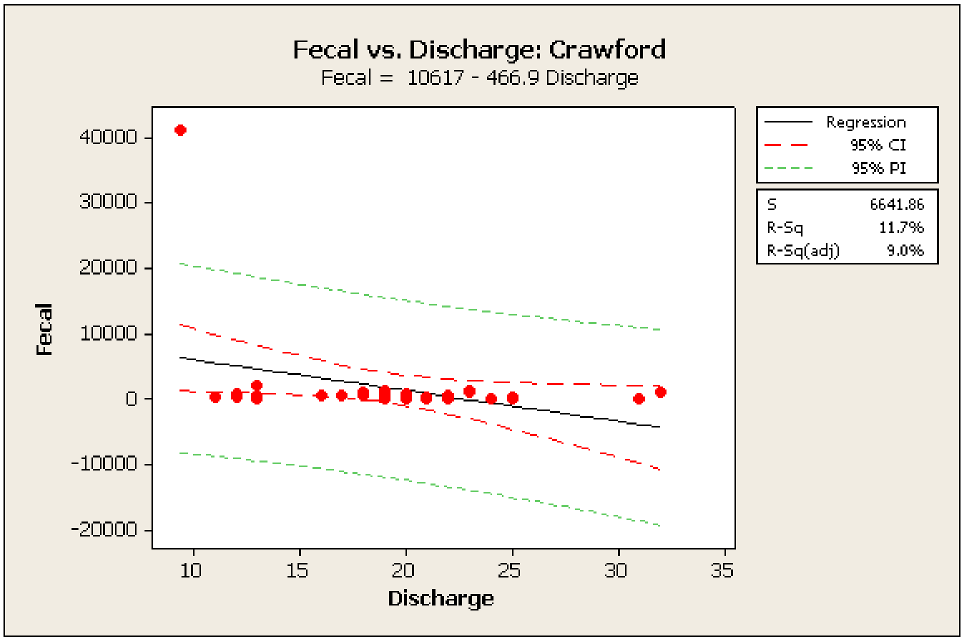



**Figure B-18.** Box Plot of Fecal Coliforms Versus Discharge for Crawford.

RSI-1465-04-159

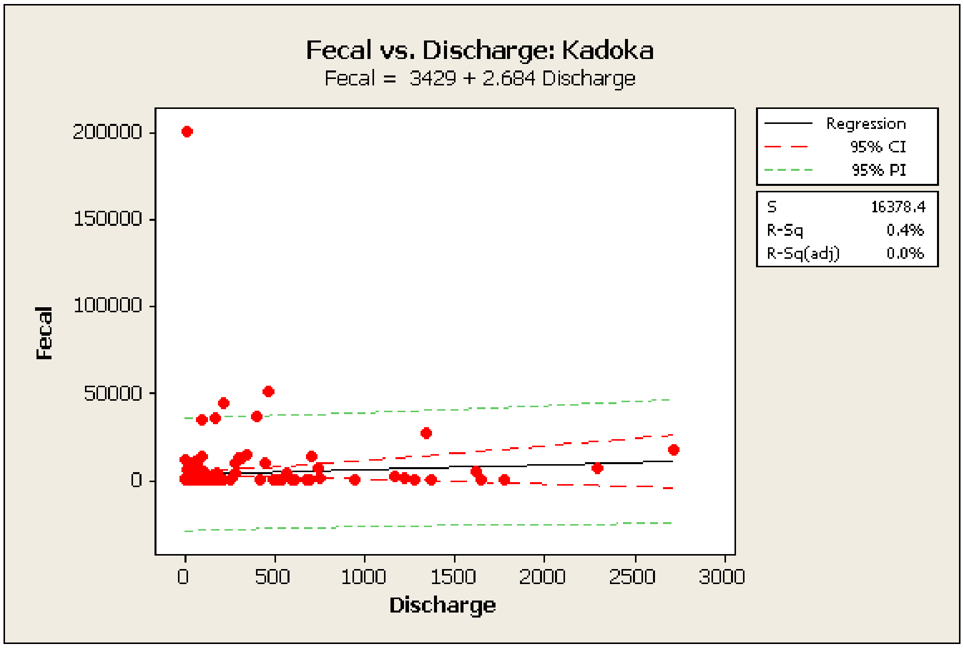



**Figure B-19.** Box Plot of Fecal Coliforms Versus Discharge for Kadoka.

RSI-1465-04-160

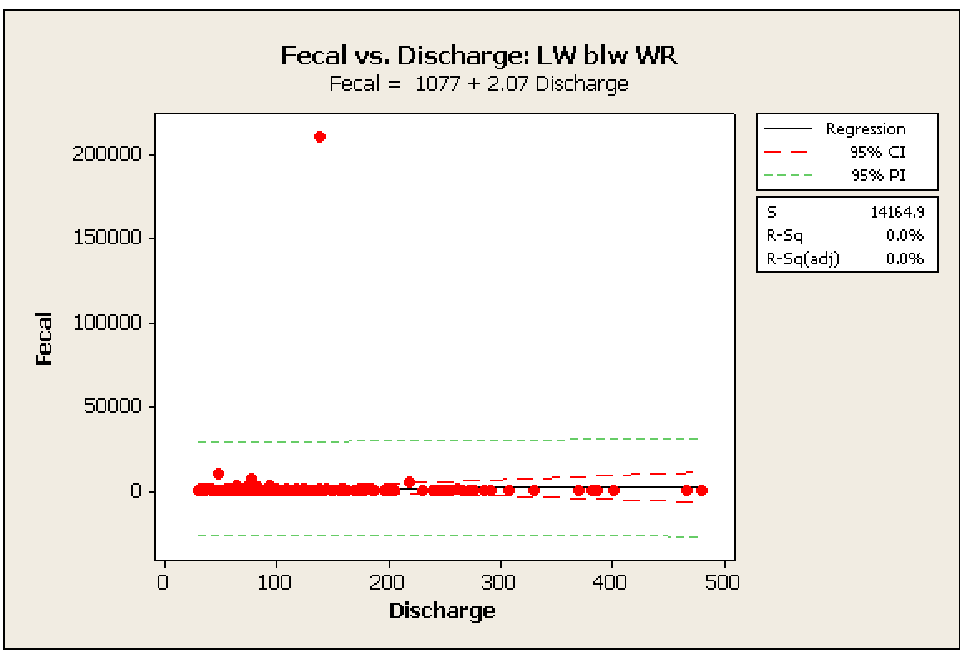



**Figure B-20.** Box Plot of Fecal Coliforms Versus Discharge for Litte White River Below White River.

RSI-1465-04-161

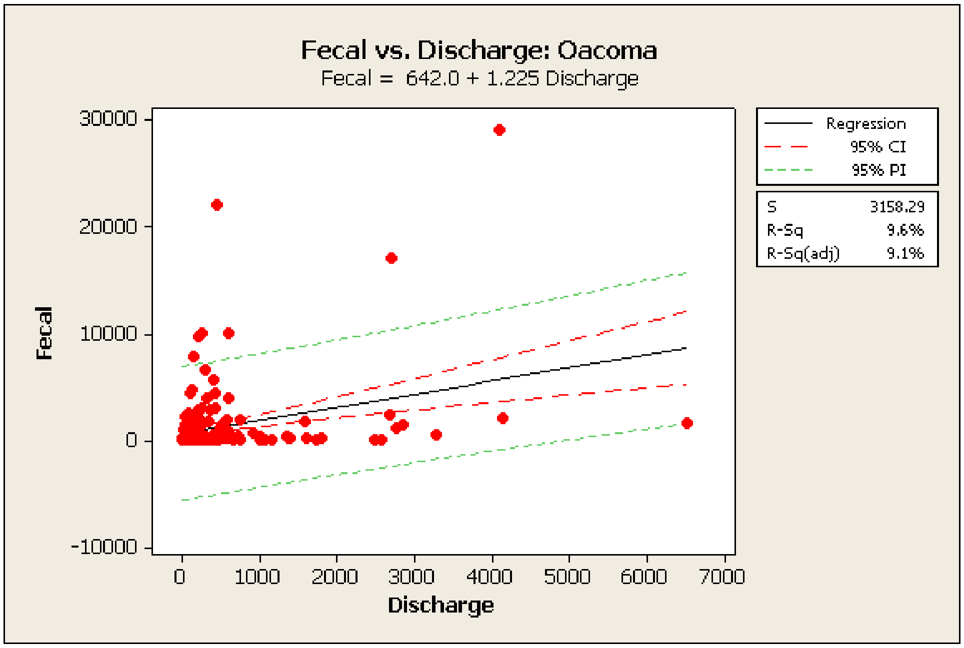



**Figure B-21.** Box Plot of Fecal Coliforms Versus Discharge for Oacoma.

RSI-1465-04-162

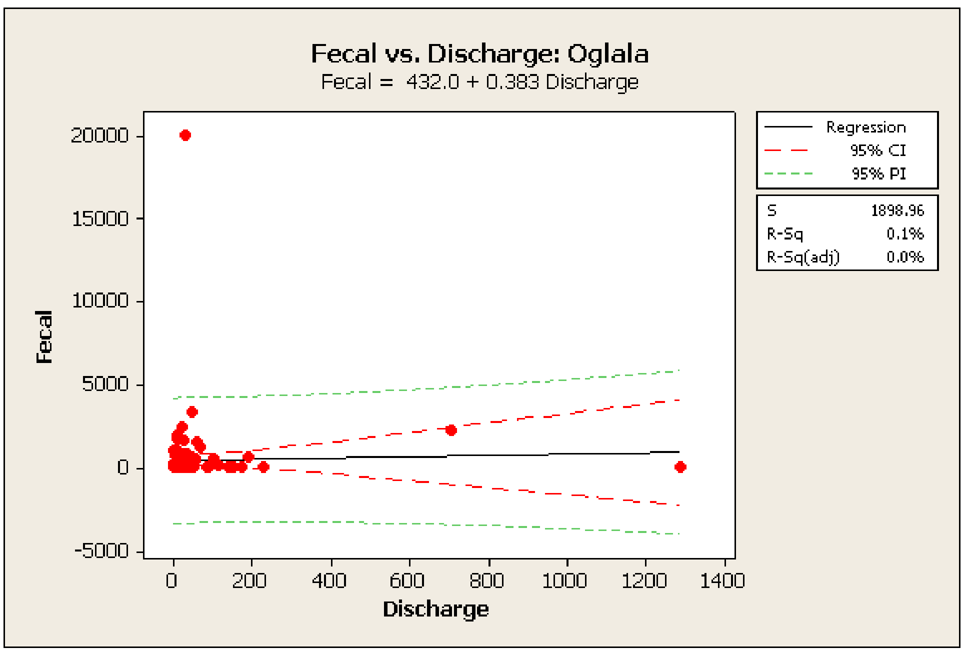



**Figure B-22.** Box Plot of Fecal Coliforms Versus Discharge for Oglala.

RSI-1465-04-163

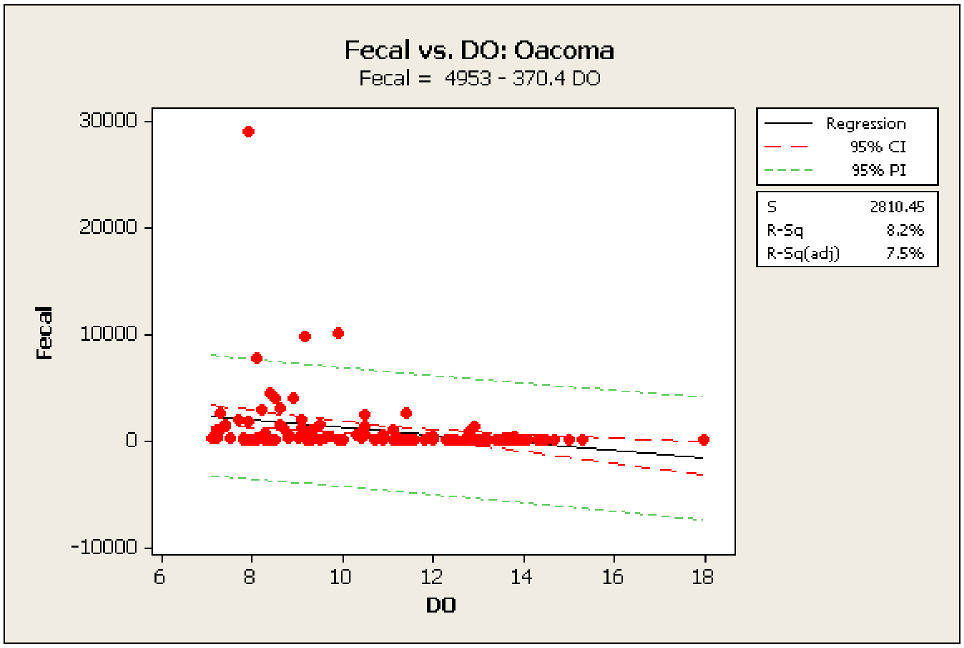



**Figure B-23.** Box Plot of Fecal Coliforms Versus Dissolved Oxygen for Oacoma.

RSI-1465-04-164

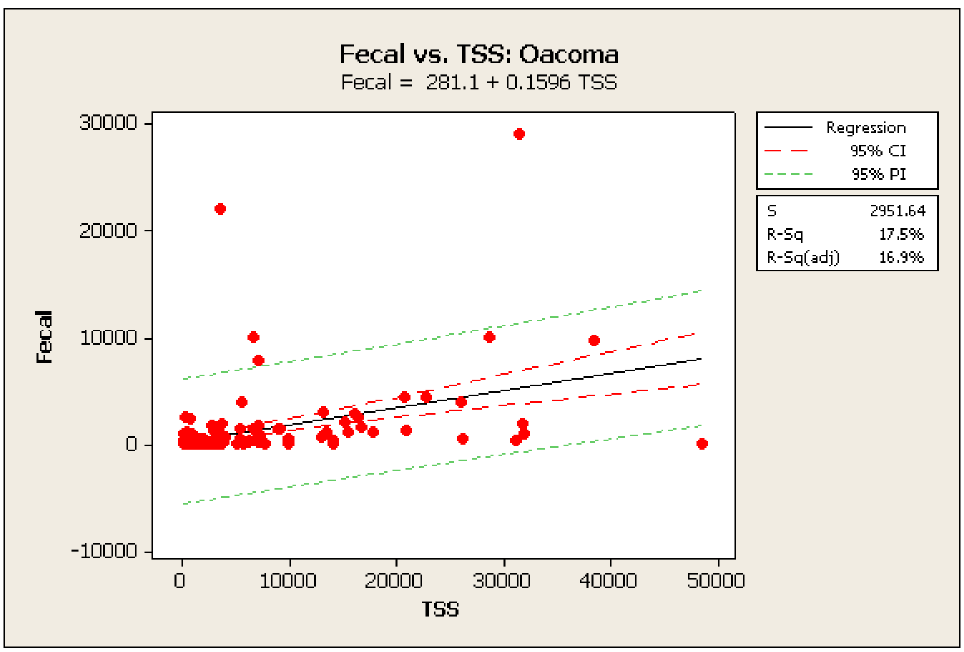



**Figure B-24.** Box Plot of Fecal Coliforms Versus Total Suspended Solids for Oacoma.

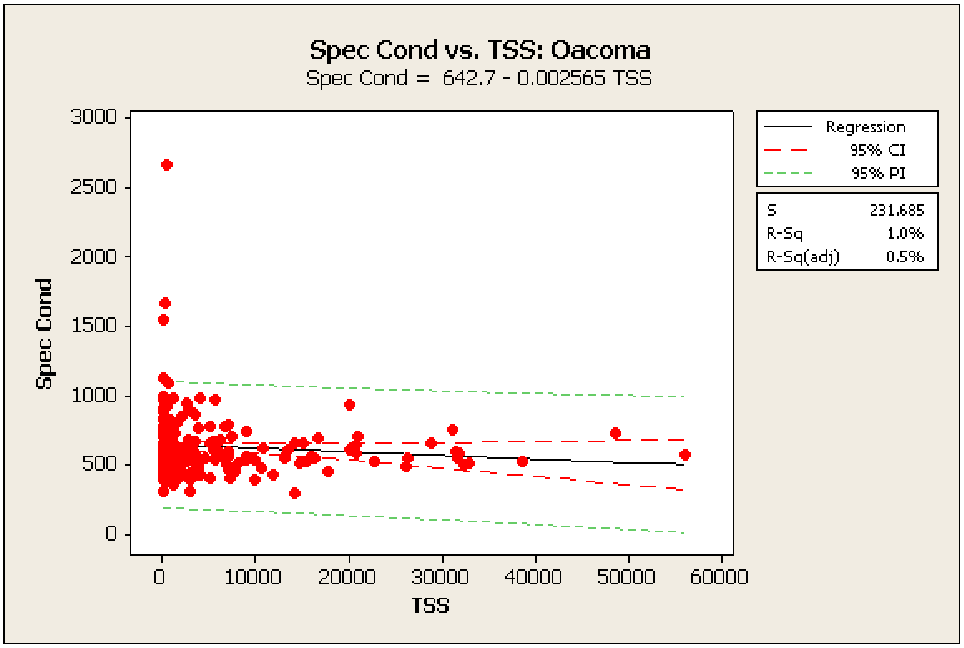



**Figure B-25.** Box Plot of Specific Conductivity Versus Total Suspended Solids for Oacoma.

RSI-1465-04-166

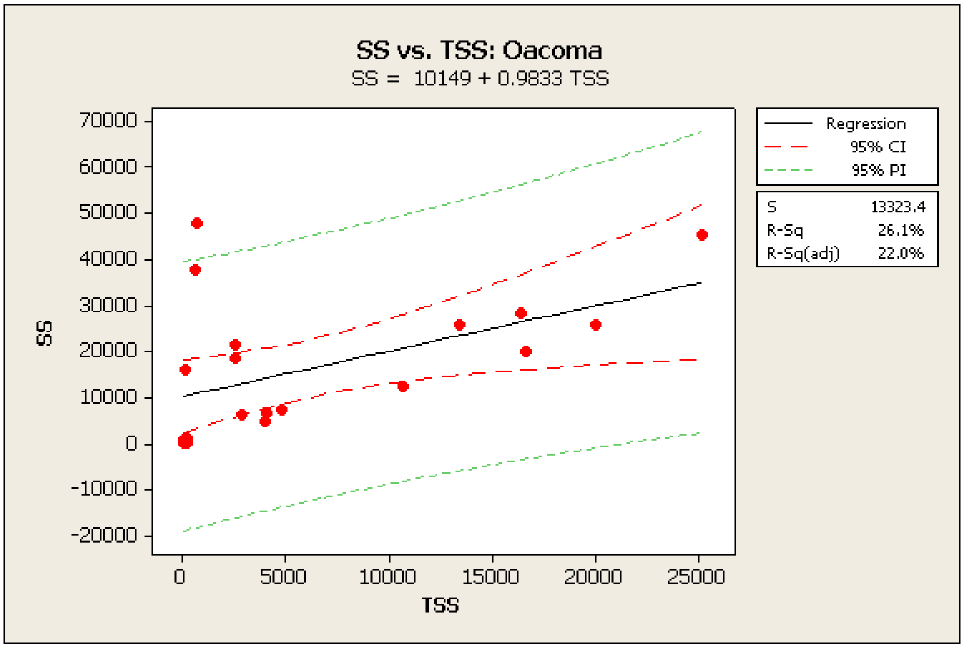



**Figure B-26.** Box Plot of Suspended Sediment Versus Total Suspended Solids for Oacoma.

RSI-1465-04-167

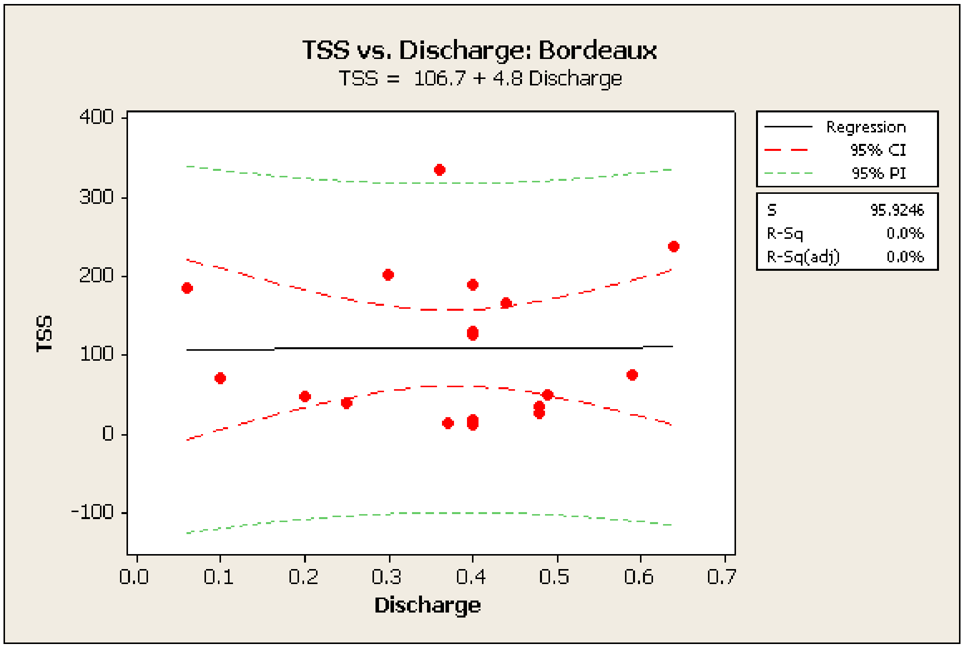



**Figure B-27.** Box Plot of Total Suspended Solids Versus Discharge for Bordeaux.

RSI-1465-04-168

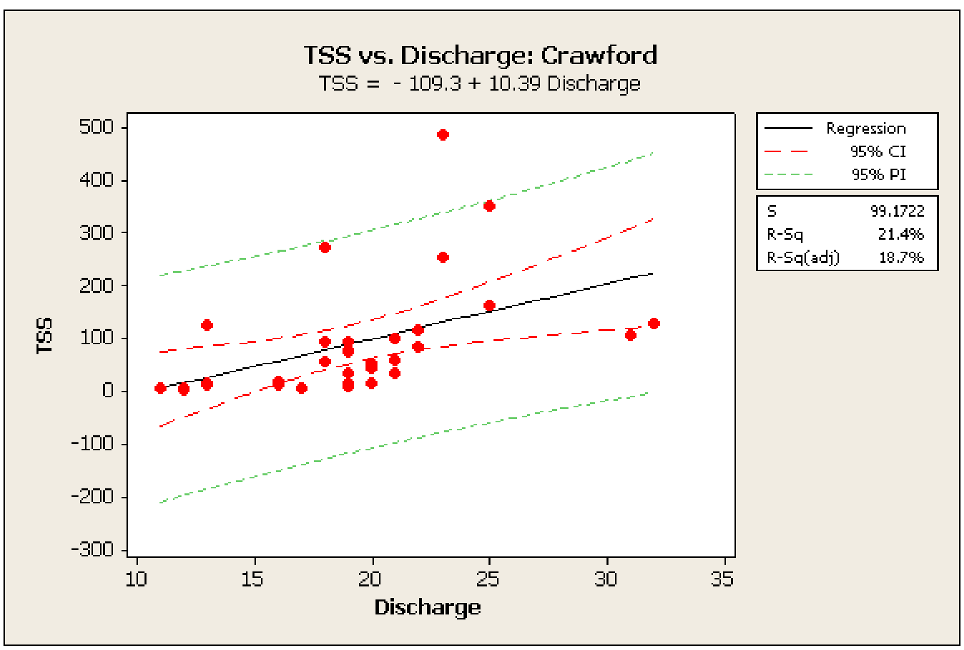



**Figure B-28.** Box Plot of Total Suspended Solids Versus Discharge for Crawford.

RSI-1465-04-169

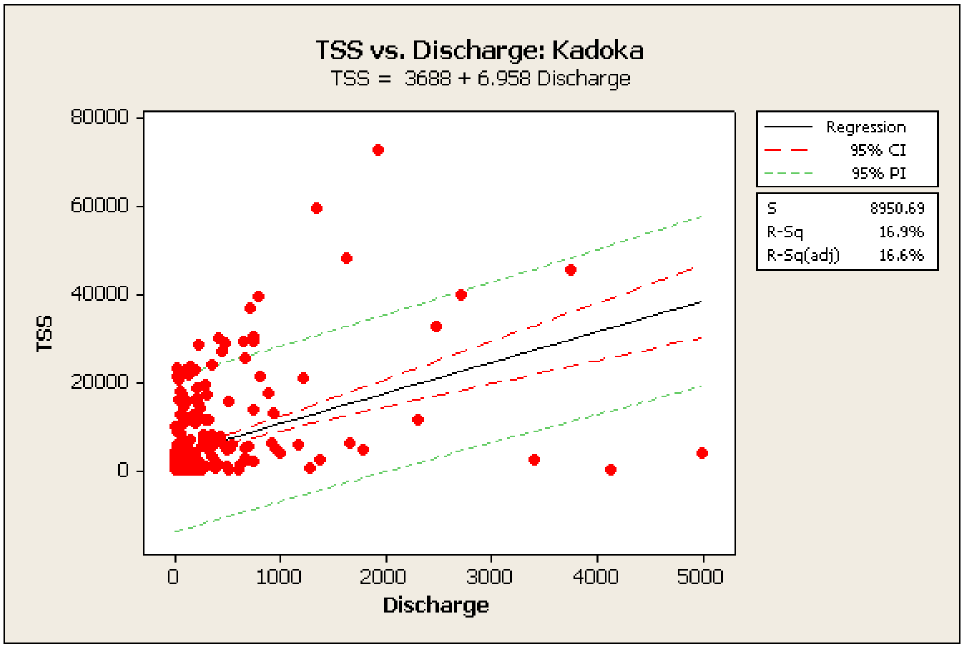



**Figure B-29.** Box Plot of Total Suspended Solids Versus Discharge for Kadoka.

RSI-146p5-04-170

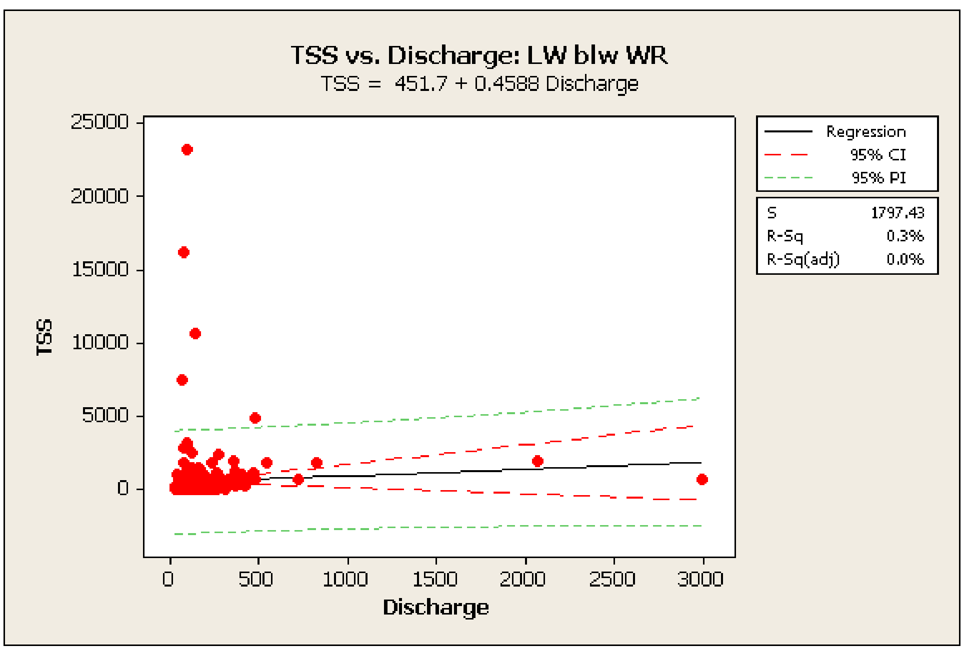



**Figure B-30.** Box Plot of Total Suspended Solids Versus Discharge for Little White River Below White River.

RSI-1465-04-171

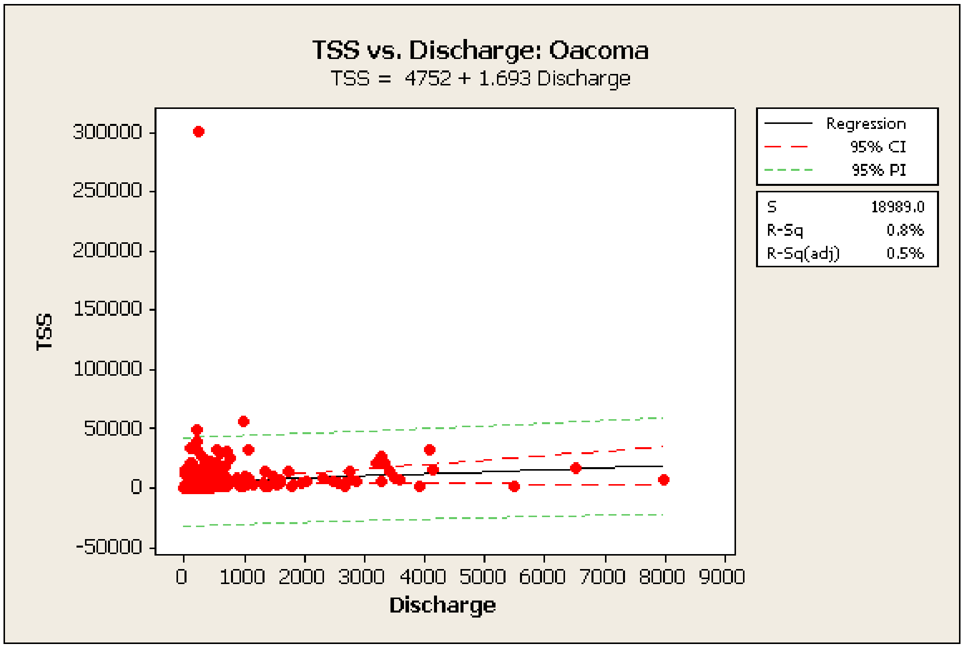



**Figure B-31.** Box Plot of Total Suspended Solids Versus Discharge for Oacoma.

RSI-1465-04-172

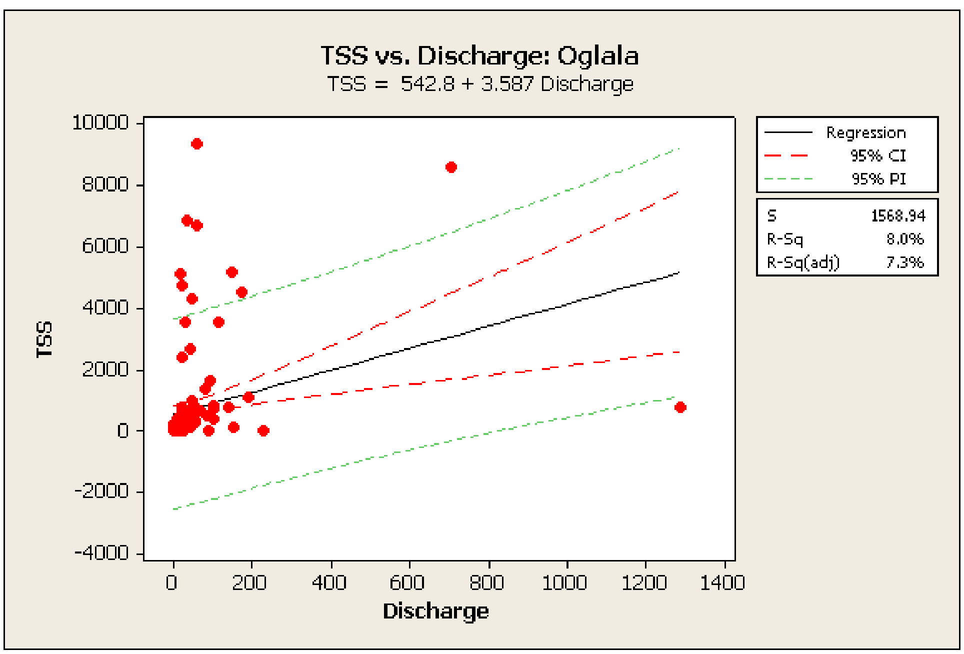



**Figure B-32.** Box Plot of Total Suspended Solids Versus Discharge for Oglala.

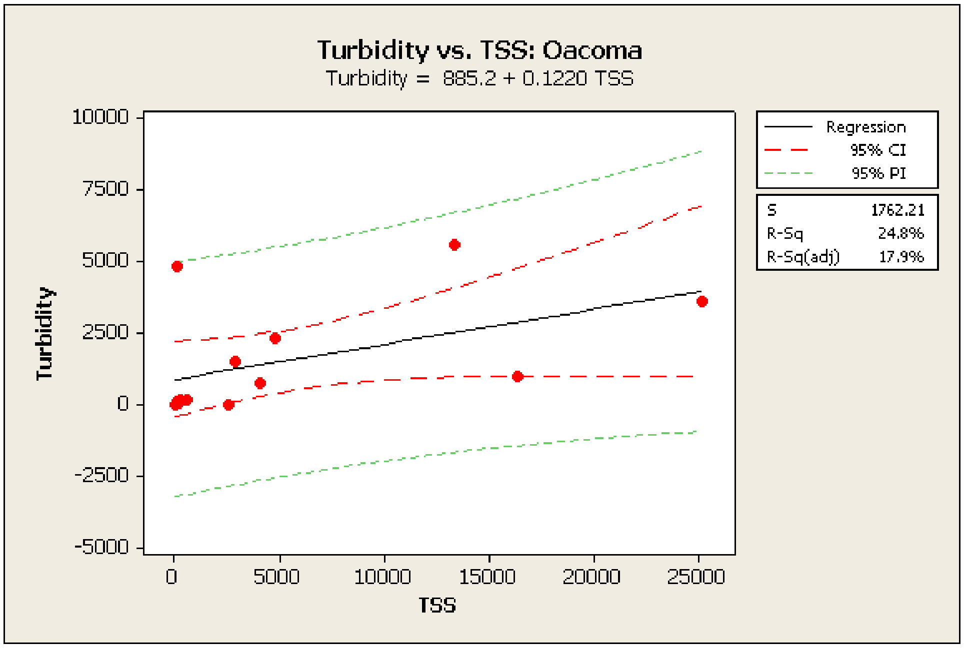



**Figure B-33.** Box Plot of Turbidity Versus Total Suspended Solids for Oacoma.

# APPENDIX C

# LOAD DURATION CURVES

RSI-1465-04-036

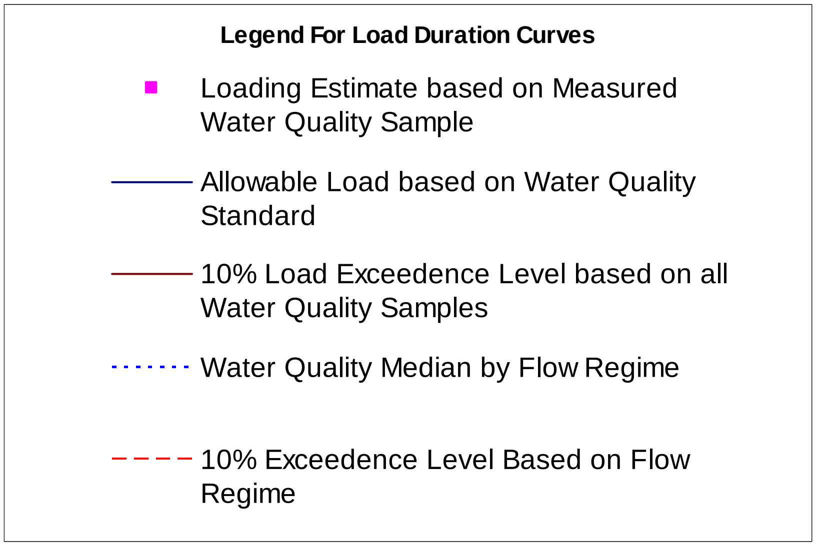



**Figure C-1.** Legend for Load Duration Curves for the White River Watershed.

RSI-1465-04-037

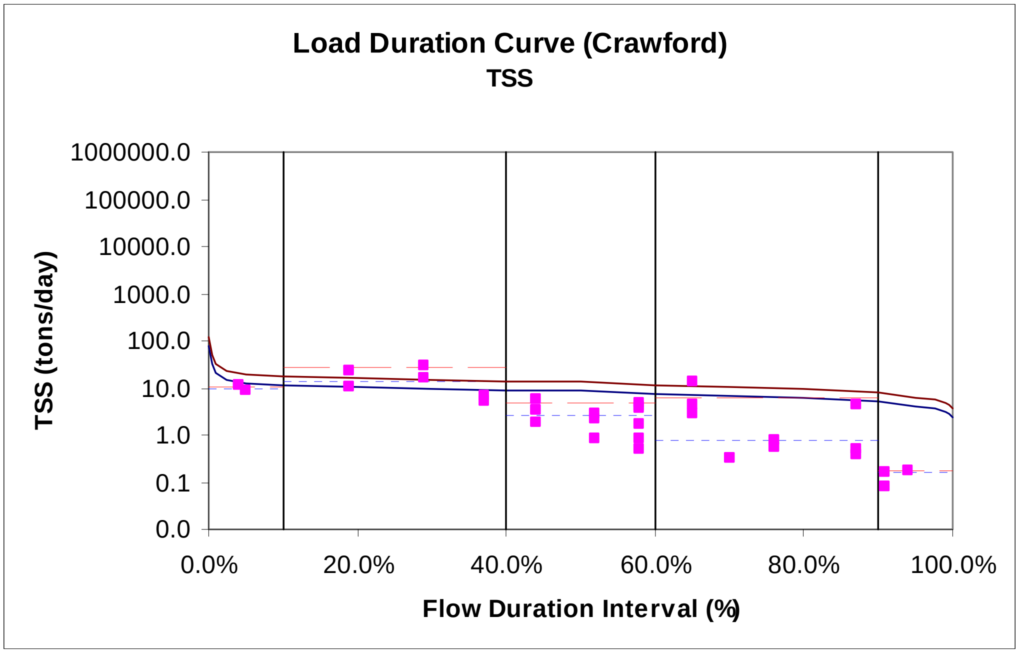



**Figure C-2.** Load Duration Curves for TSS for Crawford.

RSI-1465-04-038

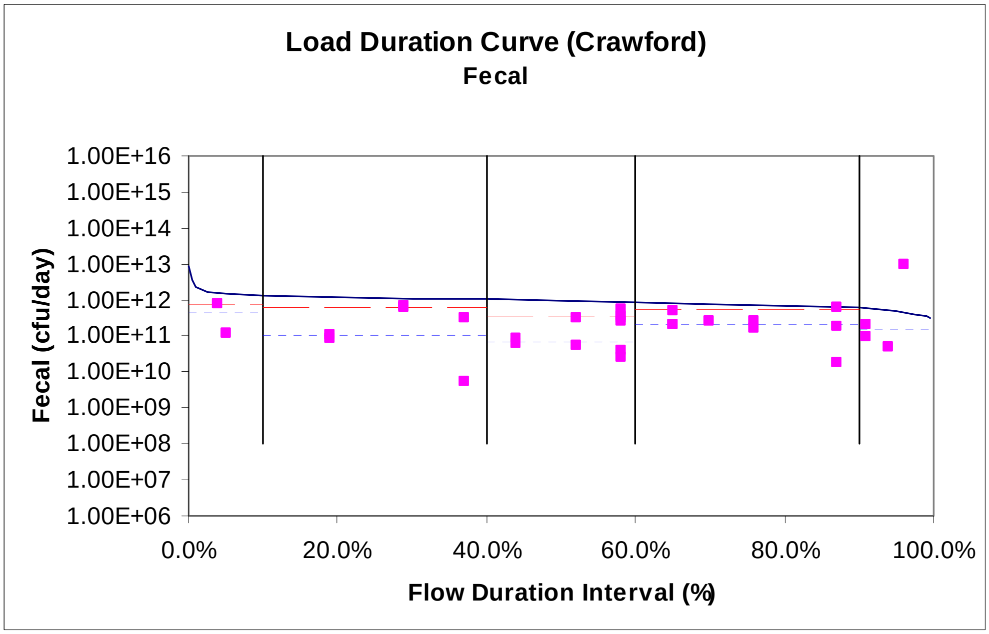



**Figure C-3.** Load Duration Curves for Fecal Coliforms for Crawford.

RSI-1465-04-039

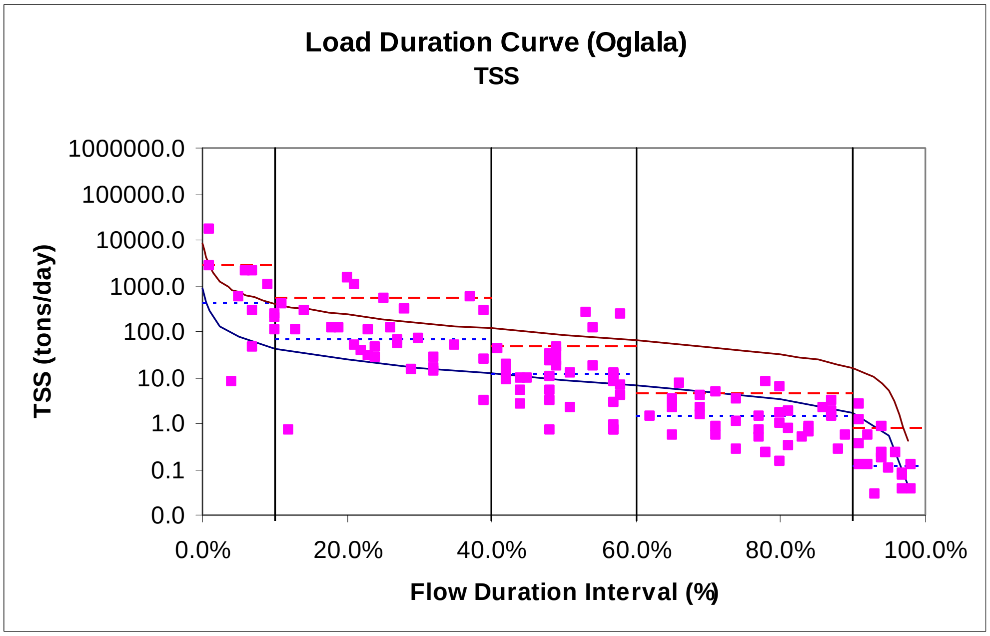



**Figure C-4.** Load Duration Curves for TSS for Oglala.

RSI-1465-04-040

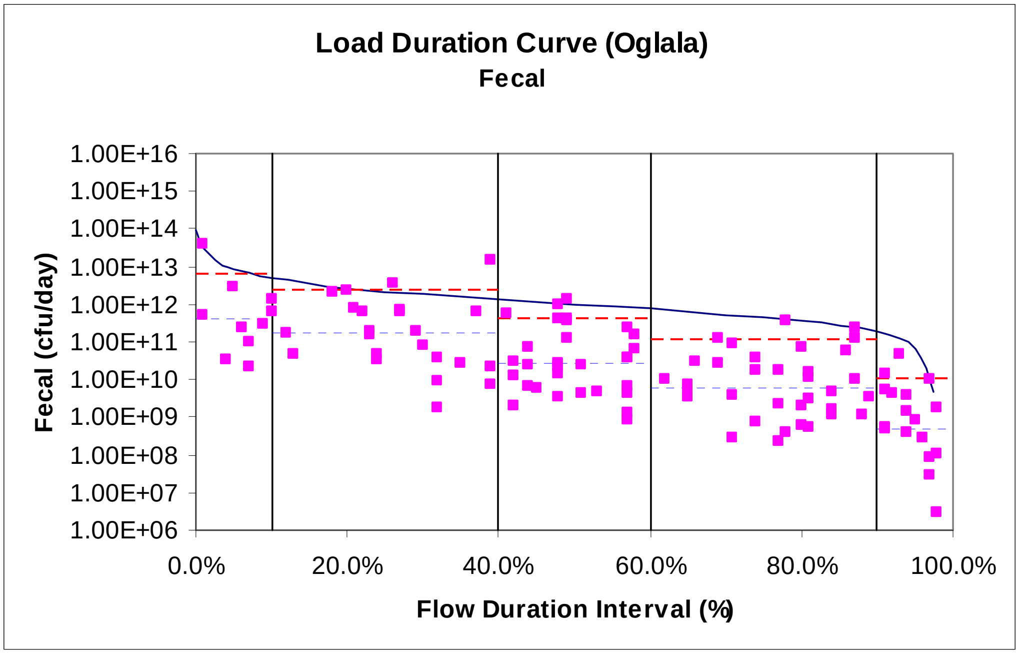



**Figure C-5.** Load Duration Curves for Fecal Coliforms for Oglala.

RSI-1465-05-007

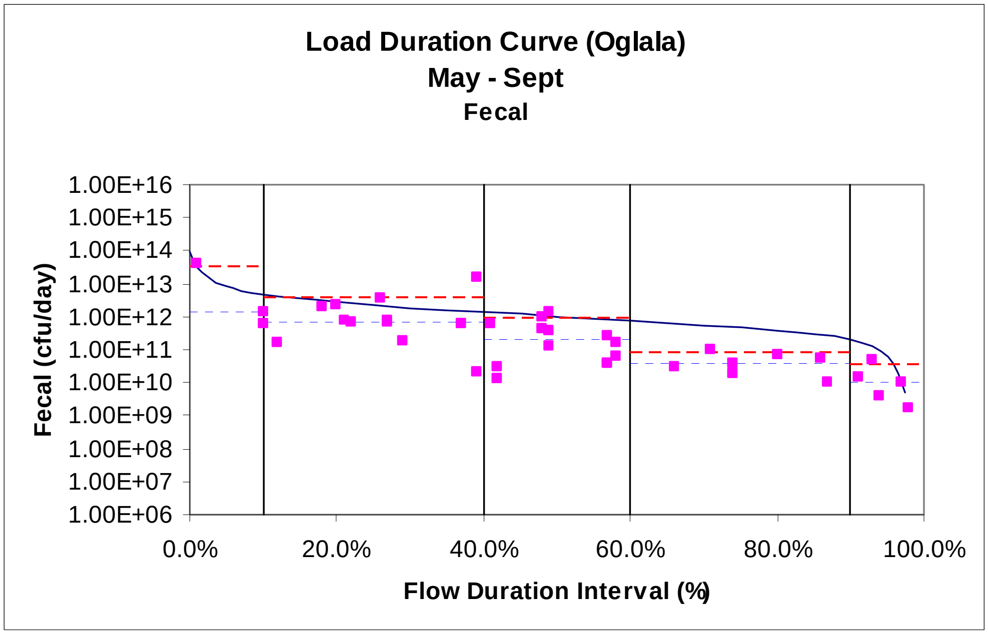



**Figure C-6.** Load Duration Curves for Fecal Coliforms for Oglala (May–September).

RSI-1465-04-041

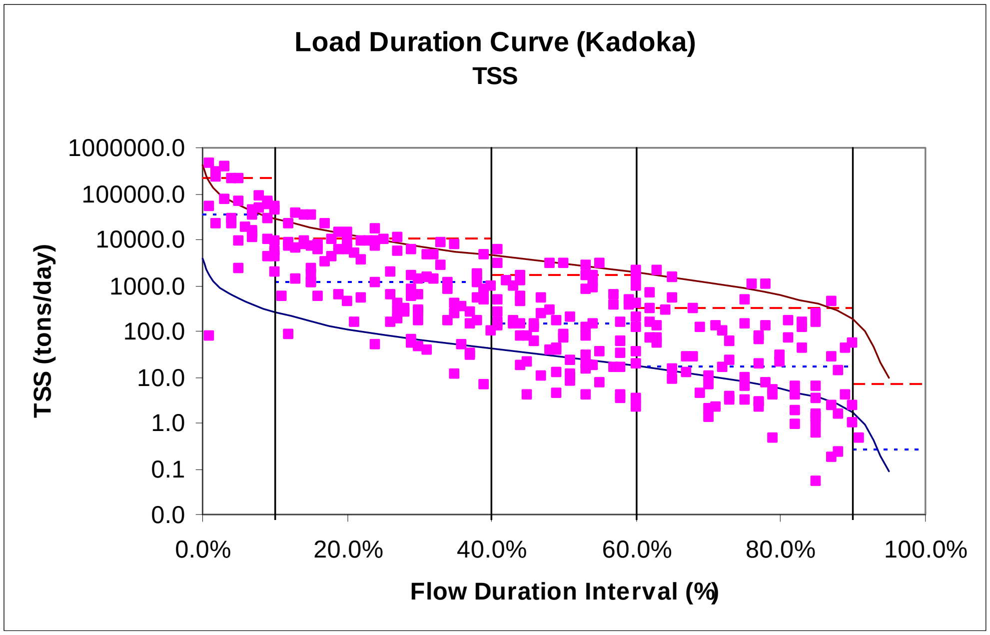



**Figure C-7.** Load Duration Curves for TSS for Kadoka.

RSI-1465-05-008

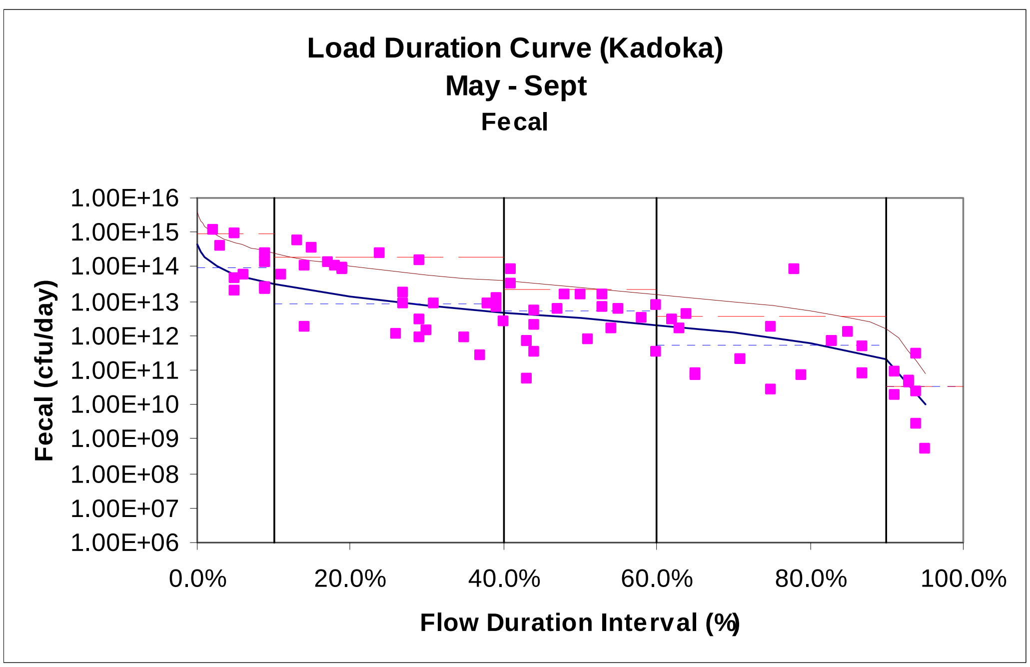



**Figure C-8.** Load Duration Curves for Fecal Coliforms for Kadoka (May–September).

RSI-1465-04-042

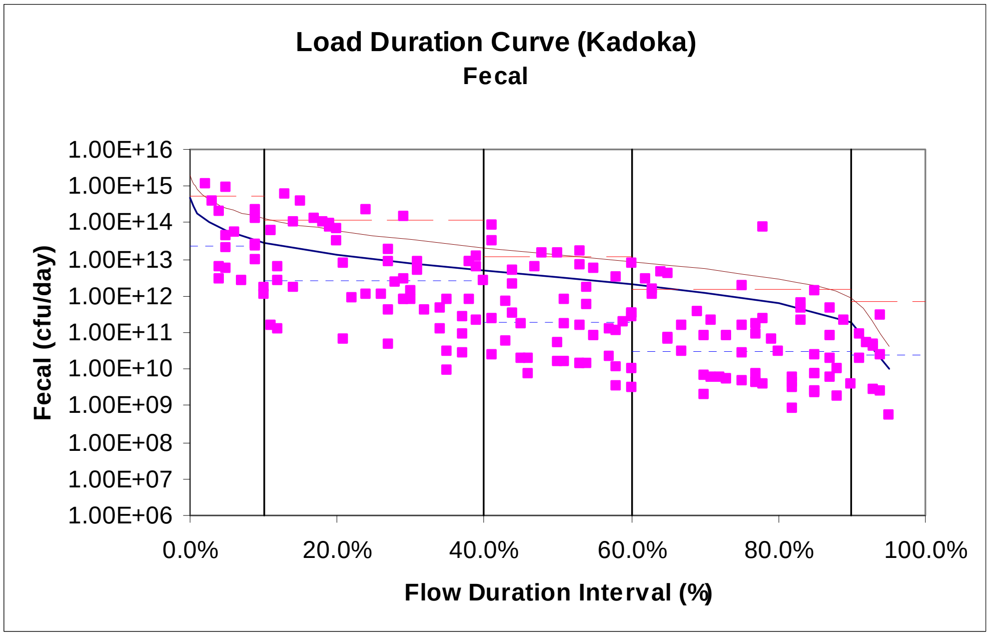



**Figure C-9.** Load Duration Curves for Fecal Coliforms for Kadoka.

RSI-1465-04-043

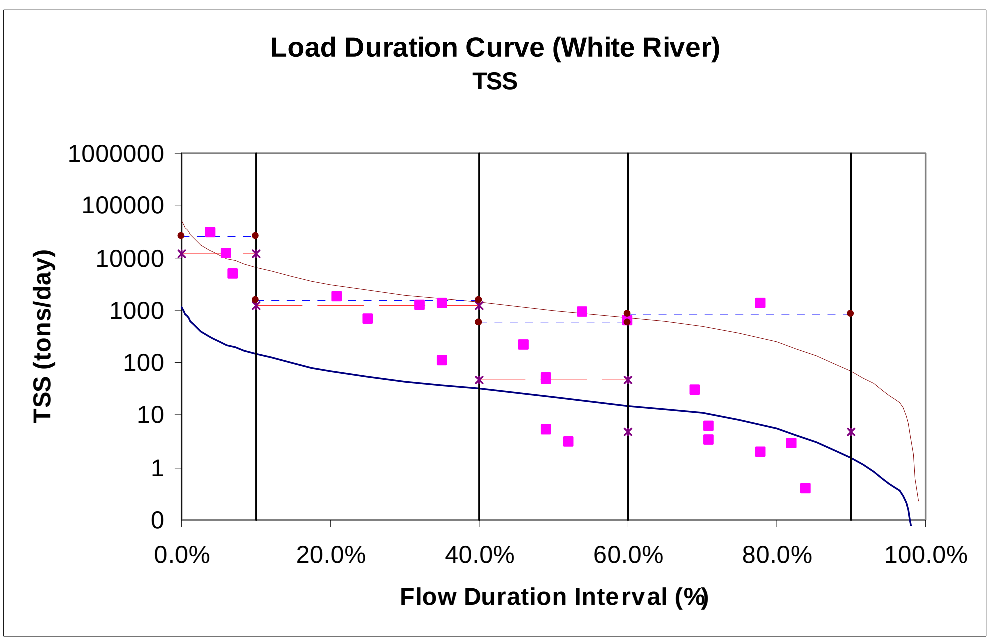



**Figure C-10.** Load Duration Curves for TSS for White River.

RSI-1465-04-044

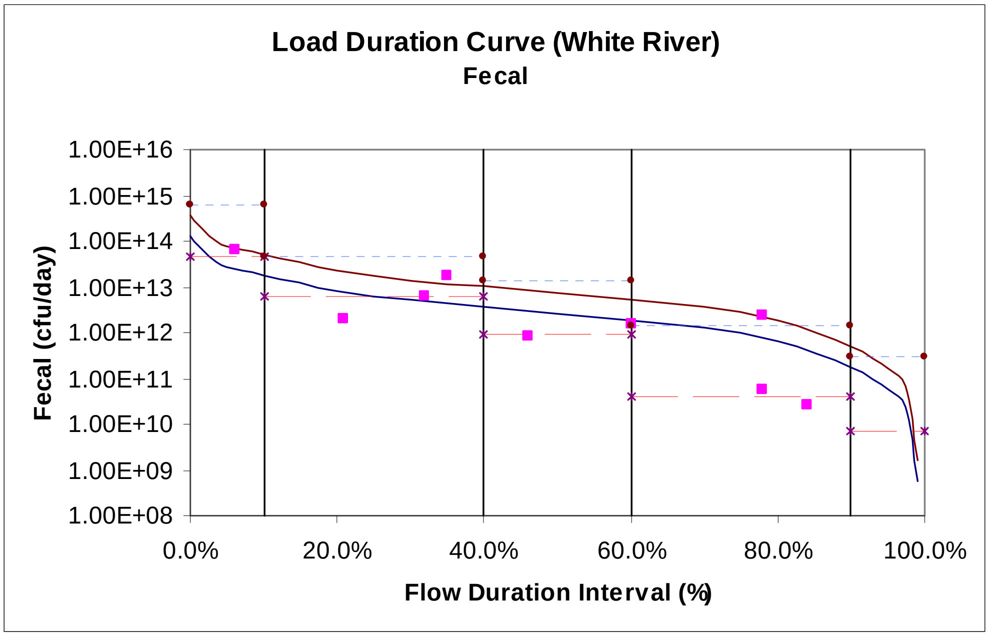



**Figure C-11.** Load Duration Curves for Fecal Coliforms for White River.

RSI-1465-04-045

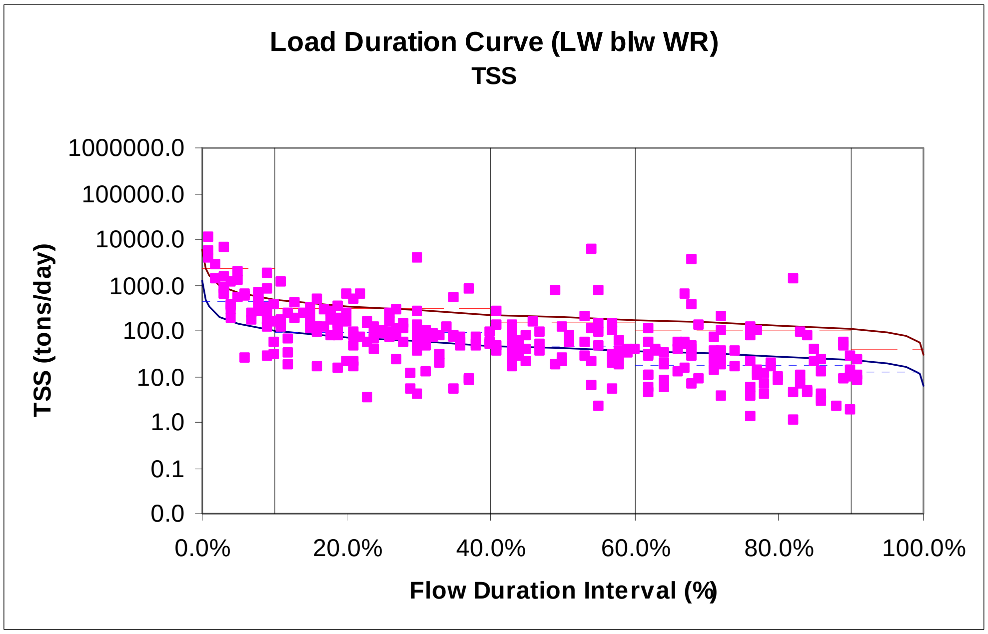



**Figure C-12.** Load Duration Curves for TSS for Little White River Below the Town of White River.

RSI-1465-04-046

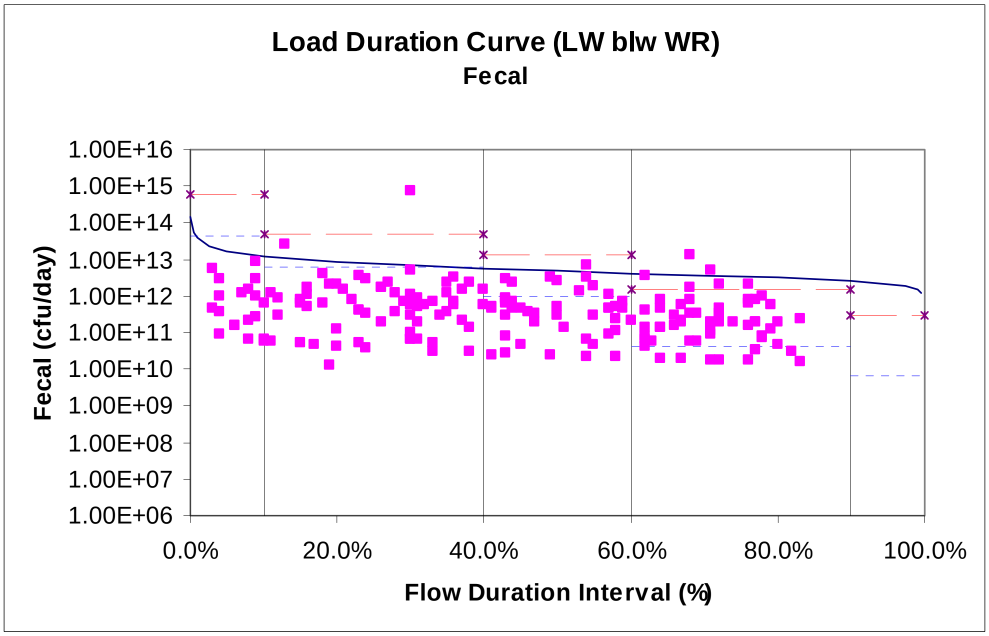



**Figure C-13.** Load Duration Curves for Fecal Coliforms for Little White River Below the Town of White River.

RSI-1465-04-047

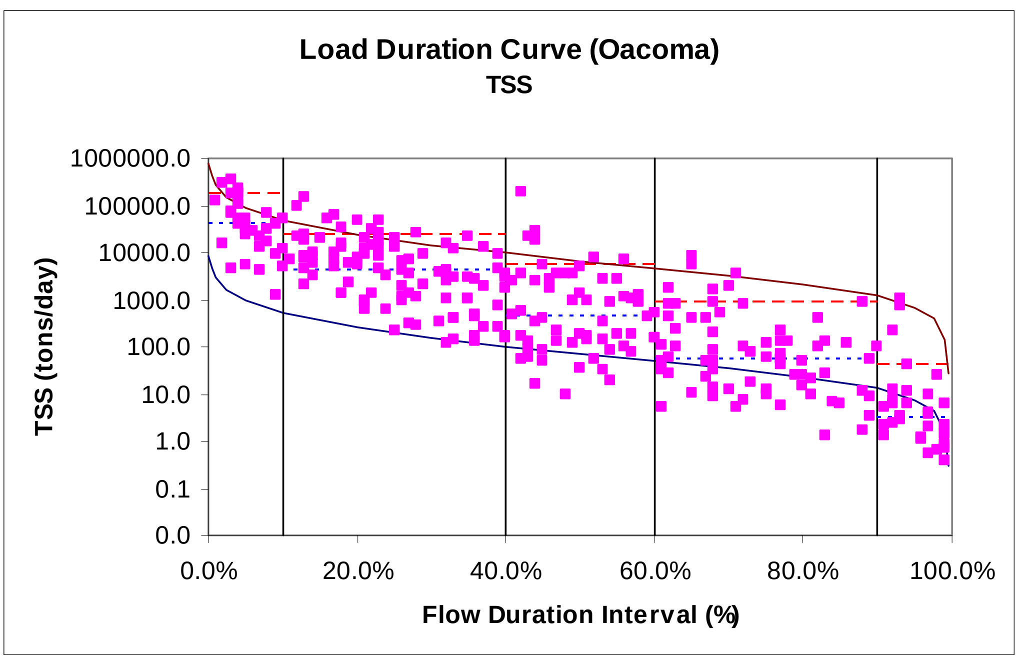



**Figure C-14.** Load Duration Curves for TSS for Oacoma.

RSI-1465-04-048

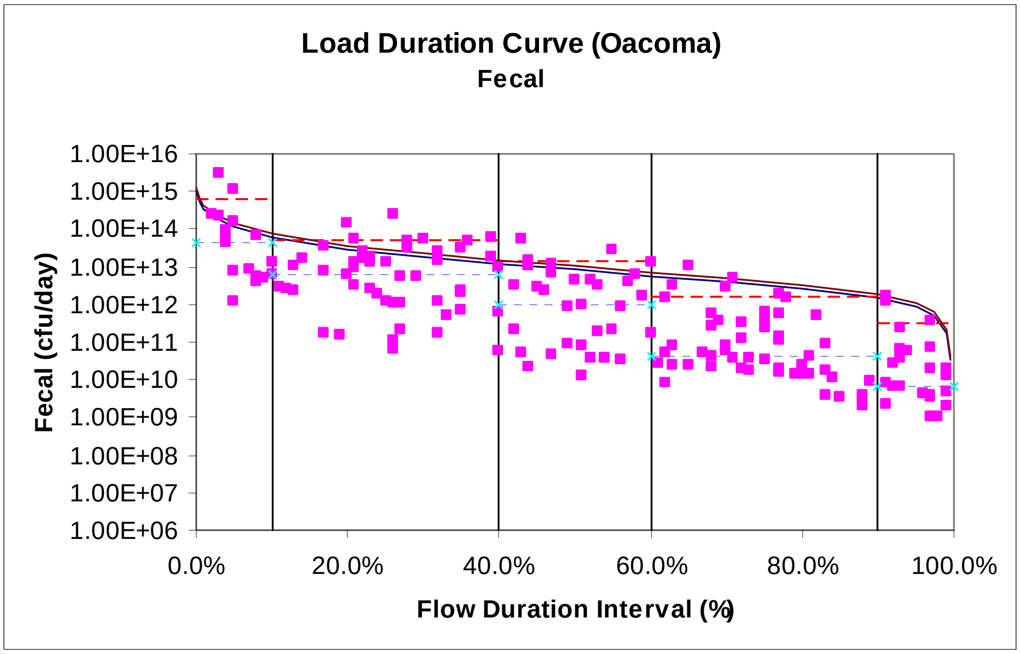



**Figure C-15.** Load Duration Curves for Fecal Coliforms for Oacoma.

RSI-1465-05-009

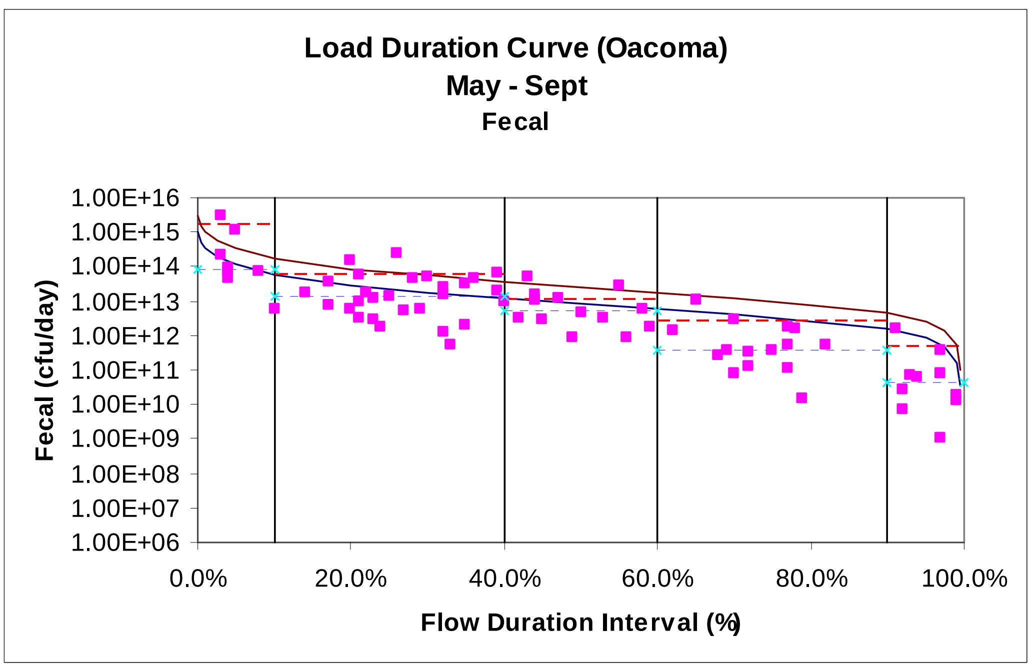



**Figure C-16.** Load Duration Curves for Fecal Coliforms for Oacoma (May–September).

# APPENDIX D

# FLUX MODELING RESULTS

# APPENDIX E

# TREND ANALYSIS PLOTS

RSI-1465-05-001

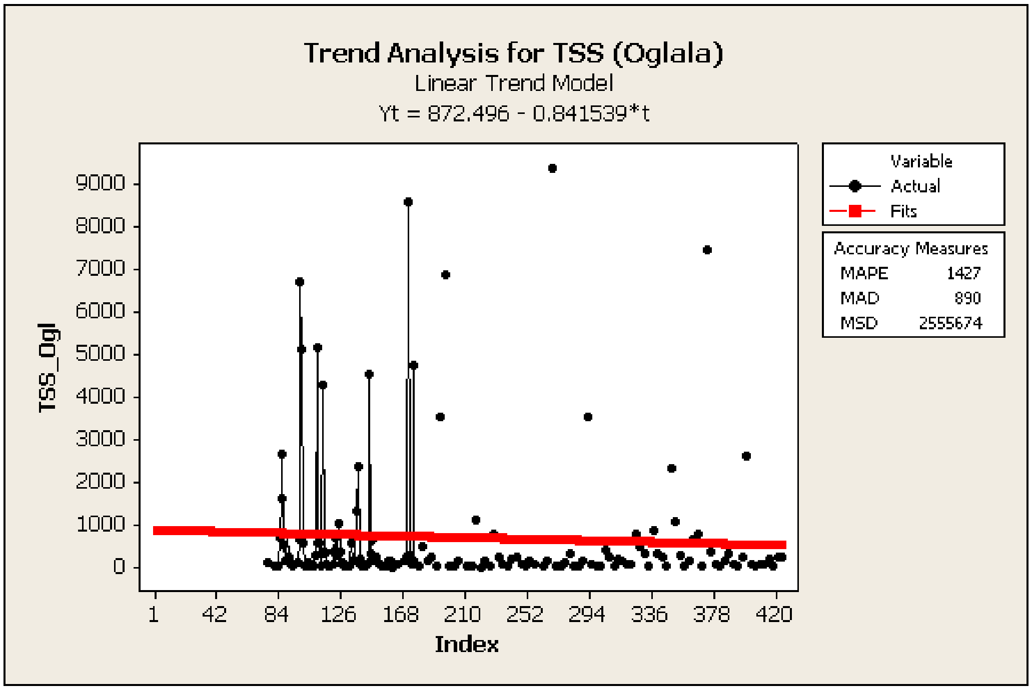



**Figure E-1.** Ranking of Canopy Cover of Small Trees at Each Station.

RSI-1465-05-002

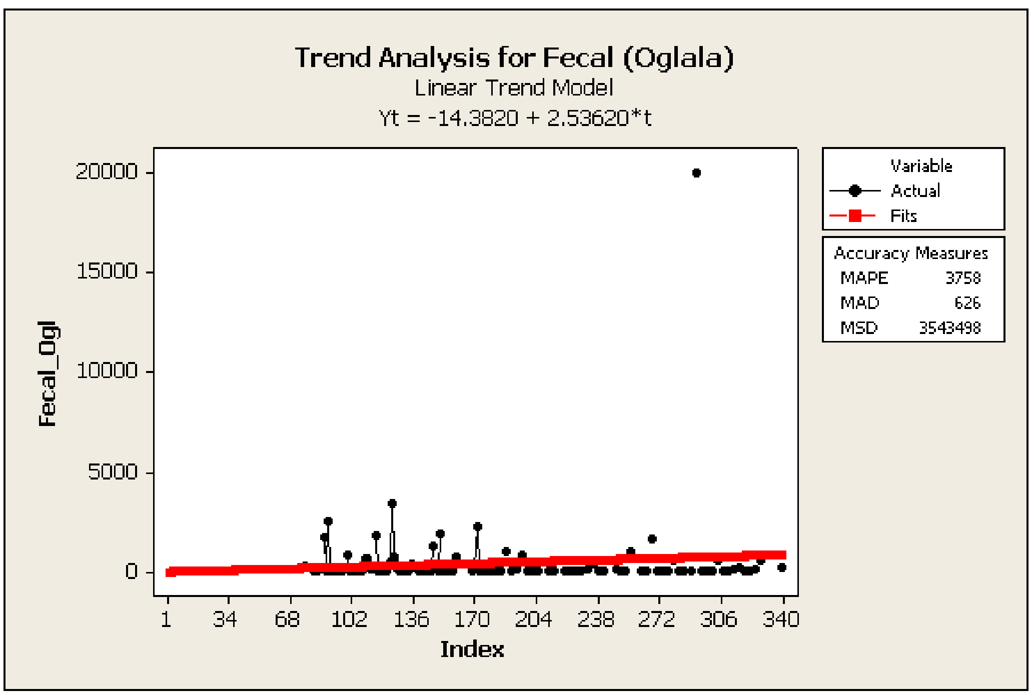



**Figure E-2.** Ranking of Total Understory at Each Station.

RSI-1465-05-003

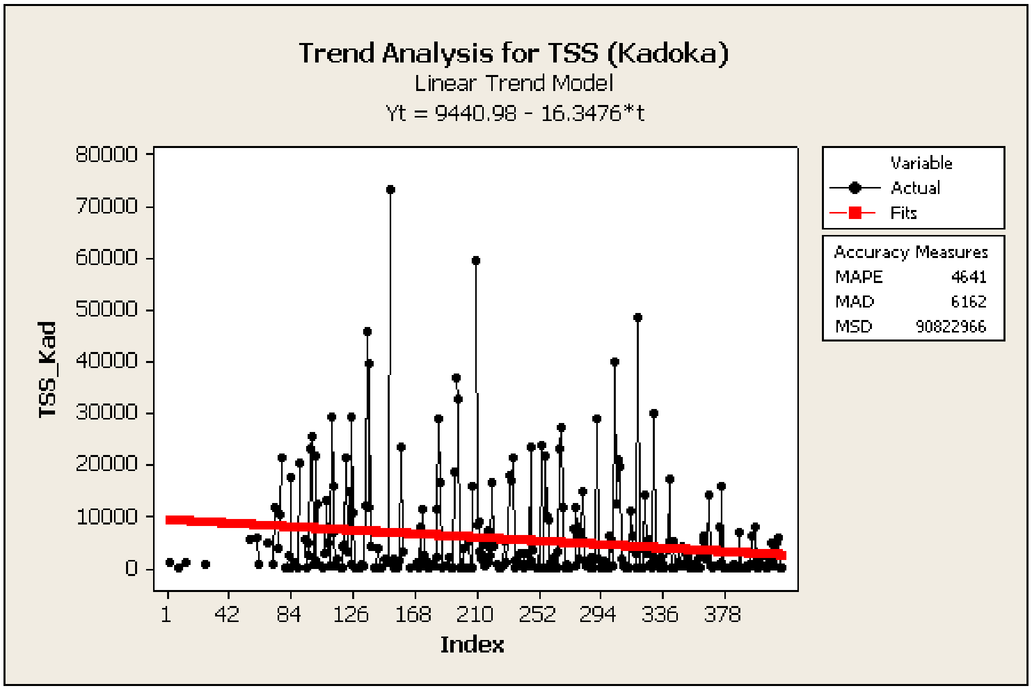



**Figure E-3.** Ranking of Canopy Cover of Small Trees at Each Station.

RSI-1465-05-004

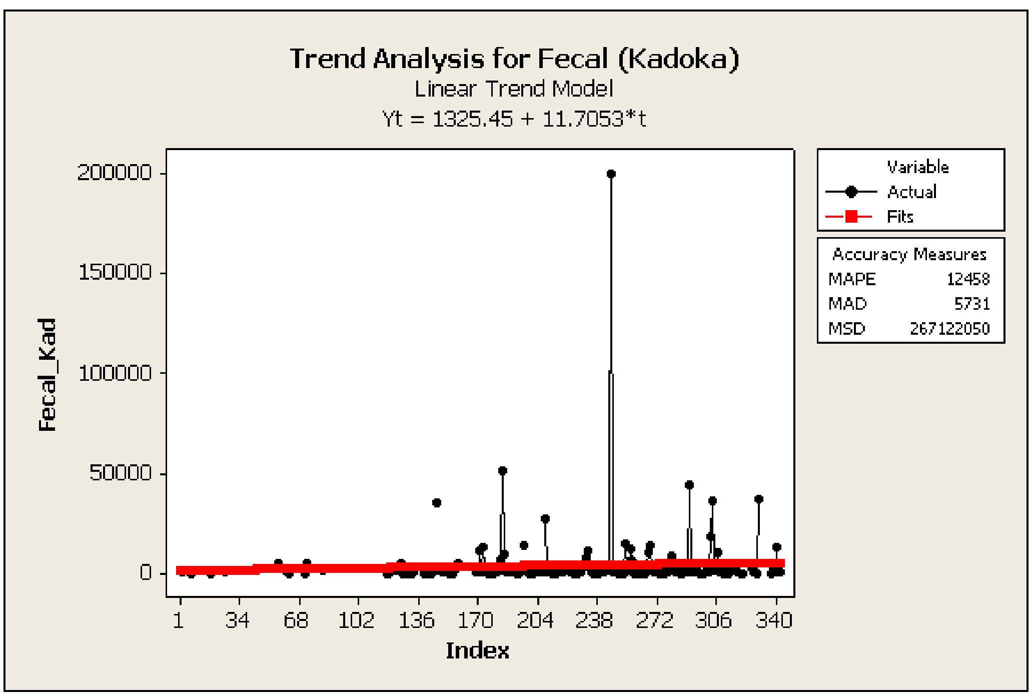



**Figure E-4.** Ranking of Total Understory at Each Station.

RSI-1465-05-005

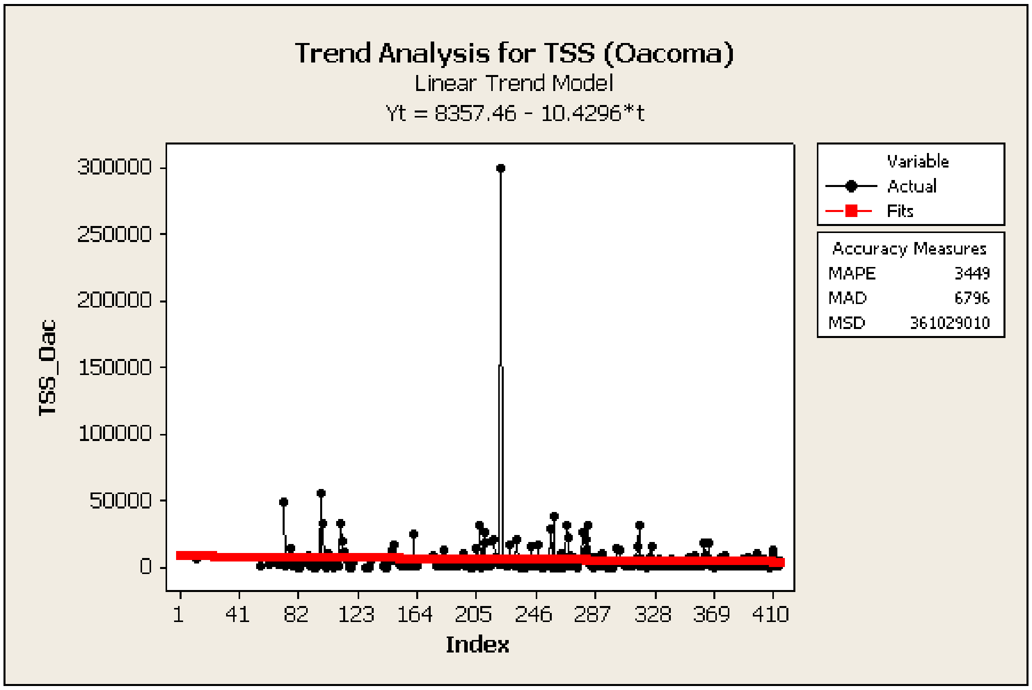



**Figure E-5.** Ranking of Canopy Cover of Small Trees at Each Station.

RSI-1465-05-006

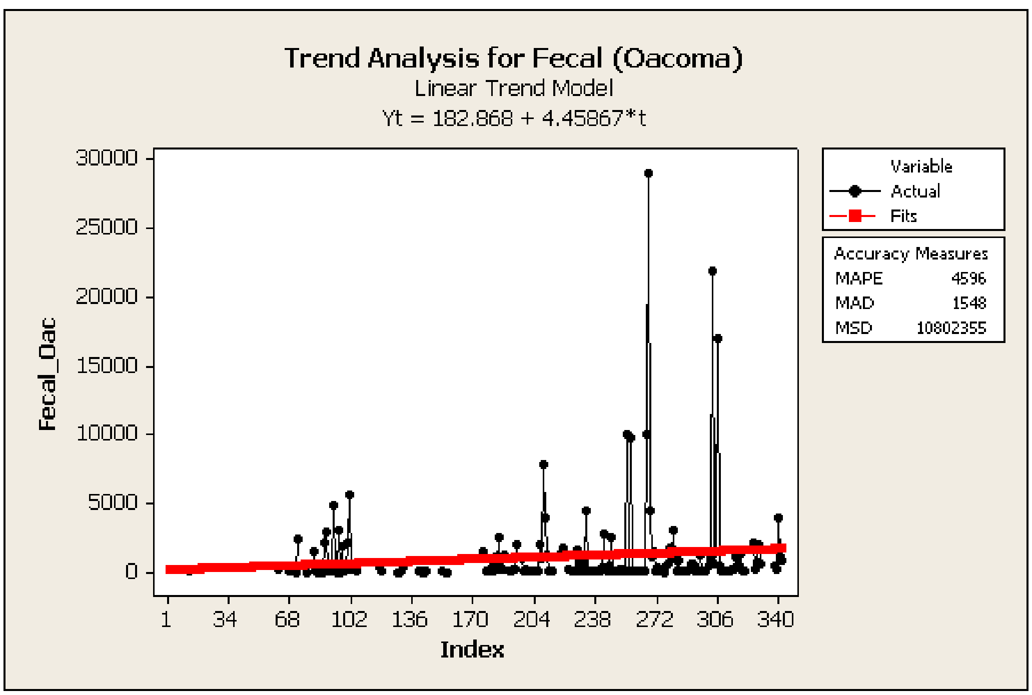



**Figure E-6.** Ranking of Total Understory at Each Station.

# APPENDIX F

# FIELD DATA SHEETS

# STREAM ASSESSMENT FORM - STREAMS/RIVERS

Reviewed by (Initial): ______

SITE ID: WSDP99-________ DATE: __/__/2001

## WATERSHED ACTIVITIES AND DISTURBANCES OBSERVED (Intensity: Blank=Not observed, L=Low, M=Moderate, H=Heavy)

| Residential | Recreational | Agricultural | Industrial | Stream Management |
|---|---|---|---|---|
| L M H Residences | L M H Hiking Trails | L M H Cropland | L M H Industrial Plants | L M H Liming |
| L M H Maintained Lawns | L M H Parks, Campgrounds | L M H Pasture | L M H Mines/Quarries | L M H Chemical Treatment |
| L M H Construction | L M H Primitive Parks, Camping | L M H Livestock Use | L M H Oil/Gas Wells | L M H Angling Pressure |
| L M H Pipes, Drains | L M H Trash/Litter | L M H Orchards | L M H Power Plants | L M H Dredging |
| L M H Dumping | L M H Surface Films | L M H Poultry | L M H Logging | L M H Channelization |
| L M H Roads | | L M H Irrigation Equip. | L M H Evidence of Fire | L M H Water Level Fluctuations |
| L M H Bridge/Culverts | | L M H Water Withdrawal | L M H Odors | L M H Fish Stocking |
| L M H Sewage Treatment | | | L M H Commercial | L M H Dams |

## SITE CHARACTERISTICS (200 m radius)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Waterbody Character | Pristine | ☐ 5 | ☐ 4 | ☐ 3 | ☐ 2 | ☐ 1 | Highly Disturbed |
| | Appealing | ☐ 5 | ☐ 4 | ☐ 3 | ☐ 2 | ☐ 1 | Unappealing |
| Beaver | Beaver Signs: | ☐ Absent | ☐ Rare | ☐ Common | | | |
| | Beaver Flow Modifications: | ☐ None | ☐ Minor | ☐ Major | | | |
| Dominant Land Use | Dominant Land Use Around 'X' | ☐ Forest | ☐ Agriculture | ☐ Range | ☐ Urban | ☐ Suburban/Town | |
| | If Forest, Dominant Age Class | ☐ 0 - 25 yrs. | ☐ 25 - 75 yrs. | ☐ > 75 yrs. | | | |

## WEATHER

## GENERAL ASSESSMENT (Biotic Integrity, Vegetation diversity, Local anecdotal information)

39447

# SAMPLE COLLECTION FORM - STREAMS

Reviewed by (initial): ______

SITE ID: WSDP99-

DATE: __ / __ / 2 0 0 1

## WATER CHEMISTRY

| Sample ID | Transect | Comments |
| --- | --- | --- |
| | | |

## REACH-WIDE BENTHOS SAMPLE

| Sample ID | No. of Jars | Comment |
| --- | --- | --- |
| | | |

| TRANSECT | | A | | B | | C | | D | | E | | F | | G | | H | | I | | J | | K | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SUBSTRATE | CHAN. | Sub. | Chan. | Sub. | Chan. | Sub. | Chan. | Sub. | Chan. | Sub. | Chan. | Sub. | Chan. | Sub. | Chan. | Sub. | Chan. | Sub. | Chan. | Sub. | Chan. | Sub. | Chan. |
| Fine/Sand | Pool | ☐ F | ☐ P | ☐ F | ☐ P | ☐ F | ☐ P | ☐ F | ☐ P | ☐ F | ☐ P | ☐ F | ☐ P | ☐ F | ☐ P | ☐ F | ☐ P | ☐ F | ☐ P | ☐ F | ☐ P | ☐ F | ☐ P |
| Gravel | Glide | ☐ G | ☐ GL | ☐ G | ☐ GL | ☐ G | ☐ GL | ☐ G | ☐ GL | ☐ G | ☐ GL | ☐ G | ☐ GL | ☐ G | ☐ GL | ☐ G | ☐ GL | ☐ G | ☐ GL | ☐ G | ☐ GL | ☐ G | ☐ GL |
| Coarse | Riffle | ☐ C | ☐ RI | ☐ C | ☐ RI | ☐ C | ☐ RI | ☐ C | ☐ RI | ☐ C | ☐ RI | ☐ C | ☐ RI | ☐ C | ☐ RI | ☐ C | ☐ RI | ☐ C | ☐ RI | ☐ C | ☐ RI | ☐ C | ☐ RI |
| Other: Note in Comments | Rapid | ☐ O | ☐ RA | ☐ O | ☐ RA | ☐ O | ☐ RA | ☐ O | ☐ RA | ☐ O | ☐ RA | ☐ O | ☐ RA | ☐ O | ☐ RA | ☐ O | ☐ RA | ☐ O | ☐ RA | ☐ O | ☐ RA | ☐ O | ☐ RA |

## TARGETED RIFFLE BENTHOS SAMPLE

| Sample ID | No. of Jars | Comment |
| --- | --- | --- |
| | | |

| NEAREST TRANSECT | | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | SUBSTRATE SIZE CLASSES |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Dom. Substrate | Fine/Sand | ☐ F/S | ☐ F/S | ☐ F/S | ☐ F/S | ☐ F/S | ☐ F/S | ☐ F/S | ☐ F/S | F/S - ladybug or smaller (<2 mm) |
| | Gravel | ☐ G | ☐ G | ☐ G | ☐ G | ☐ G | ☐ G | ☐ G | ☐ G | G - ladybug to tennis ball (2 to 64 mm) |
| | Coarse | ☐ C | ☐ C | ☐ C | ☐ C | ☐ C | ☐ C | ☐ C | ☐ C | C - tennis ball to car sized (64 to 4000 mm) |
| | Other: Note in Comments | ☐ O | ☐ O | ☐ O | ☐ O | ☐ O | ☐ O | ☐ O | ☐ O | O - bedrock, hardpan, wood, etc |

Additional Benthos Comments

## COMPOSITE PERIPHYTON SAMPLE

| Sample ID | Composite Volume (mL) | Number of transects sampled (0-11): |
| --- | --- | --- |
| | | |

| Assemblage ID (50-mL tube, preserved) | | Chlorophyll (GF/F filter) | | Biomass (GF/F Filter) | |
| --- | --- | --- | --- | --- | --- |
| Sample Vol. (mL) | Flag | Sample Vol. (mL) | Flag | Sample Vol. (mL) | Flag |
| | | | | | |

| Flag | Comments |
| --- | --- |
| | |
| | |
| | |
| | |

Flag codes: K = Sample not collected; U = Suspect sample; F1, F2, etc. = misc. flag assigned by field crew. Explain all flags in comment sections.

31443

# CHANNEL CONSTRAINT AND FIELD CHEMISTRY - STREAMS/RIVERS

Reviewed by (initial): ______

SITE ID: WSDP99- ______ DATE: __ __ / __ __ / 2 0 0 1

| IN SITU MEASUREMENTS | | Station ID: (Assume X-site unless marked) |
|---|---|---|
| | | Comments |
| STREAM/RIVER DO mg/l: (optional) | __ __ . __ | |
| STREAM RIVER TEMP. (°C): | __ __ . __ | |
| TIME OF DAY: | __ __ : __ __ | |

## CHANNEL CONSTRAINT

**CHANNEL PATTERN (Check One)**

- ☐ **One channel**
- ☐ **Anastomosing (complex) channel -** (Relatively long major and minor channels branching and rejoining.)
- ☐ **Braided channel -** (Multiple short channels branching and rejoining - mainly one channel broken up by numerous mid-channel bars.)

**CHANNEL CONSTRAINT (Check One)**

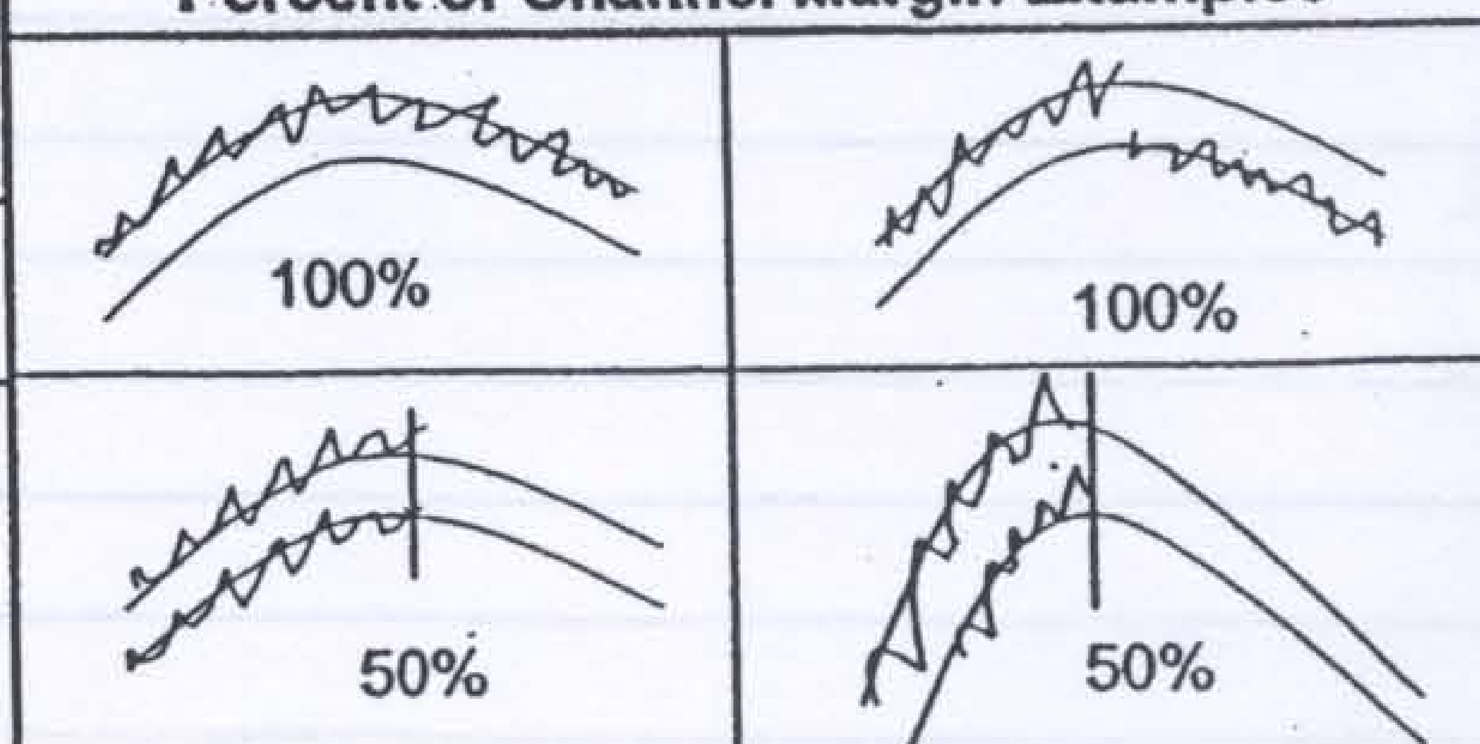
- ☐ **Channel very constrained in V-shaped valley** (i.e. it is very unlikely to spread out over valley or erode a new channel during flood)
- ☐ **Channel is in Broad Valley** but channel movement by erosion during floods is **constrained by Incision** (Flood flows do not commonly spread over valley floor or into multiple channels.)
- ☐ **Channel is in Narrow Valley but is not very constrained,** but limited in movement by relatively narrow valley floor (< ~10 x bankfull width)
- ☐ **Channel is Unconstrained in Broad Valley** (i.e. during flood it can fill off-channel areas and side channels, spread out over flood plain, or easily cut new channels by erosion)

**CONSTRAINING FEATURES (Check One)**

- ☐ **Bedrock** (i.e. channel is a bedrock-dominated gorge)
- ☐ **Hillslope** (i.e. channel constrained in narrow V-shaped valley)
- ☐ **Terrace** (i.e. channel is constrained by its own incision into river/stream gravel/soil deposits)
- ☐ **Human Bank Alterations** (i.e. constrained by rip-rap, landfill, dike, road, etc.)
- ☐ **No constraining features**

Percent of channel length with margin in contact with constraining feature: __ __ __ % (0-100%) --->

**Percent of Channel Margin Examples**




Bankfull width: __ __ __ (m)

Valley width (Visual Estimated Average): __ __ __ __ (m)

Note: Be sure to include distances between both sides of valley border for valley width.

**If you cannot see the valley borders, record the distance you can see and mark this box.** ☐

**Comments**

38480

# STREAM DISCHARGE FORM

Reviewed by (Initials): ________

SITE ID: WSDP99-________ DATE: __ __ / __ __ / 2 0 0 1

## ☐ Velocity Area

| Distance Units | Depth Units | Velocity Units |
|---|---|---|
| ☐ ft ☐ cm | ☐ ft ☐ cm | ☐ ft/s XX.X ☐ m/s X.XX |

(Final measurement should be left bank.)

| | Dist. from Bank (cm) | Depth | Velocity | Flag |
|---|---|---|---|---|
| 1 | 0 | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

## ☐ Timed Filling

| Repeat | Volume (L) | Time (s) | Flag |
|---|---|---|---|
| 1 | __ __ . __ | __ __ . __ | __ __ |
| 2 | __ __ . __ | __ __ . __ | __ __ |
| 3 | __ __ . __ | __ __ . __ | __ __ |
| 4 | __ __ . __ | __ __ . __ | __ __ |
| 5 | __ __ . __ | __ __ . __ | __ __ |

## ☐ Neutral Bouyant Object

| | Float 1 | Float 2 | Float 3 |
|---|---|---|---|
| Float Dist. ☐ ft ☐ m | | | |
| Float Time (s) | | | |
| Flag | | | |

**Cross Sections on Float Reach**

| | Upper Section | Middle Section | Lower Section |
|---|---|---|---|
| Width ☐ ft ☐ m | __ __ . __ | __ __ . __ | __ __ . __ |
| Depth 1 (cm) | | | |
| Depth 2 (cm) | | | |
| Depth 3 (cm) | | | |
| Depth 4 (cm) | | | |
| Depth 5 (cm) | | | |

If discharge is determined directly in field, record value here: Q = ________ ☐ cfs ☐ $m^3/s$

| Flag | Comments |
|---|---|
| | |
| | |
| | |

Flag Codes: K = No measurement or observation made; U = Suspect measurement or observation; Q = Unacceptable QC check associated with measurement; Z = Last station measured (if not Station 20); F1, F2, etc. = Miscellaneous flags assigned by each field crew. Explain all flags in comments section.

26383

## STREAM ASSESSMENT FORM - STREAM/RIVERS (cont.)

Reviewed by (initial): ____

SITE ID: WSDP99-

DATE: ___ / ___ / 2 0 0 1

### GENERAL ASSESSMENT (continued)

39447

**Draw a map of the site with location of most upstream and most downstream transects.**
**Include locations of photographic points, direction of photograph, and frame number.**

Approximate Distance

## On Site Description Data

**Section A**

| | | | | |
|---|---|---|---|---|
| **Project Site ID:** | | T______, R______, _______1/4 of | | **Date:** |
| Stream Name: | | Sec______ | | Time: |
| **Transect 1(Upstream)** | | | **Transect 11(Downstream)** | |
| **GPS Coordinates (utm):** | Northing: | Easting: | Northing: | Easting: |
| Investigators: | | | | |

**Section B**

| **Preliminary Mean Stream Width (PMSW)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Width Number | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Sum | Avg. PMSW |
| Width (0.1m) | | | | | | | | | | | | |
| Transect Spacing * | | | | | | | | | | | | |
| *If PMSW <10m space transects every 3 PMSW. If >10m, transects are spaced every 2 PMSW. | | | | | | | | | | | | |
| **Total Reach Length**: | | | | | | | | | | | | |
| Reach Length = 11 Transects, 10 distances apart X 3 PMSW = 30 PMSW or 20 PMSW if width >10m. | | | | | | | | | | | | |

**Section C**

| **Water Quality** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Reading** | **Time (2400)** | **Water Temperature (°C)** | **Air Temperature (oC)** | **Turbidity (NTU)** | **Secchi (cm)** | **Dissolved Oxygen (mg/L** | **Specific Conductance (µS/cm)** | **Conductivity (µS/cm)** |
| Morning | | | | | | | | |
| Afternoon | | | | | | | | |

**Visual Observations**

| **5) Odor** (Severe, Extreme, Moderate, Mild, None) | **6) Septic** (Severe, Extreme, Moderate, Mild, None) | **7) Deadfish** (Severe, Extreme, Moderate, Mild, None) | **8) Surface Film** (Severe, Extreme, Moderate, Mild, None) |
|---|---|---|---|

**5) Color:**

**6) Ice Cover** (Severe, Extreme, Moderate, Mild, None)

| **Weather Conditions:** | **Current** | **Past 24 hrs** |
|---|---|---|
| Clear/sunny | ☐ | ☐ |
| Partly cloudy | ☐ | ☐ |
| Intermittent showers | ☐ | ☐ |
| Steady rain | ☐ | ☐ |
| Heavy rain | ☐ | ☐ |

**Field Comments:**

**Section D**

| | |
|---|---|
| **Habitats Available number of each (also place on map Section E)** | Pool______, Run/Glide______, Riffle______, Other (describe) __________ (Table 10.0.1)<br>Lengths of Riffle(s):_______, _______, _______, _______, _______. (meters)<br>Nearest Transect # :_______, _______, _______, _______, _______.<br>Total Length (riffles) =__________<br>Pool Forming Elements = __________ (Table 10.0.1) |

# PHab: CHANNEL/RIPARIAN CROSS-SECTION FORM - STREAMS

Reviewed by (Initials): ________

SITE ID: WSDP99-________ DATE: ___/___/2001 TRANSECT: ☐A ☐B ☐C ☐D ☐E ☐F X-tra Side Channel ☐G ☐H ☐I ☐J ☐K ☐

## SUBSTRATE CROSS-SECTIONAL INFORMATION

| | Dist LB XX.XX m | Depth XXX cm | Size Class Code | Embed. 0-100% | Flag |
|---|---|---|---|---|---|
| Left | | | | | |
| LCtr | | | | | |
| Ctr | | | | | |
| RCtr | | | | | |
| Right | | | | | |

| SUBSTRATE SIZE CLASS CODES | Embed. (%) |
|---|---|
| RS = Bedrock (Smooth) - (Larger than a car) | 0 |
| RR = Bedrock ( Rough) - (Larger than a car) | 0 |
| BL = Boulder (250 to 4000 mm) - (Basketball to car) | |
| CB = Cobble (64 to 250 mm) - (Tennis ball to Basketball) | |
| GC = Coarse Gravel (16 to 64 mm) - (Marble to Tennis ball) | |
| GF = Fine Gravel (2 to 16 mm) - (Ladybug to marble) | |
| SA = Sand (0.06 to 2 mm) - (Gritty - up to Ladybug size) | 100 |
| FN = Silt / Clay / Muck - (Not Gritty) | 100 |
| HP = Hardpan - (Firm, Consolidated Fine Substrate) | 0 |
| WD = Wood - (Any Size) | |
| OT = Other (Write comment below) | |

## FISH COVER/ OTHER

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(circle one)

| | Cover in Channel | Flag |
|---|---|---|
| Filamentous Algae | 0 1 2 3 4 | |
| Macrophytes | 0 1 2 3 4 | |
| Woody Debris >0.3 m (BIG) | 0 1 2 3 4 | |
| Brush/Woody Debris <0.3 m (SMALL) | 0 1 2 3 4 | |
| Live Trees or Roots | 0 1 2 3 4 | |
| Overhanging Veg. =<1 m of Surface | 0 1 2 3 4 | |
| Undercut Banks | 0 1 2 3 4 | |
| Boulders | 0 1 2 3 4 | |
| Artificial Structures | 0 1 2 3 4 | |

## VISUAL RIPARIAN ESTIMATES

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)

D = Deciduous
C = Coniferous
E = Broadleaf Evergreen
M = Mixed
N = None

| RIPARIAN VEGETATION COVER | Left Bank | Right Bank | Flag |
|---|---|---|---|
| **Canopy (>5 m high)** | | | |
| Vegetation Type | D C E M N | D C E M N | |
| BIG Trees (Trunk >0.3 m DBH) | 0 1 2 3 4 | 0 1 2 3 4 | |
| SMALL Trees (Trunk <0.3 m DBH) | 0 1 2 3 4 | 0 1 2 3 4 | |
| **Understory (0.5 to 5 m high)** | | | |
| Vegetation Type | D C E M N | D C E M N | |
| Woody Shrubs & Saplings | 0 1 2 3 4 | 0 1 2 3 4 | |
| Non-Woody Herbs, Grasses, & Forbs | 0 1 2 3 4 | 0 1 2 3 4 | |
| **Ground Cover (<0.5 m high)** | | | |
| Woody Shrubs & Saplings | 0 1 2 3 4 | 0 1 2 3 4 | |
| Non-Woody Herbs, Grasses and Forbs | 0 1 2 3 4 | 0 1 2 3 4 | |
| Barren, Bare Dirt or Duff | 0 1 2 3 4 | 0 1 2 3 4 | |

0 = Not Present P = >10 m C = Within 10 m B = On Bank

| HUMAN INFLUENCE | Left Bank | Right Bank | Flag |
|---|---|---|---|
| Wall/Dike/Revetment /Riprap/Dam | 0 P C B | 0 P C B | |
| Buildings | 0 P C B | 0 P C B | |
| Pavement/Cleared Lot | 0 P C B | 0 P C B | |
| Road/Railroad | 0 P C B | 0 P C B | |
| Pipes (Inlet/Outlet) | 0 P C B | 0 P C B | |
| Landfill/Trash | 0 P C B | 0 P C B | |
| Park/Lawn | 0 P C B | 0 P C B | |
| Row Crops | 0 P C B | 0 P C B | |
| Pasture/Range/Hay Field | 0 P C B | 0 P C B | |
| Logging Operations | 0 P C B | 0 P C B | |
| Mining Activity | 0 P C B | 0 P C B | |

## BANK MEASUREMENTS

| | Bank Angle 0 - 360 | Undercut Dist. (m) | Flag |
|---|---|---|---|
| Left | | | |
| Right | | | |
| Wetted Width XXX.X m | | | |
| Bar Width XX.X m | | | |
| Bankfull Width XXX.X m | | | |
| Bankfull Height XX.X m | | | |
| Incised Height XX.X m | | | |

## CANOPY COVER MEASUREMENTS

DENSIOMETER (0-17Max)

| | | Flag | | | Flag |
|---|---|---|---|---|---|
| CenUp | | | CenR | | |
| CenL | | | Left | | |
| CenDwn | | | Right | | |

Flag codes: K = Sample not collected; U = Suspect sample; F1, F2, etc. = misc. flag assigned by field crew. Explain all flags in comment sections.

| Flag | Comments |
|---|---|
| | |
| | |
| | |

37859

# RIPARIAN "LEGACY" TREES AND INVASIVE ALIEN PLANTS

Reviewed by (initial): ______

22977

SITE ID: WSDP99-________ DATE: ___ / ___ / 2 0 0 1

| Tran | Trees not Visible | DBH (m) | Height (m) | Dist. from wetted margin (m) | Type | Taxonomic Category | ALIEN PLANT SPECIES PRESENT IN LEFT AND RIGHT RIPARIAN PLOTS — Check all that are present |
|---|---|---|---|---|---|---|---|
| | | **LARGEST LEGACY TREE VISIBLE FROM THIS STATION** | | | | | |
| A | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ____ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ____ | ☐ NONE ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |
| B | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ____ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ____ | ☐ NONE ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |
| C | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ____ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ____ | ☐ NONE ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |

## INSTRUCTIONS

**Legacy trees** are defined as the largest tree within your search area, which is as far as you can see, but within maximum limits as follows:

Wadeable Streams: Confine search to no more than 50 m from left and right bank and extending upstream to next transect (for 'K' look upstream 4 channel widths)

Non-wadeable Rivers: Confine search to no more than 100 m from left and right bank and extending both upstream and downstream as far as you can see confidently.

**Alien Plants**: Confine search to riparian plots on left and right bank

Wadeable Streams: 10 m x 10 m

Non-wadeable Rivers: 10 m x 20 m

Not all aliens are to be identified in all states. See Field Manual and Plant Identification Guide.

## TAXONOMIC CATEGORIES

Acacia/Mesquite
Alder/Birch
Ash
Maple/Boxelder
Oak
Poplar/Cottonwood
Sycamore
Willow
Unknown or Other Deciduous

Cedar/Cypress/Sequoia
Fir (including Douglas fir and hemlock)
Juniper
Pine
Spruce
Unknown or Other Conifer

Unknown or Other Broadleaf Evergreen

Snag (Dead tree of any species)

## ALIEN SPECIES

| | | |
|---|---|---|
| RC Grass | Reed canarygrass | *Phalaris arundinacea* |
| Engl Ivy | English ivy | *Hedera helix* |
| ChGrass | Cheat grass | *Bromus tectorum* |
| Salt Ced | Salt Cedar | *Tamarix spp.* |
| Can This | Canada thistle | *Cirsium arvense* |
| M This | Musk thistle | *Carduus nutans* |
| Hblack | Himalayan blackberry | *Rubus discolor* |
| Teasel | Teasel | *Dipsacus fullonum* |
| Spurge | Leafy spurge | *Euphobia esula* |
| G Reed | Giant reed | *Arundo donax* |
| C Burd | Common burdock | *Arctim minus* |
| Rus Ol | Russian-olive | *Elaeagnus angustifolia* |

## COMMENTS

**Transects D to K continued on other side**

# RIPARIAN "LEGACY" TREES AND INVASIVE ALIEN PLANTS

Reviewed by (initial): ______

22977

SITE ID: WSDP99-________ DATE: ____/____/2 0 0 1

| Tran | Trees not Visible | LARGEST LEGACY TREE VISIBLE FROM THIS STATION: DBH (m) | Height (m) | Dist. from wetted margin (m) | Type | Taxonomic Category | | ALIEN PLANT SPECIES PRESENT IN LEFT AND RIGHT RIPARIAN PLOTS: Check all that are present |
|---|---|---|---|---|---|---|---|---|
| D | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ______ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ______ | ☐ NONE | ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |
| E | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ______ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ______ | ☐ NONE | ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |
| F | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ______ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ______ | ☐ NONE | ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |
| G | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ______ | ☐ NONE | ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |
| H | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ______ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ______ | ☐ NONE | ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |
| I | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ______ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ______ | ☐ NONE | ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |
| J | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ______ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ______ | ☐ NONE | ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |
| K | ☐ | ☐ 0-0.1 ☐ .75-2<br>☐ .1-.3 ☐ >2<br>☐ .3-.75 | ☐ <5<br>☐ 5-15<br>☐ 15-30<br>☐ >30 | ______ | ☐ Deciduous<br>☐ Coniferous<br>☐ Broadleaf Evergreen | ______ | ☐ NONE | ☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed<br>☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd<br>☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol |

## On Site Description Data

**Section A**

| | | | |
|---|---|---|---|
| **Project Site ID:** | | T_____, R_____, _____1/4 of | **Date:** |
| Stream Name: | | Sec______ | Time: |
| **Transect 1(Upstream)** | | **Transect 11(Downstream)** | |
| **GPS Coordinates (utm):** | Northing: | Easting: | Northing: | Easting: |
| Investigators: | | | | |

**Section B**

| **Preliminary Mean Stream Width (PMSW)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Width Number | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Sum | Avg. PMSW |
| Width (0.1m) | | | | | | | | | | | | |
| Transect Spacing * | | | | | | | | | | | | |
| *If PMSW <10m space transects every 3 PMSW. If >10m, transects are spaced every 2 PMSW. | | | | | | | | | | | | |
| **Total Reach Length:** | | | | | | | | | | | | |
| Reach Length = 11 Transects, 10 distances apart X 3 PMSW = 30 PMSW or 20 PMSW if width >10m. | | | | | | | | | | | | |

**Section C**

| **Water Quality** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Reading** | **Time (2400)** | **Water Temperature (°C)** | **Air Temperature (oC)** | **Turbidity (NTU)** | **Secchi (cm)** | **Dissolved Oxygen (mg/L** | **Specific Conductance (µS/cm)** | **Conductivity (µS/cm)** |
| Morning | | | | | | | | |
| Afternoon | | | | | | | | |

| **Visual Observations** | | | |
|---|---|---|---|
| **5) Odor (Severe, Extreme, Moderate, Mild, None)** | **6) Septic (Severe, Extreme, Moderate, Mild, None)** | **7) Deadfish (Severe, Extreme, Moderate, Mild, None)** | **8) Surface Film (Severe, Extreme, Moderate, Mild, None)** |
| **5) Color:** | | **6) Ice Cover (Severe, Extreme, Moderate, Mild, None)** | |

| **Weather Conditions:** | **Current** | **Past 24 hrs** | **Field Comments:** |
|---|---|---|---|
| Clear/sunny | ☐ | ☐ | |
| Partly cloudy | ☐ | ☐ | |
| Intermittent showers | ☐ | ☐ | |
| Steady rain | ☐ | ☐ | |
| Heavy rain | ☐ | ☐ | |

**Section D**

| | |
|---|---|
| **Habitats Available number of each (also place on map Section E)** | Pool_____, Run/Glide_____, Riffle_____, Other (describe) __________ (Table 10.0.1)<br>Lengths of Riffle(s):_______, _______, _______, _______, _______. (meters)<br>Nearest Transect # :_______, _______, _______, _______, _______.<br>Total Length (riffles) =__________<br>Pool Forming Elements = __________ (Table 10.0.1) |

## Stream Survey Data Sheet

**Site Name** ____________ **Site ID** ____________ **Transect** ____________

### Channel Profile

| Station | Reading | Station | Reading | Station | Reading |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

### Rosgen Measurements

| | | | |
|---|---|---|---|
| Rod @ Max Depth | ________ | (1) | |
| Rod @ Bankfull | ________ | (2) | |
| Max Bankfull | ________ | (3) | (1)-(2) |
| Twice Bankfull | ________ | (4) | (3)*2 |
| Req'd Rod @ Flood Prone | ________ | (5) | (1)-(4) |
| Flood Prone Width | ________ | (6) | |
| Bankfull Width | ________ | (7) | |

### Slope / 1st Supplemental

| Rod | Transect | Bearing | Rod | Transect | Bearing | Rod | Transect | Bearing |
|---|---|---|---|---|---|---|---|---|
| | @ | | | @ | | | @ | |
| | @ | | | @ | | | @ | |
| | @ | | | @ | | | @ | |
| | @ | | | @ | | | @ | |
| | @ | | | @ | | | @ | |
| | @ | | | @ | | | @ | |

| | Left Bank | Right bank |
|---|---|---|
| Bank Slumpage (present or Absent) | | |
| Bank Length | | |
| Length of Streambank Vegetated | | |
| Length of Stremabank Eroded | | |
| Length of Streambank deposited | | |
| Riparian Landuse (circle one) | cropland shrub woodland/forested<br>pasture/rangeland barnyard<br>prairie developed<br>wetland other________ | cropland shrub woodland/forested<br>pasture/rangeland barnyard<br>prairie developed<br>wetland other________ |
| Animal Vegetation Use (circle one) | none moderate<br>low high | none moderate<br>low high |
| Riparian Vegetation Type (dominant) | sedge/rush cottonwoods willows<br>grassw/forb silver maple<br>green ash shrubs other ______ | sedge/rush cottonwoods willows<br>grassw/forb silver maple<br>green ash shrubs other ______ |
| Riparian Age Class(es) of Trees, if present | seedling/sprout decadent<br>young/sapling mature dead | seedling/sprout decadent<br>young/sapling mature dead |

**Stage**

Depth ________ ft

Time ________

Discharge ________ cfs

**CEM Stage** ________

**Geologic Material** ________

**Lithology** ________

Reviewed by (initial):______

# PHAB: THALWEG PROFILE & WOODY DEBRIS FORM STREAMS

SITE ID: WSDP99-______ DATE: ___/___/2 0 0 1

TRANSECT: ☐ A-B ☐ B-C ☐ C-D ☐ D-E ☐ E-F ☐ F-G ☐ G-H ☐ H-I ☐ I-J ☐ J-K

For Transect A-B ONLY: Increment (m) X.X: ____ Total Reach Length (m): ____

## THALWEG PROFILE

| STATION | THALWEG DEPTH (cm) (XXX) | WETTED WIDTH (m) (XXX.X) | BAR WIDTH[1] Present | BAR WIDTH[1] XX.X | SOFT /SMALL SEDIMENT | CHANNEL UNIT CODE | POOL FORM CODE | SIDE CHANNEL | BACK WATER | FLAG | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | Y N | | Y N | | | Y N | Y N | | |
| 1 | | | Y N | | Y N | | | Y N | Y N | | |
| 2 | | | Y N | | Y N | | | Y N | Y N | | |
| 3 | | | Y N | | Y N | | | Y N | Y N | | |
| 4 | | | Y N | | Y N | | | Y N | Y N | | |
| *5 | | | Y N | | Y N | | | Y N | Y N | | |
| 6 | | | Y N | | Y N | | | Y N | Y N | | |
| *7 | | | Y N | | Y N | | | Y N | Y N | | |
| 8 | | | Y N | | Y N | | | Y N | Y N | | |
| 9 | | | Y N | | Y N | | | Y N | Y N | | |
| 10 | | | Y N | | Y N | | | Y N | Y N | | |
| 11 | | | Y N | | Y N | | | Y N | Y N | | |
| 12 | | | Y N | | Y N | | | Y N | Y N | | |
| 13 | | | Y N | | Y N | | | Y N | Y N | | |
| 14 | | | Y N | | Y N | | | Y N | Y N | | |

## SUBSTRATE

| Station (5 or 7) | LFT | LCTR | CTR | RCTR | RGT | FLAG |
|---|---|---|---|---|---|---|
| * | | | | | | |

| FLAG | COMMENTS |
|---|---|
| | |
| | |

## LARGE WOODY DEBRIS

(≥10 cm small end diameter; ≥1.5 m length)

CHECK IF ALL UNMARKED BOXES ARE ZERO ☐ FLAG ____

| DIAMETER LARGE END | PIECES ALL/PART IN BANKFULL CHANNEL Length 1.5-5m | PIECES ALL/PART IN BANKFULL CHANNEL 5-15m | PIECES ALL/PART IN BANKFULL CHANNEL >15m | PIECES BRIDGE ABOVE BANKFULL CHANNEL Length 1.5-5m | PIECES BRIDGE ABOVE BANKFULL CHANNEL 5-15m | PIECES BRIDGE ABOVE BANKFULL CHANNEL >15m |
|---|---|---|---|---|---|---|
| 0.1-<0.3 m | | | | | | |
| 0.3-0.6 m | | | | | | |
| 0.6-0.8 m | | | | | | |
| >0.8 m | | | | | | |

### SUBSTRATE SIZE CLASS CODES

RS = BEDROCK (SMOOTH) - (LARGER THAN A CAR)
RR = BEDROCK ( ROUGH) - (LARGER THAN A CAR)
BL = BOULDER (250 TO 4000 mm) - BASKETBALL TO CAR)
CB = COBBLE (64 TO 250 mm) - (TENNIS BALL TO BASKETBALL)
GC = COARSE GRAVEL (16 TO 64 mm) - (MARBLE TO TENNIS BALL)
GF = FINE GRAVEL (2 TO 16 mm) - (LADYBUG TO MARBLE)
SA = SAND (0.06 TO 2 mm) - (GRITTY - UP TO LADYBUG SIZE)
FN = SILT/ CLAY / MUCK - (NOT GRITTY)
HP = HARDPAN - (FIRM, CONSOLIDATED FINE SUBSTRATE)
WD = WOOD - (ANY SIZE)
OT = OTHER (COMMENT ON OTHER SIDE)

### POOL FORM CODES

N = Not a pool
W = Large Woody Debris
R = Rootwad
B = Boulder or Bedrock
F = Unknown, fluvial

COMBINATIONS:
eg. WR, BR, WRB

### CHANNEL UNIT CODES

PP = Pool, Plunge
PT = Pool, Trench
PL = Pool, Lateral Scour
PB = Pool, Backwater
PD = Pool, Impoundment
GL = Glide
RI = Riffle
RA = Rapid
CA = Cascade
FA = Falls
DR = Dry Channel

39811

Flag Codes: K = no measurement made; U = suspect measurement; F1, F2, ect. = flags assigned by each field crew. Explain all flags in comments. 1 = Measure Bar Width at Station 0 and Mid-Station (5 or 7).

Reviewed by (Initials): ________

# TORRENT EVIDENCE ASSESSMENT FORM - STREAMS

SITE ID: WSDP99-________ DATE: __ / __ / 2001

## TORRENT EVIDENCE

Please X any of the following that are evident.

### EVIDENCE OF TORRENT SCOURING:

| | |
|---|---|
| ☐ | 01 - Stream channel has a recently devegetated corridor two or more times the width of the low flow channel. This corridor lacks riparian vegetation with possible exception of fireweed, even-aged alder or cottonwood seedlings, grasses, or other herbaceous plants. |
| ☐ | 02 - Stream substrate cobbles or large gravel particles are NOT IMBRICATED. (Imbricated means that they lie with flat sides horizontal and that they are stacked like roof shingles -- imagine the upstream direction as the top of the "roof.") In a torrent scour or deposition channel, the stones are laying in unorganized patterns, lying "every which way." In addition many of the substrate particles are angular (not "water-worn.") |
| ☐ | 03 - Channel has little evidence of pool-riffle structure. (For example, could you ride a mountain bike down the channel?) |
| ☐ | 04 - The stream channel is scoured down to bedrock. |
| ☐ | 05 - There are gravel or cobble berms (little levees) above bankfull level. |
| ☐ | 06 - Downstream of the scoured reach (possibly several miles), there are massive deposits of sediment, logs, and other debris. |
| ☐ | 07 - Riparian trees have fresh bark scars at many points along the stream at seemingly unbelievable heights above the channel bed. |
| ☐ | 08 - Riparian trees have fallen into the channel as a result of scouring near their roots. |

### EVIDENCE OF TORRENT DEPOSITS:

| | |
|---|---|
| ☐ | 09 - There are massive deposits of sediment, logs, and other debris in the reach. They may contain wood and boulders that, in your judgement, could not have been moved by the stream at even extreme flood stage. |
| ☐ | 10 - If the stream has begun to erode newly laid deposits, it is evident that these deposits are "MATRIX SUPPORTED." This means that the large particles, like boulders and cobbles, are often not touching each other, but have silt, sand, and other fine particles between them (their weight is supported by these fine particles -- in contrast to a normal stream deposit, where fines, if present, normally "fill-in" the interstices between coarser particles.) |

### NO EVIDENCE

| | |
|---|---|
| ☐ | 11 - No evidence of torrent scouring or torrent deposits. |

## COMMENTS

5118

# APPENDIX G

# BIOLOGICAL DATA RESULTS

**Respec - White River**
**EcoAnalysts, Inc.**
**Data are adjusted for subsampling**

| **Stream** | **White River** | **White River** | **White River** | **Bear in the Lodge Cr** | **White River** | **White River** | **White River** | **White River** | **White River** |
|---|---|---|---|---|---|---|---|---|---|
| **Site** | **nr Oacoma** | **Westover** | **nr Kadoka** | **nr Wanblee** | **nr Oglala** | **nr SD-NE state ln** | **nr SD-NE state ln** | **nr Chadron** | **Crawford** |
| **Rep** | **200001** | **150001** | **700001** | **670001** | **600001** | **568501A** | **568501B** | **550001** | **400001** |
| **Date** | **10-25-2003** | **10-24-2003** | **10-25-2003** | **10-26-2003** | **10-26-2003** | **10-29-2003** | **10-29-2003** | **10-30-2003** | **10-30-2003** |
| **Percent Subsampled** | **100.00** | **100.00** | **100.00** | **83.33** | **75.19** | **100.00** | **47.85** | **79.37** | **66.67** |
| **EcoAnalysts Sample ID** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| **Abundance Measures** | | | | | | | | | |
| Corrected Abundance | 11.00 | 11.00 | 3.00 | 440.40 | 425.60 | 277.00 | 687.61 | 400.68 | 457.50 |
| EPT Abundance | 1.00 | 0.00 | 0.00 | 60.00 | 207.48 | 16.00 | 64.79 | 25.20 | 133.50 |
| **Dominance Measures** | | | | | | | | | |
| 1st Dominant Taxon | Bezzia Palpomyia sp. | Lopescladius sp. | Lopescladius sp. | Probezzia sp. | Caenis latipennis | Parakiefferiella sp. | Parakiefferiella sp. | Parakiefferiella sp. | Microcylloepus sp. |
| 1st Dominant Abundance | 3.00 | 3.00 | 2.00 | 90.00 | 206.20 | 117.00 | 261.30 | 190.30 | 76.50 |
| 2nd Dominant Taxon | Dolichopodidae | Probezzia sp. | Simulium sp. | Parakiefferiella sp. | Corixidae | Dubiraphia sp. | Probezzia sp. | Dubiraphia sp. | Pseudochironomus sp. |
| 2nd Dominant Abundance | 3.00 | 2.00 | 1.00 | 67.20 | 63.84 | 40.00 | 100.30 | 57.96 | 70.50 |
| 3rd Dominant Taxon | Polypedilum sp. | Polypedilum sp. | | Tricorythodes sp. | Dubiraphia sp. | Probezzia sp. | Dubiraphia sp. | Simulium sp. | Hydropsyche betteni |
| 3rd Dominant Abundance | 2.00 | 2.00 | 0.00 | 30.00 | 34.58 | 27.00 | 56.43 | 39.06 | 55.50 |
| 1 Dominant Taxon | 27.27 | 27.27 | 66.67 | 20.44 | 48.44 | 42.24 | 37.99 | 47.48 | 16.72 |
| 2 Dominant Taxa | 54.55 | 45.45 | 100.00 | 35.69 | 63.44 | 56.68 | 52.58 | 61.95 | 32.13 |
| 3 Dominant Taxa | 72.73 | 63.64 | 100.00 | 42.51 | 71.56 | 66.43 | 60.79 | 71.70 | 44.26 |
| **Richness Measures** | | | | | | | | | |
| Species Richness | 6.00 | 6.00 | 2.00 | 43.00 | 23.00 | 23.00 | 30.00 | 28.00 | 28.00 |
| EPT Richness | 1.00 | 0.00 | 0.00 | 7.00 | 2.00 | 3.00 | 7.00 | 4.00 | 6.00 |
| Ephemeroptera Richness | 0.00 | 0.00 | 0.00 | 2.00 | 1.00 | 1.00 | 3.00 | 1.00 | 2.00 |
| Plecoptera Richness | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| Trichoptera Richness | 1.00 | 0.00 | 0.00 | 4.00 | 1.00 | 2.00 | 4.00 | 3.00 | 3.00 |
| Chironomidae Richness | 3.00 | 4.00 | 1.00 | 11.00 | 9.00 | 6.00 | 9.00 | 7.00 | 11.00 |
| Oligochaeta Richness | 0.00 | 1.00 | 0.00 | 4.00 | 2.00 | 1.00 | 2.00 | 3.00 | 3.00 |
| Non-Chiro. Non-Olig. Richness | 3.00 | 1.00 | 1.00 | 28.00 | 12.00 | 16.00 | 19.00 | 18.00 | 14.00 |
| Rhyacophila Richness | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Community Composition** | | | | | | | | | |
| Ephemeroptera | 0.00 | 0.00 | 0.00 | 7.63 | 48.44 | 3.61 | 6.69 | 5.03 | 7.87 |
| Plecoptera | 0.00 | 0.00 | 0.00 | 1.63 | 0.00 | 0.00 | 0.00 | 0.00 | 1.64 |
| Trichoptera | 9.09 | 0.00 | 0.00 | 4.36 | 0.31 | 2.17 | 2.74 | 1.26 | 19.67 |
| EPT | 9.09 | 0.00 | 0.00 | 13.62 | 48.75 | 5.78 | 9.42 | 6.29 | 29.18 |
| Coleoptera | 0.00 | 0.00 | 0.00 | 8.17 | 9.69 | 18.41 | 11.25 | 14.47 | 17.70 |
| Diptera | 90.91 | 90.91 | 100.00 | 56.95 | 21.56 | 61.73 | 65.05 | 65.41 | 33.77 |
| Oligochaeta | 0.00 | 9.09 | 0.00 | 8.99 | 3.13 | 6.14 | 4.26 | 5.97 | 7.87 |
| Baetidae | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 |
| Brachycentridae | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Chironomidae | 36.36 | 72.73 | 66.67 | 25.34 | 13.44 | 46.93 | 46.20 | 51.26 | 29.51 |
| Ephemerellidae | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Hydropsychidae | 9.09 | 0.00 | 0.00 | 3.81 | 0.00 | 0.00 | 0.61 | 0.31 | 15.41 |
| Odonata | 0.00 | 0.00 | 0.00 | 0.27 | 0.31 | 0.00 | 2.13 | 0.94 | 0.00 |
| Perlidae | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pteronarcyidae | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Simuliidae | 0.00 | 0.00 | 33.33 | 5.18 | 0.00 | 3.25 | 0.61 | 9.75 | 0.98 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Functional Group Composition** | | | | | | | | | |
| Filterers | 9.09 | 0.00 | 33.33 | 8.99 | 0.00 | 3.97 | 1.22 | 10.69 | 16.39 |
| Gatherers | 0.00 | 45.45 | 66.67 | 40.33 | 21.56 | 69.68 | 54.71 | 69.81 | 58.36 |
| Predators | 63.64 | 18.18 | 0.00 | 35.97 | 13.44 | 17.69 | 26.44 | 9.43 | 12.46 |
| Scrapers | 0.00 | 0.00 | 0.00 | 5.45 | 1.25 | 3.25 | 2.43 | 1.26 | 5.90 |
| Shredders | 18.18 | 18.18 | 0.00 | 3.54 | 0.31 | 1.08 | 1.52 | 0.63 | 2.62 |
| Piercer-Herbivores | 0.00 | 0.00 | 0.00 | 5.72 | 15.00 | 4.33 | 7.60 | 3.14 | 4.26 |
| Unclassified | 9.09 | 18.18 | 0.00 | 0.00 | 48.44 | 0.00 | 6.08 | 5.03 | 0.00 |
| Filterer Richness | 1.00 | 0.00 | 1.00 | 3.00 | 0.00 | 2.00 | 2.00 | 3.00 | 3.00 |
| Gatherer Richness | 0.00 | 3.00 | 1.00 | 14.00 | 9.00 | 7.00 | 11.00 | 10.00 | 15.00 |
| Predator Richness | 3.00 | 1.00 | 0.00 | 15.00 | 9.00 | 9.00 | 11.00 | 10.00 | 7.00 |
| Scraper Richness | 0.00 | 0.00 | 0.00 | 4.00 | 2.00 | 3.00 | 3.00 | 2.00 | 1.00 |
| Shredder Richness | 1.00 | 1.00 | 0.00 | 5.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Piercer-Herbivore Richness | 0.00 | 0.00 | 0.00 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Unclassified | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 | 1.00 | 0.00 |
| **Diversity/Evenness Measures** | | | | | | | | | |
| Shannon-Weaver H' (log 10) | 0.73 | 0.75 | 0.28 | 1.29 | 0.80 | 0.92 | 1.00 | 0.87 | 1.19 |
| Shannon-Weaver H' (log 2) | 2.41 | 2.48 | 0.92 | 4.28 | 2.67 | 3.05 | 3.34 | 2.88 | 3.95 |
| Shannon-Weaver H' (log e) | 1.67 | 1.72 | 0.64 | 2.97 | 1.85 | 2.11 | 2.31 | 2.00 | 2.74 |
| Margalef's Richness | 2.09 | 2.09 | 0.91 | 6.90 | 3.63 | 3.91 | 4.44 | 4.51 | 4.41 |
| Pielou's J' | 0.93 | 0.96 | 0.92 | 0.79 | 0.59 | 0.67 | 0.68 | 0.60 | 0.82 |
| Simpson's Heterogeneity | 0.87 | 0.89 | 0.67 | 0.92 | 0.72 | 0.78 | 0.81 | 0.74 | 0.91 |
| **Biotic Indices** | | | | | | | | | |
| Indiv. w HBI Value | 63.64 | 63.64 | 100.00 | 73.02 | 42.19 | 88.45 | 75.68 | 89.31 | 92.13 |
| Hilsenhoff Biotic Index | 5.57 | 4.86 | 3.00 | 6.44 | 7.12 | 6.42 | 6.43 | 6.31 | 5.82 |
| Indiv. w MTI Value | 54.55 | 18.18 | 33.33 | 43.60 | 29.38 | 38.27 | 28.27 | 32.39 | 68.85 |
| Metals Tolerance Index | 4.17 | 4.00 | 5.00 | 4.18 | 4.48 | 3.96 | 4.20 | 4.35 | 3.96 |
| Indiv. w FSBI Value | 9.09 | 0.00 | 33.33 | 15.26 | 0.00 | 3.25 | 1.52 | 10.06 | 15.74 |
| Fine Sediment Biotic Index | 2.00 | -99.00 | 3.00 | 26.00 | -99.00 | 3.00 | 9.00 | 5.00 | 26.00 |
| FSBI - average | 0.33 | -99.00 | 1.50 | 0.60 | -99.00 | 0.13 | 0.30 | 0.18 | 0.93 |
| FSBI - weighted average | 2.00 | -99.00 | 3.00 | 3.36 | -99.00 | 3.00 | 2.80 | 2.97 | 4.17 |
| Indiv. w TPM Value | 27.27 | 18.18 | 33.33 | 28.07 | 24.38 | 22.02 | 20.36 | 29.25 | 18.69 |
| Temp. Pref. Metric - average | 0.50 | 0.33 | 2.50 | 0.56 | 0.43 | 0.30 | 0.67 | 0.89 | 0.79 |
| TPM - weighted average | 1.67 | 2.00 | 5.00 | 2.20 | 1.10 | 1.59 | 1.34 | 2.53 | 2.32 |
| DEQ MBI | 2.07 | 2.04 | 1.36 | 3.45 | 2.51 | 2.33 | 2.71 | 2.35 | 3.34 |
| **Karr BIBI Metrics** | | | | | | | | | |
| Long-Lived Taxa Richness | 0.00 | 0.00 | 0.00 | 5.00 | 2.00 | 3.00 | 2.00 | 2.00 | 1.00 |
| Clinger Richness | 2.00 | 1.00 | 1.00 | 13.00 | 6.00 | 8.00 | 9.00 | 5.00 | 12.00 |
| Clingers | 27.27 | 18.18 | 33.33 | 28.07 | 10.63 | 25.63 | 15.50 | 25.47 | 56.72 |
| Intolerant Taxa Richness | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 2.00 | 0.00 | 1.00 |
| Tolerant taxa | 0.00 | 9.09 | 0.00 | 14.53 | 13.86 | 12.27 | 6.25 | 8.74 | 4.59 |
| **Montana DEQ Metrics** | | | | | | | | | |
| MT Biotic Index | 5.57 | 4.86 | 3.00 | 6.44 | 7.12 | 6.42 | 6.43 | 6.31 | 5.82 |
| C-Gatherers + C- Filterers | 9.09 | 45.45 | 100.00 | 49.32 | 21.56 | 73.65 | 55.93 | 80.50 | 74.75 |
| Scraper + Shredder | 18.18 | 18.18 | 0.00 | 8.99 | 1.56 | 4.33 | 3.95 | 1.89 | 8.52 |
| Univoltine | 54.55 | 36.36 | 66.67 | 31.61 | 19.38 | 60.65 | 51.06 | 63.84 | 39.02 |
| Multivoltine | 9.09 | 0.00 | 33.33 | 17.17 | 50.63 | 9.75 | 11.25 | 16.04 | 34.75 |
| Semivoltine | 0.00 | 0.00 | 0.00 | 7.08 | 15.63 | 5.78 | 9.42 | 3.14 | 0.98 |
| Hydropsychinae | 9.09 | 0.00 | 0.00 | 3.81 | 0.00 | 0.00 | 0.61 | 0.31 | 15.41 |
| **UIN** | 381-1 | 381-2 | 381-3 | 381-4 | 381-5 | 381-6 | 381-7 | 381-8 | 381-9 |

| | | Westover | Oacoma | Crawford | Whitney | State-Line | State-Line | Oglala | Bear Lodge | Kadoka |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Ecological Indicator** | **150003** | **200003** | **400003** | **550003** | **568503a** | **568503b** | **600003** | **670003** | **700003** |
| 1 | **pH** | 3.4 | 3.0 | 3.9 | 3.4 | 3.1 | 3.2 | 3.3 | 3.1 | 3.2 |
| 2 | **Salinity** | 2.0 | 2.1 | 2.1 | 2.2 | 2.1 | 2.3 | 1.9 | 2.3 | 2.0 |
| 3 | **Organic Nitrogen** | 1.9 | 2.0 | 2.0 | 1.6 | 1.6 | 1.5 | 1.1 | 1.3 | 1.2 |
| 4 | **Oxygen requirement** | 2.2 | 2.2 | 2.0 | 1.8 | 1.9 | 1.8 | 1.8 | 1.6 | 1.9 |
| 5 | **Saprobity** | 2.3 | 2.5 | 2.0 | 1.7 | 2.0 | 1.8 | 1.9 | 1.7 | 1.9 |
| 6 | **Trophic state** | 3.8 | 4.1 | 4.3 | 3.8 | 3.7 | 3.9 | 3.9 | 3.7 | 4.0 |
| 7 | **Moisture** | 2.1 | 1.8 | 2.0 | 1.9 | 1.9 | 1.9 | 2.0 | 1.9 | 2.0 |
| 8 | **silt tolerant taxa** | 72.8 | 94.6 | 46.3 | 64 | 67.3 | 62.6 | 62.5 | 84.2 | 76.5 |
| 9 | **species richness** | 22 | 20 | 22 | 30 | 31 | 26 | 24 | 25 | 9 |

# APPENDIX H

# BED MATERIAL SAMPLING RESULTS

**Table H-1. Particle Size Distribution for Crawford**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 461.63 | 100% | 0% |
| 4.75 | 29.76 | 431.87 | 94% | 6% |
| 1.18 | 18.74 | 413.13 | 89% | 4% |
| 0.85 | 9.53 | 403.60 | 87% | 2% |
| 0.59 | 10.78 | 392.82 | 85% | 2% |
| 0.425 | 11.73 | 381.09 | 83% | 3% |
| 0.300 | 15.62 | 365.47 | 79% | 3% |
| 0.149 | 94.88 | 270.59 | 59% | 21% |
| 0.075 | 186.25 | 84.34 | 18% | 40% |
| 0.062 | 31.94 | 52.40 | 11% | 7% |
| 0.031 | 13.70 | 38.70 | 8% | 3% |
| 0.016 | 9.40 | 29.30 | 6% | 2% |
| 0.008 | 4.10 | 25.20 | 5% | 1% |
| 0.004 | 2.70 | 22.50 | 5% | 1% |
| 0.002 | -0.50 | 23.00 | 5% | 0% |

RSI-1465-04-049

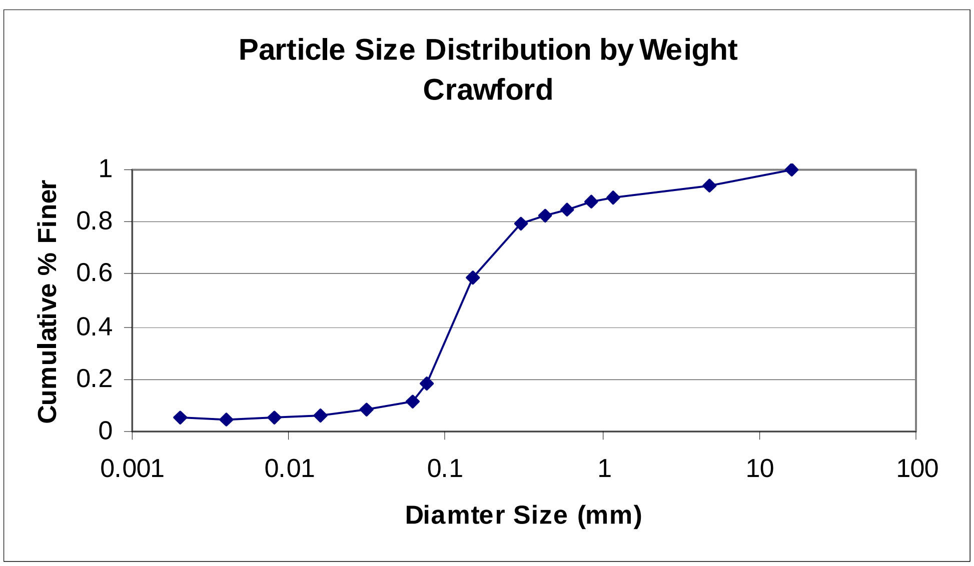



**Figure H-1.** Particle Size Distribution by Weight for Bed Material Samples for Crawford.

**Table H-2. Particle Size Distribution for Whitney**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 285.14 | 100% | 0% |
| 4.75 | 16.68 | 268.46 | 94% | 6% |
| 1.18 | 12.96 | 255.50 | 90% | 5% |
| 0.85 | 11.87 | 243.63 | 85% | 4% |
| 0.59 | 14.28 | 229.35 | 80% | 5% |
| 0.425 | 8.57 | 220.78 | 77% | 3% |
| 0.300 | 7.23 | 213.55 | 75% | 3% |
| 0.149 | 22.84 | 190.71 | 67% | 8% |
| 0.075 | 70.64 | 120.07 | 42% | 25% |
| 0.062 | 29.30 | 90.77 | 32% | 10% |
| 0.031 | 20.30 | 70.47 | 25% | 7% |
| 0.016 | 12.83 | 57.63 | 20% | 5% |
| 0.008 | 3.50 | 54.13 | 19% | 1% |
| 0.004 | 9.57 | 44.57 | 16% | 3% |
| 0.002 | 0.23 | 44.33 | 16% | 0% |

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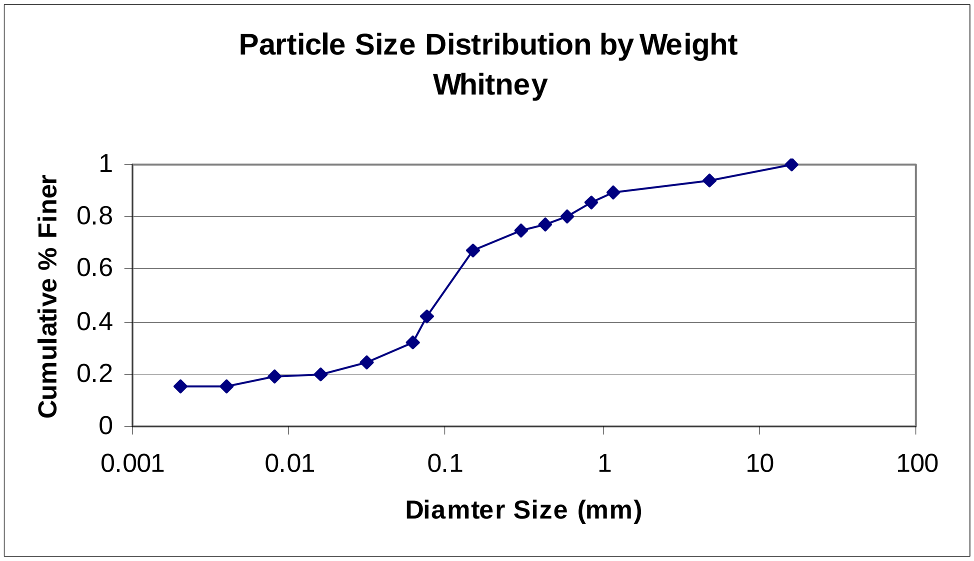


**Figure H-2.** Particle Size Distribution by Weight for Bed Material Samples for Whitney.

**Table H-3. Particle Size Distribution for State Line**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 480.83 | 100% | 0% |
| 4.75 | 28.58 | 452.25 | 94% | 6% |
| 1.18 | 137.72 | 314.53 | 65% | 29% |
| 0.85 | 63.35 | 251.18 | 52% | 13% |
| 0.59 | 66.31 | 184.87 | 38% | 14% |
| 0.425 | 49.63 | 135.24 | 28% | 10% |
| 0.300 | 28.57 | 106.67 | 22% | 6% |
| 0.149 | 18.30 | 88.37 | 18% | 4% |
| 0.075 | 2.94 | 85.43 | 18% | 1% |
| 0.062 | 10.45 | 74.98 | 16% | 2% |
| 0.031 | 2.52 | 72.46 | 15% | 1% |
| 0.016 | 5.88 | 66.58 | 14% | 1% |
| 0.008 | 6.16 | 60.42 | 13% | 1% |
| 0.004 | 7.11 | 53.31 | 11% | 1% |
| 0.002 | 8.90 | 44.41 | 9% | 2% |

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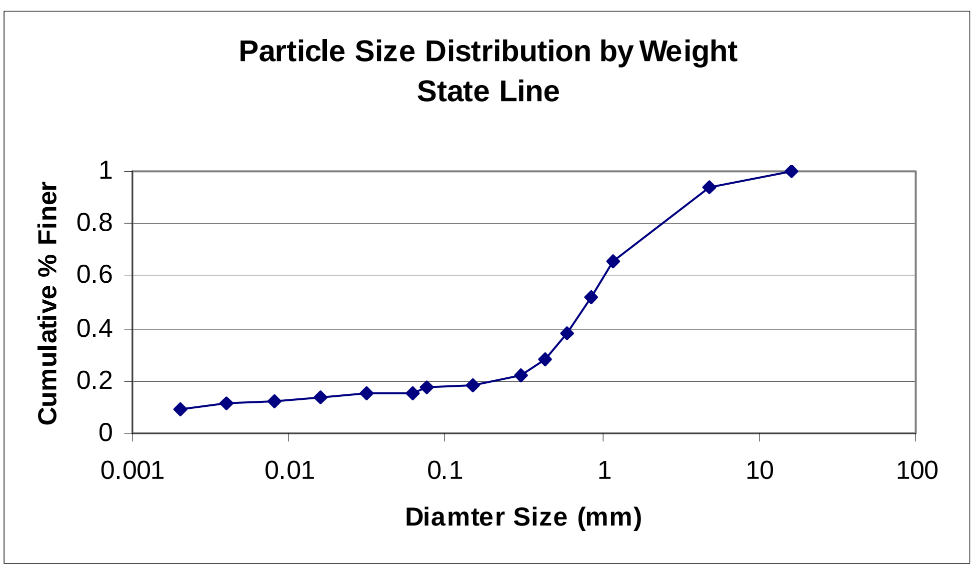


**Figure H-3.** Particle Size Distribution by Weight for Bed Material Samples for State Line.

**Table H-4. Particle Size Distribution for Oglala**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 460.36 | 100% | 0% |
| 4.75 | 21.54 | 438.82 | 95% | 5% |
| 1.18 | 46.05 | 392.77 | 85% | 10% |
| 0.85 | 15.25 | 377.52 | 82% | 3% |
| 0.59 | 22.30 | 355.22 | 77% | 5% |
| 0.425 | 30.98 | 324.24 | 70% | 7% |
| 0.300 | 30.45 | 293.79 | 64% | 7% |
| 0.149 | 66.53 | 227.26 | 49% | 14% |
| 0.075 | 58.59 | 168.67 | 37% | 13% |
| 0.062 | 64.37 | 104.30 | 23% | 14% |
| 0.031 | 5.18 | 99.12 | 22% | 1% |
| 0.016 | 14.14 | 84.98 | 18% | 3% |
| 0.008 | 13.16 | 71.82 | 16% | 3% |
| 0.004 | 6.72 | 65.10 | 14% | 1% |
| 0.002 | 11.76 | 53.34 | 12% | 3% |

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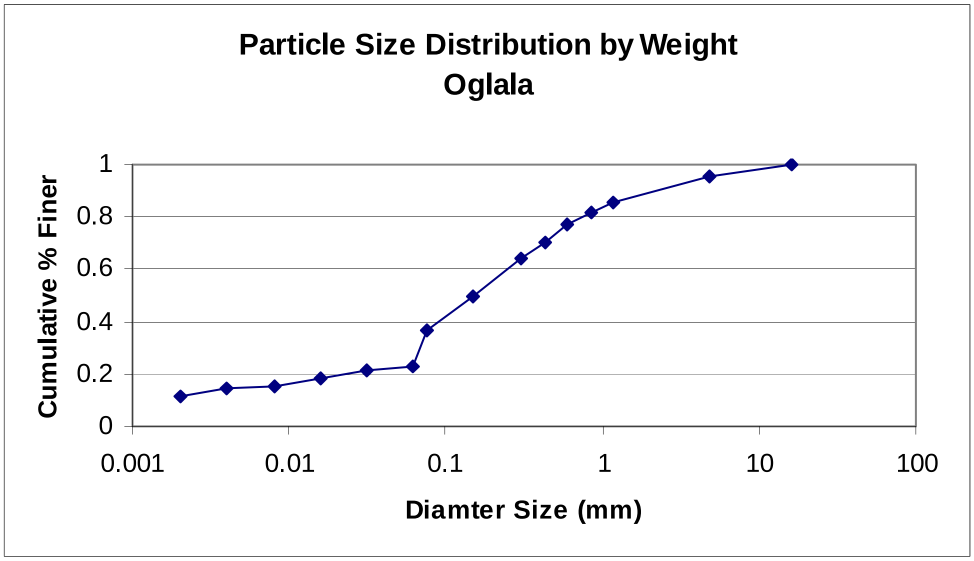


**Figure H-4.** Particle Size Distribution by Weight for Bed Material Samples for Oglala.

**Table H-5. Particle Size Distribution for Rockyford**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 615.80 | 100% | 0% |
| 4.75 | 367.86 | 247.94 | 40% | 60% |
| 1.18 | 94.28 | 153.66 | 25% | 15% |
| 0.85 | 22.01 | 131.65 | 21% | 4% |
| 0.59 | 22.77 | 108.88 | 18% | 4% |
| 0.425 | 18.37 | 90.51 | 15% | 3% |
| 0.300 | 11.32 | 79.19 | 13% | 2% |
| 0.149 | 11.38 | 67.81 | 11% | 2% |
| 0.075 | 8.15 | 59.66 | 10% | 1% |
| 0.062 | 21.13 | 38.53 | 6% | 3% |
| 0.031 | 5.21 | 33.32 | 5% | 1% |
| 0.016 | 3.02 | 30.30 | 5% | 0% |
| 0.008 | 3.58 | 26.71 | 4% | 1% |
| 0.004 | 2.55 | 24.16 | 4% | 0% |
| 0.002 | 2.52 | 21.64 | 4% | 0% |

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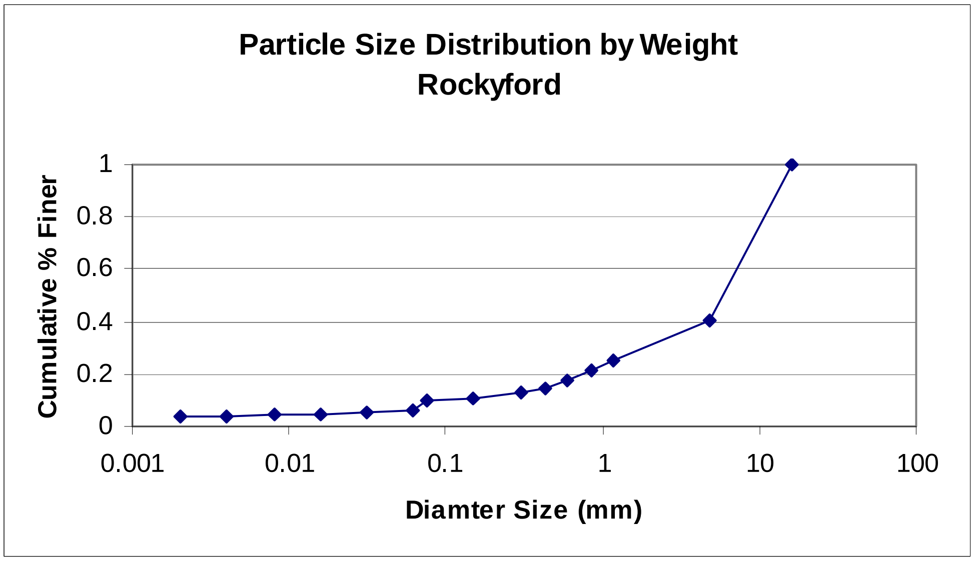


**Figure H-5.** Particle Size Distribution by Weight for Bed Material Samples for Rockyford.

**Table H-6. Particle Size Distribution for Bear in the Lodge**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 388.75 | 100% | 0% |
| 4.75 | 125.66 | 263.09 | 68% | 32% |
| 1.18 | 98.98 | 164.11 | 42% | 25% |
| 0.85 | 10.07 | 154.04 | 40% | 3% |
| 0.59 | 9.54 | 144.50 | 37% | 2% |
| 0.425 | 10.05 | 134.45 | 35% | 3% |
| 0.300 | 9.26 | 125.19 | 32% | 2% |
| 0.149 | 11.06 | 114.13 | 29% | 3% |
| 0.075 | 15.43 | 98.70 | 25% | 4% |
| 0.062 | 28.70 | 70.00 | 18% | 7% |
| 0.031 | 0.00 | 70.00 | 18% | 0% |
| 0.016 | 14.00 | 56.00 | 14% | 4% |
| 0.008 | 14.00 | 42.00 | 11% | 4% |
| 0.004 | 14.00 | 28.00 | 7% | 4% |
| 0.002 | 0.00 | 28.00 | 7% | 0% |

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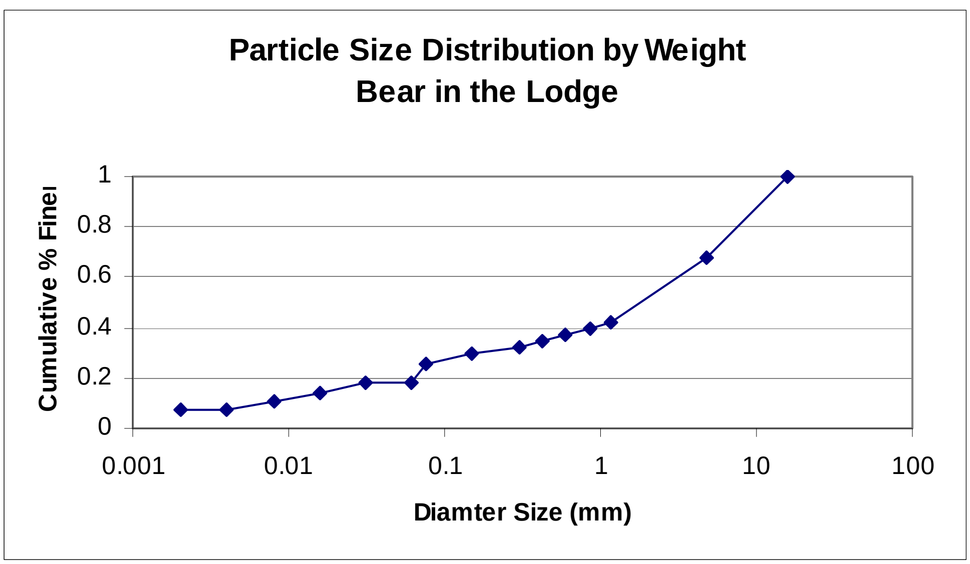



**Figure H-6.** Particle Size Distribution by Weight for Bed Material Samples for Bear in the Lodge.

**Table H-7. Particle Size Distribution for Kadoka**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 437.53 | 100% | 0% |
| 4.75 | 47.06 | 390.47 | 89% | 11% |
| 1.18 | 49.84 | 340.63 | 78% | 11% |
| 0.85 | 39.26 | 301.37 | 69% | 9% |
| 0.59 | 77.92 | 223.45 | 51% | 18% |
| 0.425 | 81.90 | 141.55 | 32% | 19% |
| 0.300 | 51.90 | 89.65 | 20% | 12% |
| 0.149 | 38.98 | 50.67 | 12% | 9% |
| 0.075 | 8.67 | 42.00 | 10% | 2% |
| 0.062 | 19.60 | 22.40 | 5% | 4% |
| 0.031 | 0.00 | 22.40 | 5% | 0% |
| 0.016 | 0.00 | 22.40 | 5% | 0% |
| 0.008 | 0.00 | 22.40 | 5% | 0% |
| 0.004 | 5.60 | 16.80 | 4% | 1% |
| 0.002 | 0.00 | 16.80 | 4% | 0% |

RSI-1465-04-055

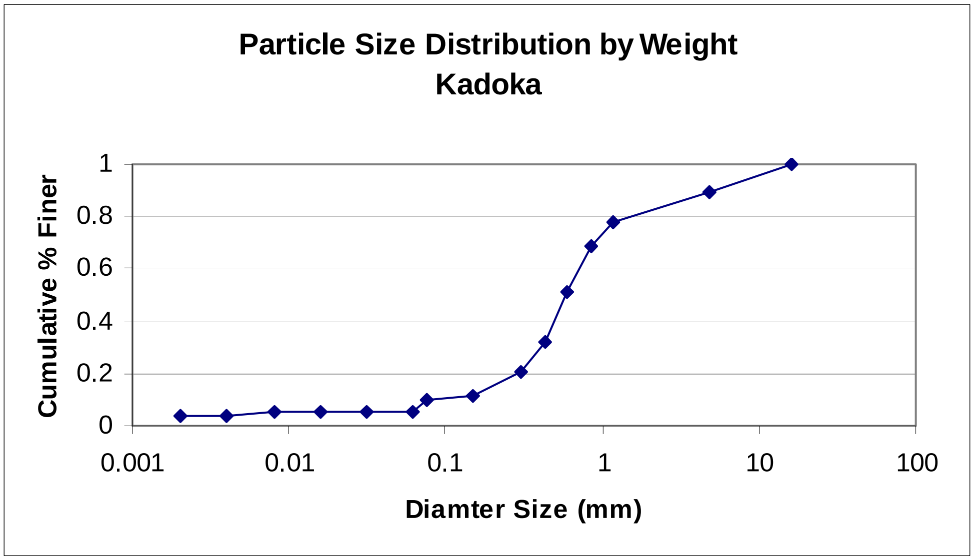



**Figure H-7.** Particle Size Distribution by Weight for Bed Material Samples for Kadoka.

**Table H-8. Particle Size Distribution for Black Pipe**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 424.56 | 100% | 0% |
| 4.75 | 6.10 | 418.46 | 99% | 1% |
| 1.18 | 88.30 | 330.16 | 78% | 21% |
| 0.85 | 54.16 | 276.00 | 65% | 13% |
| 0.59 | 64.46 | 211.54 | 50% | 15% |
| 0.425 | 55.04 | 156.50 | 37% | 13% |
| 0.300 | 28.06 | 128.44 | 30% | 7% |
| 0.149 | 14.95 | 113.49 | 27% | 4% |
| 0.075 | 5.57 | 107.92 | 25% | 1% |
| 0.062 | 16.92 | 91.00 | 21% | 4% |
| 0.031 | 7.00 | 84.00 | 20% | 2% |
| 0.016 | 14.00 | 70.00 | 16% | 3% |
| 0.008 | 14.00 | 56.00 | 13% | 3% |
| 0.004 | 7.00 | 49.00 | 12% | 2% |
| 0.002 | 7.00 | 42.00 | 10% | 2% |

RSI-1465-04-056

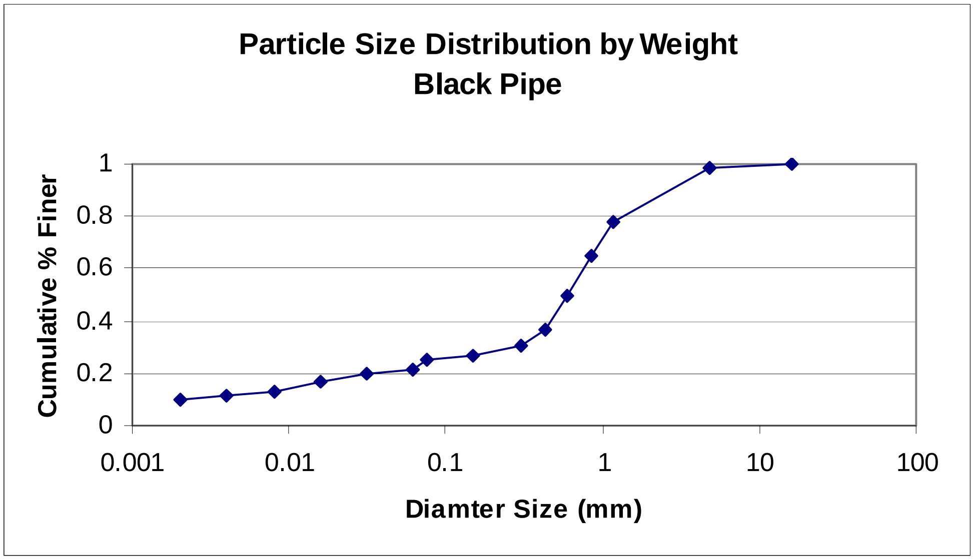



**Figure H-8.** Particle Size Distribution by Weight for Bed Material Samples for Black Pipe.

**Table H-9. Particle Size Distribution for Westover**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 582.61 | 100% | 0% |
| 4.75 | 11.34 | 571.27 | 98% | 2% |
| 1.18 | 37.26 | 534.01 | 92% | 6% |
| 0.85 | 31.48 | 502.53 | 86% | 5% |
| 0.59 | 52.26 | 450.27 | 77% | 9% |
| 0.425 | 118.25 | 332.02 | 57% | 20% |
| 0.300 | 140.22 | 191.80 | 33% | 24% |
| 0.149 | 150.68 | 41.12 | 7% | 26% |
| 0.075 | 10.30 | 30.82 | 5% | 2% |
| 0.062 | -22.07 | 52.89 | 9% | -4% |
| 0.031 | 12.44 | 40.44 | 7% | 2% |
| 0.016 | 0.00 | 40.44 | 7% | 0% |
| 0.008 | 6.22 | 34.22 | 6% | 1% |
| 0.004 | -3.11 | 37.33 | 6% | -1% |
| 0.002 | 3.11 | 34.22 | 6% | 1% |

RSI-1465-04-057

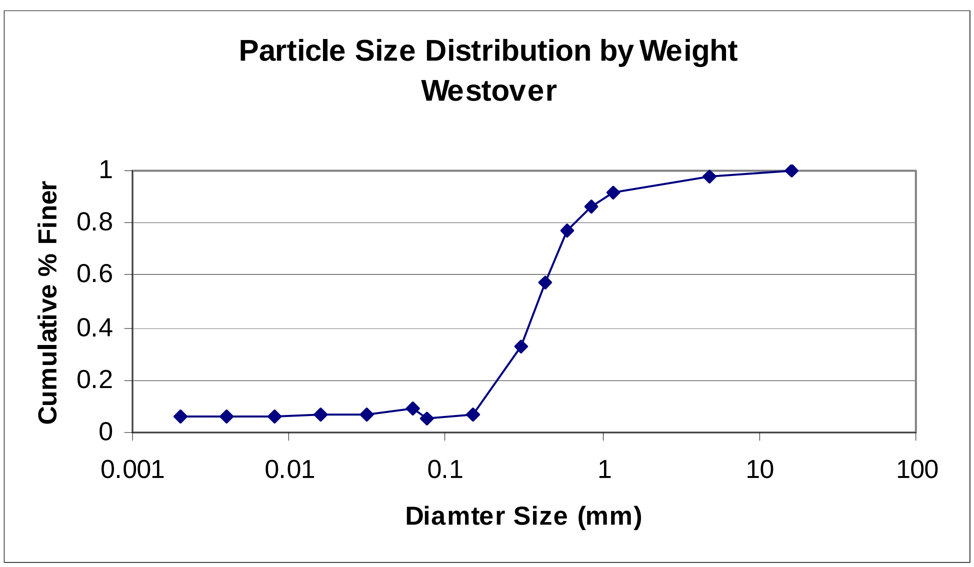



**Figure H-9.** Particle Size Distribution by Weight for Bed Material Samples for Westover.

**Table H-10. Particle Size Distribution for Oacoma**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 4.75 | 18.62 | 662.03 | 97% | 3% |
| 1.18 | 26.09 | 635.94 | 93% | 4% |
| 0.85 | 25.09 | 610.85 | 90% | 4% |
| 0.59 | 61.35 | 549.50 | 81% | 9% |
| 0.425 | 132.74 | 416.76 | 61% | 20% |
| 0.300 | 184.06 | 232.70 | 34% | 27% |
| 0.149 | 164.54 | 68.16 | 10% | 24% |
| 0.075 | 15.97 | 52.19 | 8% | 2% |
| 0.062 | 15.86 | 36.33 | 5% | 2% |
| 0.031 | 1.40 | 34.93 | 5% | 0% |
| 0.016 | 0.21 | 34.72 | 5% | 0% |
| 0.008 | 5.67 | 29.05 | 4% | 1% |
| 0.004 | 1.40 | 27.65 | 4% | 0% |
| 0.002 | 2.17 | 25.48 | 4% | 0% |
| 4.75 | 18.62 | 662.03 | 97% | 3% |

RSI-1465-04-058

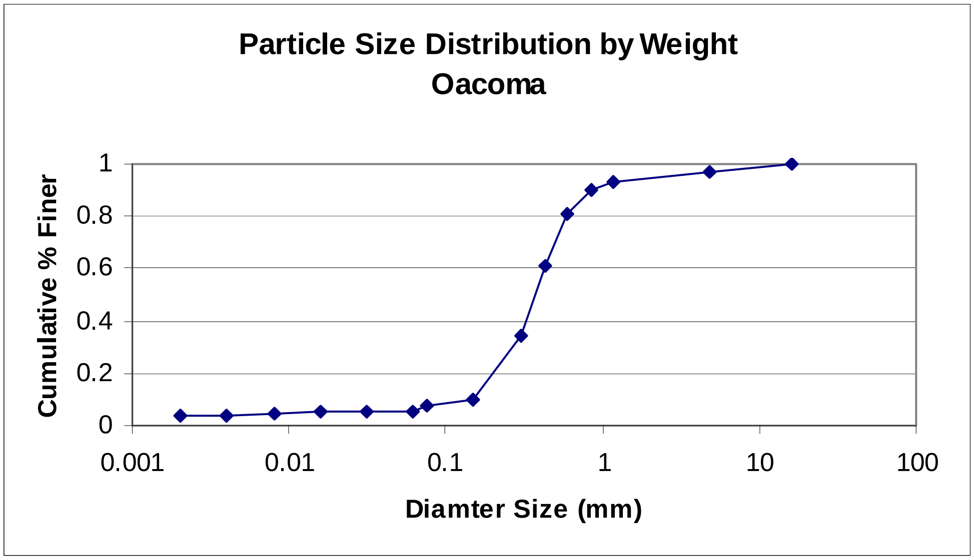



**Figure H-10.** Particle Size Distribution by Weight for Bed Material Samples for Oacoma.

**Table H-11. Particle Size Distribution (Oacoma QA/QC)**

| Particle Size | Weight Retained | Weight Finer | % Finer | % of total |
|---|---|---|---|---|
| 16 | 0.00 | 564.38 | 100% | 0% |
| 4.75 | 2.62 | 561.76 | 100% | 0% |
| 1.18 | 14.57 | 547.19 | 97% | 3% |
| 0.85 | 16.42 | 530.77 | 94% | 3% |
| 0.59 | 48.22 | 482.55 | 86% | 9% |
| 0.425 | 124.62 | 357.93 | 63% | 22% |
| 0.300 | 148.58 | 209.35 | 37% | 26% |
| 0.149 | 149.26 | 60.09 | 11% | 26% |
| 0.075 | 19.11 | 40.98 | 7% | 3% |
| 0.062 | 6.13 | 34.85 | 6% | 1% |
| 0.031 | 1.25 | 33.60 | 6% | 0% |
| 0.016 | 1.55 | 32.05 | 6% | 0% |
| 0.008 | 1.00 | 31.05 | 6% | 0% |
| 0.004 | 2.40 | 28.65 | 5% | 0% |
| 0.002 | 1.10 | 27.55 | 5% | 0% |

RSI-1465-04-059

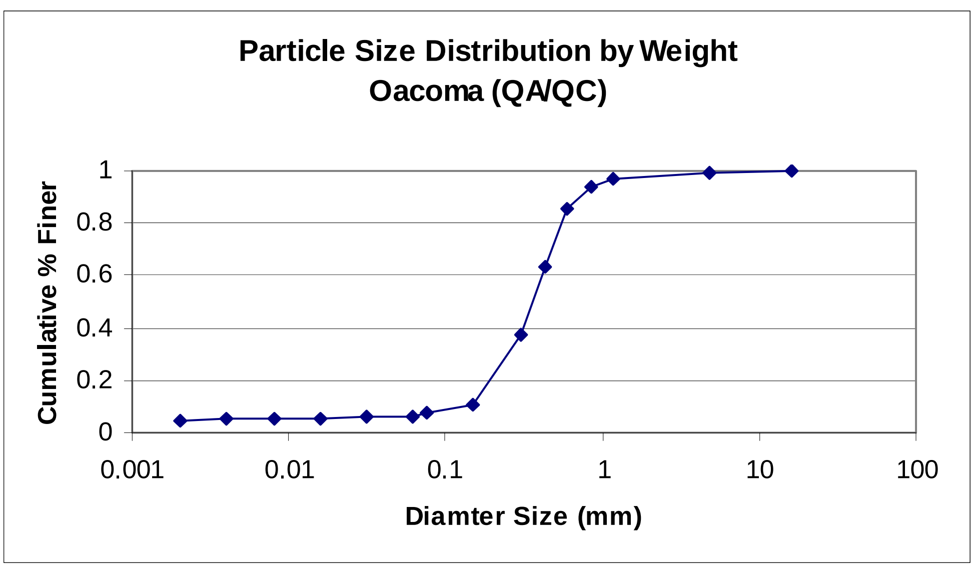



**Figure H-11.** Particle Size Distribution by Weight for Bed Material Samples for Oacoma (QA/QC).

# APPENDIX I

# PHYSICAL HABITAT ASSESSMENT

**Table I-1. Definition of Physical Habitat Metrics Used for Data Analysis (Page 1 of 8)**

| Metric Variable Name | Units | Metric Description |
|---|---|---|
| **Identification Variables** | | |
| STRM_ID | | Stream reach identification code |
| YEAR | | Year of site visit |
| **Stream Classification** | | |
| Rosgen | | Rosgen Stream Classification |
| CEM | | Schumm's Channel Evolution Model |
| **Channel Morphology Metrics** | | |
| REACHLEN | ft | Length of sample reach |
| XDEPTH | ft | Mean thalweg depth |
| SDDEPTH | ft | Standard deviation of thalweg depth |
| XWIDTH | ft | Mean wetted width |
| SDWIDTH | ft | Standard deviation of wetted width |
| XWXD | ft | Mean wetted width × mean thalweg depth |
| SDWXD | ft | SD of wetted width × SD thalweg depth |
| XWD_RAT | ft | Mean wetted width/depth |
| SDWD_RAT | ft | Standard deviation of wetted width/thalweg depth |
| PCT-FA | % | Percent falls |
| PCT_CA | % | Percent cascade |
| PCT_RA | % | Percent rapids |
| PCT_RI | % | Percent riffle |
| PCT_GL | % | Percent glide |
| PCT_PD | % | Percent impoundment pool |
| PCT_PP | % | Percent plunge pool |
| PCT_PL | % | Percent lateral scour pool |

**Table I-1. Definition of Physical Habitat Metrics Used for Data Analysis (Page 2 of 8)**

| Metric Variable Name | Units | Metric Description |
|---|---|---|
| PCT_PT | % | Percent trench pool |
| PCT_PB | % | Percent backwater pool |
| PCT_P | % | Percent pool (unspecified type) |
| PCT_DR | % | Percent dry channel |
| PCT_SB | % | Percent subsurface flow |
| PCT_DRS | % | Percent dry or subsurface flow |
| PCT_FAST | % | Percent falls + cascade + rapids+ riffles |
| PCT_SLOW | % | Percent glides + all pool types |
| PCT_POOL | % | Percent all pool types |
| **Channel Cross-Section and Bank Morphology Metrics** | | |
| XBKA | deg | Mean bank angle |
| XUN | ft | Mean bank undercut distance |
| MEDBKUN | ft | Median bank undercut distance |
| XBKF_W | ft | Mean bankfull width |
| XBKF_H | ft | Mean bankfull height |
| XINC_H | ft | Mean incision height |
| Slumpage | % | **Percent of transect banks with slumpage |
| Bank_length | ft | **Mean bank length |
| Vegetated | ft | **Mean length of vegetated bank |
| Eroded | ft | **Mean length of eroded bank |
| Deposited | ft | **Mean length of deposited bank |
| **Channel Sinuosity and Slope Metrics** | | |
| SINU | | Channel sinuosity |
| XSLOPE | % | Water surface gradient over reach |

**Table I-1. Definition of Physical Habitat Metrics Used for Data Analysis (Page 3 of 8)**

| Metric Variable Name | Units | Metric Description |
|---|---|---|
| XBEARING | deg | Mean direction of reach flow |
| VSLOPE | | Standard deviation of water surface gradient |
| **Residual Pool Metrics** | | |
| PCTRSED | % | Thalweg small sediments (% of reach length) |
| **Substrate Size and Composition Metrics** | | |
| SUB_X | mm | *Substrate mean size class |
| SUB_V | mm | *Standard deviation of substrate size class |
| SUB_Q3 | mm | *75th percentile of substrate size class |
| SUB_MED | mm | *Substrate median size class |
| SUB_Q1 | mm | *25th percetile of substrate size class |
| SUB_IQR | mm | *Interquartile range of substrate size class |
| LSUB_DMM | mm | *Log10 (estimated geometric mean of sub. diameter) |
| SUB_X | mm | **Substrate mean size class |
| SUB_V | mm | **Standard deviation of substrate size class |
| SUB_Q3 | mm | **75th percentile of substrate size class |
| SUB_MED | mm | **Substrate median size class |
| SUB_Q1 | mm | **25th percetile of substrate size class |
| SUB_IQR | mm | **Interquartile range of substrate size class |
| XEMBED | % | Sustrate mean embeddedness–channel + margin |
| VEMBED | % | SD of embeddness–channel + margin |
| XCEMBED | % | Sustrate mean embeddedness–mid-channel |
| VCEMBED | % | SD embeddedness–midchannel |
| PCT_RS | % | Substrate % smooth bedrock (>4,000mm) |
| PCT_RR | % | Substrate % rough bedrock (> 4,000mm) |

**Table I-1. Definition of Physical Habitat Metrics Used for Data Analysis (Page 4 of 8)**

| Metric Variable Name | Units | Metric Description |
|---|---|---|
| PCT_BDRK | % | Substrate % bedrock |
| PCT_BL | % | Substrate % boulder (250–4,000 mm) |
| PCT_CB | % | Substrate % cobble (64–250 mm) |
| PCT_GC | % | Substrate % coarse gravel (16–64 mm) |
| PCT_BIGR | % | Substrate % coarse gravel and larger (>16 mm) |
| PCT_GF | % | Substrate % fine gravel (2–16mm) |
| PCT_SFGF | % | Substrate % fine gravel and smaller (<=16mm) |
| PCT_SA | % | Substrate % sand (0.6–2 mm) |
| PCT_FN | % | Substrate % fine (silt/clay, <0.6mm) |
| PCT_SAFN | % | Substrate % sand + fines (<2 mm) |
| PCT_OM | % | Substrate % organic detritus |
| PCT_WD | % | Substrate % wood |
| PCT_ORG | % | Substrate % wood or detritus |
| PCT_RC | % | Substrate % concrete |
| PCT_HP | % | Substrate % hard pan |
| PCT_OT | % | Substrate % miscellaneous other types |
| **Bed Substrate Stability Metrics** | | |
| LTEST | mm | $Log_{10}$ Erodible substrate diam (mm)–Quick estimate |
| | | Ltest=$log_{10}$(13.7 *(0.5*xdepth*10)(XSLOPE/100) |
| LDMB_BW4 | mm | *$Log_{10}$ Erodible substrate diam (mm) –Estimate 2 |
| | | LDMB_BW4=$Log_{10}(13.7(R_{bf} - R_w - R_p) * S)$ |
| | | where: |
| $R_{bf}$ | mm | $R_{bf}$ = 0.5[(xdepth * .3048)+(xbkf_h * .3048)]*1000 |
| $R_w$ | mm | $R_w$ = (V1W_MSQ * 1000) |

**Table I-1. Definition of Physical Habitat Metrics Used for Data Analysis (Page 5 of 8)**

| Metric Variable Name | Units | Metric Description |
|---|---|---|
| $R_p$ | mm | $R_p$ = (0.5 * RP100 *.3048* 1000) |
| S | | S = (XSLOPE ) |
| | | if $R_W >= (R_{bf} - R_p)$ then $(R_{bf} - R_w - R_p) = 0.1(R_{bf} - R_p)$ |
| LRBS_TST | mm | $Log_{10}$ [Relative Bed Stability] = (observed mean substrate diameter)/(erodible substrate diameter) –Quick Estimate |
| | | LRBS_TST=LSUB_DMM- LTEST |
| LRBS_BW4 | | $Log_{10}$ [Relative Bed Stability] = (observed mean substrate diameter)/(erodible substrate diameter) –Estimate 2 |
| | mm | LRBS_BW4 = LSUB_DMM - LDMB_BW4 |
| **Bed Material Samples** | | |
| BM_SA | % | Bed material % sand |
| BM_FN | % | Bed material % fines |
| BM_SAFN | % | Bed material % sand + fines |
| BM_GR | % | Bed material % gravel |
| **Riparian Vegetation Cover Metrics** | | |
| XCL | | Mean canopy cover (large trees) |
| XCS | | Mean canopy cover (small trees) |
| XC | | Mean canopy cover total |
| XMW | | Understory woody shrubs and sapling |
| XMH | | Understory nonwoody herbs, grass |
| XM | | Understory woody + nonwoody |
| XGW | | Ground cover woody shrubs and sapling |
| XGH | | Ground cover nonwoody herbs, grass |
| XG | | Ground cover woody + nonwoody |
| XGB | | Ground cover barren, dirt, duff |

**Table I-1. Definition of Physical Habitat Metrics Used for Data Analysis (Page 6 of 8)**

| Metric Variable Name | Units | Metric Description |
|---|---|---|
| | | **Fish Cover Metrics** |
| XFC_ALG | | Filamentous algae areal cover |
| XFC_AQM | | Aquatic macrophyte areal cover |
| XFC_LWD | | Large woody debris areal cover |
| XFC_BRS | | Brush and small woody debris areal cover |
| XFC_OHV | | Overhanging vegetation areal cover |
| XFC_RCK | | Boulder and rock ledge areal cover |
| XFC_UCB | | Undercut bank areal cover |
| XFC_HUM | | Artificial structure areal cover |
| XFC_ALL | | Sum of areal cover from all fish concealment types except algae and aquatic macrophytes |
| XFC_BIG | | Sum of cover from large wood, brush, overhanging banks and human structures |
| XFC_NAT | | Sum of cover from large wood, boulders, overhanging vegetation, boulders and undercut banks |
| PFC_xxx | | |
| | | **Large Woody Debris Metric** |
| C1W … C5W | | LWD in active channel (pieces/reach)–size classes 1…5 |
| V1W … V5W | | LWD volume in active channel ($m^3$/reach)–size classes 1…5 |
| C1WM100 … C5WM100 | | LWD in active channel (pieces/100m)–size classes 1…5 |
| V1WM100 V5WM100 | | LWD volume in active channel ($m^3$/100m)–size classes 1…5 |
| C1W_MSQ C5W_MSQ | | LWD in active channel (pieces/$m^2$)–size classes 1…5 |
| V1W_MSQ V5W_MSQ | | LWD volume in active channel ($m^3$/$m^2$)–size classes 1…5 |

**Table I-1. Definition of Physical Habitat Metrics Used for Data Analysis (Page 7 of 8)**

| Metric Variable Name | Units | Metric Description |
|---|---|---|
| C1T … C5T | | LWD in and above active channel (pieces/reach)–size classes 1…5 |
| V1T … V5T | | LWD volume in and above active channel ($m^3$/reach)–size classes 1…5 |
| C1TM100 C5TM100 | | LWD in and above active channel (pieces/100m)–size classes 1…5 |
| V1TM100 V5TM100 | | LWD volume in and above active channel ($m^3$/100m)–size classes 1…5 |
| **Riparian Cover Metrics** | | |
| XCDENBK | % | Mean % canopy density at bank |
| XCDENMID | % | Mean % canopy density midstream |
| **Human Disturbance Metrics** | | |
| W1H_BLDG | | Riparian human disturbance–Buildings (proximity-weighted index) |
| W1H_WALL | | Riparian human disturbance–Channel revetment (proximity-weighted index) |
| W1H_PVMT | | Riparian human disturbance–Pavement (proximity-weighted index) |
| W1H_ROAD | | Riparian human disturbance–Roads (proximity-weighted index) |
| W1H_PIPE | | Riparian human disturbance–Pipes, influent and effluent (proximity-weighted index) |
| W1H_LDFL | | Riparian human disturbance–Trash and Landfill (proximity-weighted index) |
| W1H_PARK | | Riparian human disturbance–Parks and Lawns (proximity-weighted index) |
| W1H_CROP | | Riparian human disturbance–Row Crop Agriculture (proximity-weighted index) |
| W1H_PSTR | | Riparian human disturbance–Pasture and Grass fields (proximity-weighted index) |

**Table I-1. Definition of Physical Habitat Metrics Used for Data Analysis (Page 8 of 8)**

| Metric Variable Name | Units | Metric Description |
|---|---|---|
| W1H_LOG | | Riparian human disturbance–Logging (proximity-weighted index) |
| W1H_MINE | | Riparian human disturbance–Mining (proximity-weighted index) |
| W1_HALL | | Riparian human disturbance index–All types (proximity-weighted sum) |
| W1_HNOAG | | Riparian human disturbance index–Nonagricultural types (proximity-weighted sum) |
| W1_HAG | | Riparian human disturbance index–Agricultural types (proximity-weighted sum) |

* EMAP Metric - substrate did not distinquish between sand and fines

** Metric not included in or modified from EMAP procedure

## Table I-2. Physical Habitat Metric Values at Sampled White River Sites (Page 1 of 9)

| Metric Variable Name | Oacoma | Westover | Black Pipe | Kadoka | Bear in the Lodge | Rockyford | Oglala | State-Line | Whitney | Crawford |
|---|---|---|---|---|---|---|---|---|---|---|
| **Identification Variables** | | | | | | | | | | |
| STREAM_ID | 6452000 | 6451500 | 6447230 | 6447000 | 6446700 | 6446200 | 6446000 | 6445685 | 6445000 | 6444000 |
| YEAR | 2004 | 2004 | 2004 | 2004 | 1900 | 2004 | 2004 | 2004 | 2004 | 2004 |
| **Stream Classification** | | | | | | | | | | |
| ROSGEN | F5 | F5 | C4 | F5 | G5c | F5 | G6c | G5c | G6c | G4 |
| CEM | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 4 |
| **Channel Morphology Metrics** | | | | | | | | | | |
| REACHLEN | 5,216 | 4,656 | 9,70 | 2,194 | 618 | 2,333.2 | 848 | 886 | 500 | 580 |
| XDEPTH | 3.80 | 2.26 | 0.59 | 1.10 | 1.68 | 1.20 | 3.80 | 2.62 | 3.27 | 3.33 |
| SDDEPTH | 1.01 | 1.10 | 0.13 | 0.24 | 0.68 | 0.31 | 2.71 | 0.73 | 0.60 | 1.05 |
| XWIDTH | 210.64 | 167.09 | 27.18 | 108.08 | 17.43 | 68.09 | 22.72 | 25.13 | 13.41 | 16.18 |
| SDWIDTH | 39.45 | 44.40 | 5.66 | 44.36 | 3.46 | 12.20 | 75.27 | 5.18 | 1.89 | 3.12 |
| XWXD | 800.61 | 377.09 | 16.06 | 119.04 | 29.20 | 81.45 | 216.30 | 65.81 | 43.81 | 53.85 |
| SDWXD | 39.91 | 48.73 | 0.71 | 10.43 | 2.34 | 3.81 | 204.19 | 3.79 | 1.13 | 3.27 |
| XWD_RAT | 55.42 | 74.04 | 46.01 | 98.13 | 10.40 | 56.93 | 14.98 | 9.59 | 4.10 | 4.86 |
| SDWD_RAT | 39.00 | 40.45 | 45.13 | 188.76 | 5.10 | 39.03 | 27.75 | 7.08 | 3.17 | 2.98 |
| PCT-FA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_CA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_RA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

## Table I-2. Physical Habitat Metric Values at Sampled White River Sites (Page 2 of 9)

| Metric Variable Name | Oacoma | Westover | Black Pipe | Kadoka | Bear in the Lodge | Rockyford | Oglala | State-Line | Whitney | Crawford |
|---|---|---|---|---|---|---|---|---|---|---|
| PCT_RI | 24% | 38% | 7% | 4% | 9% | 36% | 0% | 14% | 0% | 8% |
| PCT_GL | 75% | 57% | 93% | 96% | 78% | 54% | 100% | 76% | 79% | 30% |
| PCT_PD | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 29% |
| PCT_PP | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% |
| PCT_PL | 0% | 5% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 12% |
| PCT_PT | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_PB | 0% | 0% | 0% | 0% | 9% | 0% | 0% | 9% | 0% | 7% |
| PCT_P | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_DR | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_SB | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_DRS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_FAST | 24% | 38% | 7% | 4% | 9% | 36% | 0% | 14% | 0% | 8% |
| PCT_SLOW | 75% | 62% | 93% | 96% | 87% | 54% | 100% | 85% | 79% | 81% |
| PCT_POOL | 0% | 5% | 0% | 0% | 9% | 0% | 0% | 9% | 0% | 51% |
| **Channel Cross-Section and Bank Morphology Metrics** | | | | | | | | | | |
| XBKA | 36.33 | 29.82 | 23.95 | 28.20 | 66.05 | 20.59 | 64.68 | 71.14 | 70.09 | 39.07 |
| XUN | 0.18 | 0.47 | 0.00 | 0.00 | 0.39 | 0.00 | 0.29 | 0.29 | 0.58 | 0.37 |
| MEDBKUN | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.20 |
| XBKF_W | 254.05 | 296.73 | 49.17 | 162.38 | 20.00 | 118.41 | 24.62 | 27.82 | 14.53 | 20.02 |

## Table I-2. Physical Habitat Metric Values at Sampled White River Sites (Page 3 of 9)

| Metric Variable Name | Oacoma | Westover | Black Pipe | Kadoka | Bear in the Lodge | Rockyford | Oglala | State-Line | Whitney | Crawford |
|---|---|---|---|---|---|---|---|---|---|---|
| XBKF_H | 1.95 | 1.82 | 2.06 | 2.09 | 1.23 | 3.24 | 2.00 | 2.18 | 0.82 | 1.74 |
| XINC_H | 6.39 | 6.82 | 19.85 | 7.69 | 4.77 | 6.17 | 8.27 | 6.41 | 5.34 | 4.66 |
| Slumpage | 55% | 73% | 64% | 50% | 95% | 36% | 95% | 86% | 86% | 36% |
| Bank_length | 55.57 | 59.26 | 26.65 | 18.40 | 5.76 | 24.14 | 14.14 | 14.36 | 8.62 | 11.14 |
| Vegetated | 10.84 | 24.80 | 5.81 | 0.77 | 1.16 | 3.57 | 9.45 | 4.17 | 6.02 | 9.64 |
| Eroded | 5.48 | 8.18 | 4.11 | 8.82 | 4.45 | 4.63 | 4.90 | 4.26 | 2.56 | 0.73 |
| Deposited | 37.50 | 38.59 | 9.55 | 5.64 | 0.77 | 12.70 | 0.73 | 0.28 | 0.00 | 0.86 |
| **Channel Sinuosity and Slope Metrics** | | | | | | | | | | |
| SINU | 1.09 | 2.06 | 1.09 | 1.02 | 1.93 | 1.16 | 1.49 | 1.38 | 1.14 | 1.11 |
| XSLOPE | 0.06% | 0.08% | 0.12% | 0.08% | 0.39% | 0.10% | 0.03% | 0.04% | 0.13% | 0.19% |
| XBEARING | 133 | 119 | 237 | 86 | 343 | 75 | 47 | 330 | 25 | 10 |
| VSLOPE | 2.41E-04 | 1.32E-04 | 8.29E-02 | 1.18E-04 | 4.00E-03 | 1.57E-03 | 2.62E-04 | 6.52E-05 | 1.45E-02 | 2.46E-03 |
| **Residual Pool Metrics** | | | | | | | | | | |
| PCTRSED | 84% | 86% | 88% | 77% | 42% | 38% | 80% | 35% | 100% | 74% |
| **Substrate Size and Composition Metrics** | | | | | | | | | | |
| SUB_X | 2.03 | 2.03 | 2.50 | 2.37 | 2.48 | 2.33 | 2.07 | 2.31 | 1.90 | 2.95 |
| SUB_V | 0.17 | 0.16 | 0.67 | 0.48 | 0.61 | 0.46 | 0.31 | 0.63 | 0.30 | 1.03 |
| SUB_Q3 | 2.00 | 2.00 | 2.50 | 2.50 | 2.50 | 2.50 | 2.00 | 2.50 | 2.00 | 3.63 |
| SUB_MED | 2.00 | 2.00 | 2.50 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.50 |

## Table I-2. Physical Habitat Metric Values at Sampled White River Sites (Page 4 of 9)

| Metric Variable Name | Oacoma | Westover | Black Pipe | Kadoka | Bear in the Lodge | Rockyford | Oglala | State-Line | Whitney | Crawford |
|---|---|---|---|---|---|---|---|---|---|---|
| SUB_Q1 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| SUB_IQR | 0.00 | 0.00 | 0.50 | 0.50 | 0.50 | 0.50 | 0.00 | 0.50 | 0.00 | 1.63 |
| LSUB_DMM | 0.60 | 0.58 | 6.17 | 3.15 | 5.45 | 2.65 | 0.74 | 2.40 | 0.31 | 11.27 |
| SUB_X1 | 1.82 | 1.27 | 12.91 | 6.76 | 9.24 | 6.26 | 2.12 | 6.28 | 0.95 | 51.34 |
| SUB_V1 | 5.62 | 1.93 | 60.20 | 8.12 | 12.45 | 8.70 | 5.33 | 12.45 | 0.15 | 79.85 |
| SUB_Q3_1 | 1.00 | 1.00 | 9.50 | 13.50 | 13.50 | 9.50 | 1.00 | 4.10 | 1.00 | 60.13 |
| SUB_MED1 | 1.00 | 1.00 | 6.80 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 9.50 |
| SUB_Q1_1 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| SUB_IQR1 | 0.00 | 0.00 | 8.50 | 12.50 | 12.50 | 8.50 | 0.00 | 3.10 | 0.00 | 59.13 |
| XEMBED | 99% | 100% | 91% | 84% | 99% | 92% | 92% | 91% | 100% | 1 |
| VEMBED | 3% | 0% | 29% | 37% | 2% | 23% | 26% | 19% | 0% | 0 |
| XCEMBED | 99% | 100% | 91% | 85% | 99% | 87% | 90% | 89% | 100% | 1 |
| VCEMBED | 4% | 0% | 29% | 36% | 2% | 29% | 29% | 17% | 0% | 0 |
| PCT_RS | 0% | 0% | 2% | 0% | 0% | 0% | 0% | 1% | 0% | 0% |
| PCT_RR | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_BDRK | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_BL | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 17% |
| PCT_CB | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 17% |
| PCT_GC | 1% | 1% | 6% | 12% | 22% | 10% | 4% | 13% | 0% | 24% |

## Table I-2. Physical Habitat Metric Values at Sampled White River Sites (Page 5 of 9)

| Metric Variable Name | Oacoma | Westover | Black Pipe | Kadoka | Bear in the Lodge | Rockyford | Oglala | State-Line | Whitney | Crawford |
|---|---|---|---|---|---|---|---|---|---|---|
| PCT_BIGR | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 17% |
| PCT_GF | 3% | 2% | 60% | 37% | 25% | 36% | 2% | 15% | 0% | 2% |
| PCT_SFGF | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 17% |
| PCT_SA | 96% | 97% | 31% | 51% | 52% | 54% | 89% | 71% | 90% | 49% |
| PCT_SAFN | 96% | 97% | 31% | 51% | 52% | 54% | 89% | 71% | 90% | 49% |
| PCT_OM | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_WD | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_ORG | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_RC | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_HP | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| PCT_OT | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Bed Substrate Stability Metrics** | | | | | | | | | | |
| LTEST | 0.67 | 0.58 | 0.18 | 0.25 | 1.13 | 0.38 | 0.36 | 0.31 | 1.70 | 1.12 |
| LDMB_BW4 | 0.85 | 0.84 | 0.83 | 0.72 | 1.37 | 0.95 | 0.54 | 0.58 | 1.80 | 1.30 |
| | | | | | | | | | | |
| $R_{bf}$ | 876.44 | 620.79 | 403.83 | 485.98 | 443.04 | 676.75 | 883.95 | 731.66 | 623.04 | 772.24 |
| $R_w$ | 0.03 | 0.00 | 0.00 | 0.00 | 4.01 | 0.00 | 7.40 | 0.00 | 4.55 | 0.40 |
| $R_p$ | | | | | | | | | | |
| S | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |

## Table I-2. Physical Habitat Metric Values at Sampled White River Sites (Page 6 of 9)

| Metric Variable Name | Oacoma | Westover | Black Pipe | Kadoka | Bear in the Lodge | Rockyford | Oglala | State-Line | Whitney | Crawford |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| LRBS_TST | | | | | | | | | | |
| | –0.08 | 0.00 | 5.99 | 2.90 | 4.31 | 2.27 | 0.38 | 2.08 | –1.39 | 10.15 |
| LRBS_BW4 | | | | | | | | | | |
| **Bed Material Samples** | | | | | | | | | | |
| BM_SA | 13% | 14% | 28% | 27% | 5% | 7% | 8% | 27% | 9% | 4% |
| BM_FN | 81% | 77% | 50% | 51% | 37% | 18% | 77% | 38% | 80% | 85% |
| BM_SAFN | 93% | 92% | 78% | 78% | 42% | 25% | 85% | 65% | 90% | 89% |
| BM_GR | 7% | 8% | 22% | 22% | 58% | 75% | 15% | 35% | 10% | 11% |
| **Riparian Vegetation Cover Metrics** | | | | | | | | | | |
| XCL | 1.00 | 1.00 | 1.09 | 1.00 | 1.27 | 0.55 | 1.27 | 1.00 | 1.32 | 1.55 |
| XCS | 0.95 | 0.95 | 0.14 | 0.55 | 2.45 | 0.05 | 1.77 | 1.55 | 1.55 | 1.23 |
| XC | 1.95 | 1.95 | 1.23 | 1.55 | 3.73 | 0.59 | 3.05 | 2.55 | 2.86 | 2.77 |
| XMW | 1.36 | 1.36 | 0.09 | 0.68 | 2.27 | 0.18 | 2.64 | 1.68 | 1.95 | 1.59 |
| XMH | 1.00 | 1.00 | 0.00 | 0.36 | 0.45 | 0.00 | 0.73 | 0.09 | 1.18 | 1.36 |
| XM | 2.36 | 2.36 | 0.09 | 1.05 | 2.73 | 0.18 | 3.36 | 1.77 | 3.14 | 2.95 |
| XGW | 1.32 | 1.32 | 0.05 | 0.73 | 1.50 | 0.00 | 1.86 | 1.36 | 2.09 | 1.64 |
| XGH | 2.00 | 2.00 | 3.68 | 2.95 | 3.32 | 3.00 | 2.55 | 3.64 | 2.14 | 2.23 |
| XG | 3.32 | 3.32 | 3.73 | 3.68 | 4.82 | 3.00 | 4.41 | 5.00 | 4.23 | 3.86 |

## Table I-2. Physical Habitat Metric Values at Sampled White River Sites (Page 7 of 9)

| Metric Variable Name | Oacoma | Westover | Black Pipe | Kadoka | Bear in the Lodge | Rockyford | Oglala | State-Line | Whitney | Crawford |
|---|---|---|---|---|---|---|---|---|---|---|
| XGB | 1.77 | 1.77 | 1.09 | 2.09 | 1.36 | 2.00 | 0.77 | 0.64 | 1.18 | 1.00 |
| **Fish Cover Metrics** | | | | | | | | | | |
| XFC_ALG | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.73 |
| XFC_AQM | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.27 |
| XFC_LWD | 0.00 | 0.27 | 0.00 | 0.00 | 0.82 | 0.00 | 0.50 | 0.00 | 1.18 | 0.36 |
| XFC_BRS | 0.09 | 0.91 | 0.00 | 0.18 | 1.36 | 0.00 | 1.36 | 1.09 | 1.00 | 0.73 |
| XFC_OHV | 0.09 | 0.09 | 0.00 | 0.00 | 1.45 | 0.00 | 0.30 | 1.18 | 2.00 | 0.73 |
| XFC_RCK | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 |
| XFC_UCB | 0.36 | 0.27 | 0.00 | 0.00 | 1.82 | 0.00 | 0.60 | 0.64 | 1.20 | 1.73 |
| XFC_HUM | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.73 |
| XFC_ALL | 0.55 | 1.55 | 0.00 | 0.27 | 5.45 | 0.00 | 2.76 | 2.91 | 5.38 | 5.18 |
| XFC_BIG | 0.18 | 1.27 | 0.00 | 0.27 | 3.64 | 0.00 | 2.16 | 2.27 | 4.18 | 2.55 |
| XFC_NAT | 0.45 | 0.64 | 0.00 | 0.00 | 4.09 | 0.00 | 1.40 | 1.82 | 4.38 | 3.73 |
| **Large Woody Debris Metric** | | | | | | | | | | |
| C1W … C5W | 10.00 | | 0.00 | 0.00 | 41.00 | 0.00 | 13.00 | 0.00 | 24.00 | 16.00 |
| V1W … V5W | 3.29 | | 0.00 | 0.00 | 4.61 | 0.00 | 14.35 | 0.00 | 3.07 | 0.43 |
| C1WM100 … C5WM100 | 0.63 | | 0.00 | 0.00 | 21.77 | 0.00 | 5.03 | 0.00 | 15.75 | 9.05 |
| V1WM100 … V5WM100 | 0.21 | | 0.00 | 0.00 | 2.44 | 0.00 | 5.55 | 0.00 | 2.01 | 0.24 |
| C1W_MSQ … C5W_MSQ | 0.00 | | 0.00 | 0.00 | 0.04 | 0.00 | 0.01 | 0.00 | 0.04 | 0.01 |

## Table I-2. Physical Habitat Metric Values at Sampled White River Sites (Page 8 of 9)

| Metric Variable Name | Oacoma | Westover | Black Pipe | Kadoka | Bear in the Lodge | Rockyford | Oglala | State-Line | Whitney | Crawford |
|---|---|---|---|---|---|---|---|---|---|---|
| V1W_MSQ<br>V5W_MSQ | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| C1T … C5T | 10.00 | | 0.00 | 0.00 | 58.00 | 0.00 | 14.00 | 0.00 | 29.00 | 16.00 |
| V1T … V5T | 3.29 | | 0.00 | 0.00 | 5.71 | 0.00 | 14.35 | 0.00 | 3.30 | 0.43 |
| C1TM100 … C5TM100 | 0.63 | | 0.00 | 0.00 | 30.79 | 0.00 | 5.42 | 0.00 | 19.03 | 9.05 |
| V1TM100 … V5TM100 | 0.21 | | 0.00 | 0.00 | 3.03 | 0.00 | 5.55 | 0.00 | 2.17 | 0.24 |
| **Riparian Cover Metrics** | | | | | | | | | | |
| XCDENBK | 21.39 | 31.28 | 23.80 | 4.01 | 90.00 | 1.34 | 92.25 | 94.12 | 90.76 | 72.76 |
| XCDENMID | 0.00 | 0.00 | 1.74 | 0.13 | 76.91 | 0.00 | 34.76 | 39.57 | 72.19 | 44.71 |
| **Human Disturbance Metrics** | | | | | | | | | | |
| W1H_BLDG | 0.07 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| W1H_WALL | 0.07 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| W1H_PVMT | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| W1H_ROAD | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 |
| W1H_PIPE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| W1H_LDFL | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| W1H_PARK | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 |
| W1H_CROP | 0.12 | 0.03 | 0.00 | 0.03 | 0.14 | 0.00 | 0.00 | 0.00 | 0.30 | 0.00 |
| W1H_PSTR | 1.50 | 1.30 | 1.50 | 1.48 | 1.36 | 1.50 | 1.23 | 1.36 | 0.38 | 0.03 |
| W1H_LOG | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table I-2. Physical Habitat Metric Values at Sampled White River Sites (Page 9 of 9)**

| Metric Variable Name | Oacoma | Westover | Black Pipe | Kadoka | Bear in the Lodge | Rockyford | Oglala | State-Line | Whitney | Crawford |
|---|---|---|---|---|---|---|---|---|---|---|
| W1H_MINE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| W1_HALL | 1.76 | 1.75 | 1.50 | 1.51 | 1.50 | 1.50 | 1.23 | 1.36 | 0.89 | 0.76 |
| W1_HNOAG | 0.14 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.73 |
| W1_HAG | 1.62 | 1.33 | 1.50 | 1.51 | 1.50 | 1.50 | 1.23 | 1.36 | 0.68 | 0.03 |

**Table I-3. Correlation Analysis Results (Page 1 of 7)**

| Dependent | vs | Independent | Correlation | $R^2$ |
|---|---|---|---|---|
| **Channel Morphology vs WQ** | | | | |
| XDEPTH | vs | FECAL MEAN | – | 95.1 |
| XDEPTH | vs | FECAL_10% | – | 90.8 |
| SDDEPTH | vs | FECAL MEAN | – | 57.4 |
| XWIDTH | vs | MEAN_Q | + | 97.4 |
| XWIDTH | vs | MEDIAN | + | 94.4 |
| XWIDTH | vs | PIBI | – | 62.4 |
| XWIDTH | vs | WRIBI | – | 66.9 |
| XWIDTH | vs | TSS_MEDIAN | + | 75.8 |
| XWIDTH | vs | TSS_MEAN | + | 80.6 |
| XWIDTH | vs | TSS_10% | + | 67.5 |
| XWIDTH | vs | DA | + | 98.9 |
| SDWIDTH | vs | BIBI | – | 55.9 |
| XWXD | vs | MEAN_Q | + | 82.8 |
| XWXD | vs | MEDIAN | + | 90.4 |
| XWXD | vs | PIBI | – | 71.2 |
| XWXD | vs | WRIBI | – | 53.4 |
| XWXD | vs | DA | + | 80.8 |
| XWD_RAT | vs | TSS_MEDIAN | + | 87.9 |
| XWD_RAT | vs | TSS_MEAN | + | 84.2 |
| XWD_RAT | vs | TSS_10% | + | 93.2 |
| XWD_RAT | vs | FECAL_MEAN | + | 58.7 |
| XWD_RAT | vs | FECAL_10% | + | 72.3 |
| PCT_GL | vs | FECAL_MEDIAN | – | 68.9 |
| **Channel Cross Section vs WQ** | | | | |
| XBKA | vs | TSS_MEDIAN | – | 56.2 |
| XBKA | vs | TSS_MEAN | – | 53.2 |
| XBKA | vs | TSS_10% | – | 56.3 |

**Table I-3. Correlation Analysis Results (Page 2 of 7)**

| Dependent | vs | Independent | Correlation | $R^2$ |
|---|---|---|---|---|
| XBKF_W | vs | MEAN_Q | + | 93 |
| XBKF_W | vs | MEDIAN | + | 85 |
| XBKF_W | vs | PIBI | – | 54.1 |
| XBKF_W | vs | WRIBI | – | 68.7 |
| XBKF_W | vs | TSS_MEDIAN | + | 89.3 |
| XBKF_W | vs | TSS_MEAN | + | 92.3 |
| XBKF_W | vs | TSS_10% | + | 82.8 |
| XBKF_W | vs | DA | + | 90.7 |
| XBKF_H | vs | LTEST | – | 58.8 |
| XINC_H | vs | MEAN(DA) | + | 60 |
| XINC_H | vs | BIBI | – | 69.3 |
| **Channel Sinuosity & Slope vs WQ** | | | | |
| SINU | vs | FECAL_MEAN | - | 51.1 |
| XSLOPE | vs | FECAL_MEDIAN | + | 52 |
| **Substrate vs WQ** | | | | |
| SUB_X | vs | MEDIAN(DA) | + | 71.5 |
| SUB_X | vs | BIBI | + | 64.9 |
| SUB_X | vs | FECAL_MEDIAN | + | 96.1 |
| LSUB_DMM | vs | MEDIAN(DA) | + | 85.2 |
| LSUB_DMM | vs | BIBI | + | 78.8 |
| LSUB_DMM | vs | FECAL_MEDIAN | + | 95.6 |
| LSUB_DMM | vs | SUB_X | + | 94.4 |
| PCT_GC | vs | MEDIAN(DA) | + | 60.2 |
| PCT_GC | vs | BIBI | + | 61.8 |
| PCT_GC | vs | FECAL_MEDIAN | + | 92 |
| PCT_GC | vs | SUB_X | + | 76.1 |
| PCT_GF | vs | MEAN(DA) | + | 51.4 |

**Table I-3. Correlation Analysis Results (Page 3 of 7)**

| Dependent | vs | Independent | Correlation | $R^2$ |
|---|---|---|---|---|
| PCT_GF | vs | TSS_10% | + | 54 |
| PCT_GF | vs | FECAL_MEAN | + | 86.1 |
| PCT_GF | vs | FECAL_10% | + | 89 |
| PCT_SA | vs | MEAN(DA) | – | 52.4 |
| PCT_SA | vs | FECAL_MEDIAN | – | 67.3 |
| PCT_SA | vs | SUB_X | – | 65.4 |
| PCT_SAFN | vs | MEAN(DA) | – | 52.4 |
| PCT_SAFN | vs | FECAL_MEDIAN | – | 67.3 |
| PCT_SAFN | vs | SUB_X | – | 65.4 |
| **DENR Bank Characteristics vs WQ** | | | | |
| SLUMPAGE | vs | FECAL_MEDIAN | – | 72.7 |
| BANK_LENGTH | vs | MEAN_Q | + | 77 |
| BANK_LENGTH | vs | MEDIAN | + | 76.8 |
| BANK_LENGTH | vs | PIBI | – | 60.2 |
| BANK_LENGTH | vs | WRIBI | – | 82.7 |
| BANK_LENGTH | vs | TSS_MEDIAN | + | 50.8 |
| BANK_LENGTH | vs | TSS_MEAN | + | 56.2 |
| BANK_LENGTH | vs | DA | + | 78.8 |
| ERODED | vs | BIBI | – | 65.8 |
| ERODED | vs | TSS_MEDIAN | + | 67.6 |
| ERODED | vs | TSS_MEAN | + | 65.6 |
| **Channel Metrics vs Riparian Characteristics** | | | | |
| XDEPTH | vs | XMW | + | 53 |

**Table I-3. Correlation Analysis Results (Page 4 of 7)**

| Dependent | vs | Independent | Correlation | $R^2$ |
|---|---|---|---|---|
| XDEPTH | vs | XMH | + | 55.6 |
| XDEPTH | vs | XGW | + | 67.6 |
| SDDEPTH | vs | XMW | – | 52.1 |
| XWD_RAT | vs | XC | – | 51.8 |
| XWD_RAT | vs | XWB | + | 68.7 |
| XBKA | vs | XCS | + | 77.8 |
| XBKA | vs | XC | + | 71.5 |
| XBKA | vs | XMW | + | 72.4 |
| XBKA | vs | XGW | + | 60 |
| XBKA | vs | XG | + | 79.6 |
| XBKF_W | vs | XWB | + | 53 |
| XBKF_H | vs | XCL | – | 61 |
| XBKF_H | vs | XC | – | 57.7 |
| XBKF_H | vs | XGW | – | 55.1 |
| PCT_GF | vs | XMW | – | 55.6 |
| PCT_GF | vs | XMH | – | 67.4 |
| PCT_GF | vs | XM | – | 77.1 |
| PCT_GF | vs | XGW | – | 75.4 |
| PCT_GF | vs | XGH | + | 60.2 |
| SLUMPAGE | vs | XCS | + | 56.8 |
| SLUMPAGE | vs | XMW | + | 51.1 |
| SLUMPAGE | vs | XG | + | 58.6 |
| **Index of Biotic Integrity vs WQ** | | | | |
| PIBI | vs | Mean_q | – | 74.7 |
| PIBI | vs | median | – | 82.6 |
| PIBI | vs | DA | – | 61.6 |
| PIBI | vs | XWIDTH | – | 62.4 |

**Table I-3. Correlation Analysis Results (Page 5 of 7)**

| Dependent | vs | Independent | Correlation | $R^2$ |
|---|---|---|---|---|
| PIBI | vs | XWXD | – | 71.2 |
| PIBI | vs | XBKF-W | – | 54.1 |
| PIBI | vs | BANK LENGTH | – | 60.2 |
| PIBI | vs | XFC_BRS | + | 53.7 |
| BIBI | vs | MEDIAN(DA) | + | 80.5 |
| BIBI | vs | Fecal MEDIAN | + | 63.7 |
| BIBI | vs | SUB_X | – | 64.9 |
| BIBI | vs | XINC_H | – | 69.3 |
| BIBI | vs | PCT_GC | – | 61.8 |
| BIBI | vs | LSUB_DMM | – | 78.8 |
| BIBI | vs | ERODED | – | 65.8 |
| BIBI | vs | XCL | + | 64.7 |
| BIBI | vs | XFC_UCB | + | 79.2 |
| BIBI | vs | XFC_HUM | + | 60.9 |
| BIBI | vs | XFC_ALL | + | 63.6 |
| BIBI | vs | XFC_NAT | + | 62.4 |
| WRIBI | vs | MEAN_Q | – | 64.3 |
| WRIBI | vs | MEDIAN | – | 57.1 |
| WRIBI | vs | TSS_MEDIAN | – | 71.3 |
| WRIBI | vs | TSS MEAN | – | 76.3 |
| WRIBI | vs | DA | – | 61.4 |
| WRIBI | vs | XWIDTH | – | 66.9 |
| WRIBI | vs | XWXD | – | 53.4 |
| WRIBI | vs | XBKF_W | – | 68.7 |
| WRIBI | vs | BANK_LENGTH | + | 82.7 |
| WRIBI | vs | XCL | – | 60.2 |
| WRIBI | vs | XC | – | 50.7 |

**Table I-3. Correlation Analysis Results (Page 6 of 7)**

| Dependent | vs | Independent | Correlation | $R^2$ |
|---|---|---|---|---|
| WRIBI | vs | XFC_BRS | P | 53.2 |
| WRIBI | vs | XFC_UCB | P | 63.3 |
| WRIBI | vs | XFC_ALL | P | 75.6 |
| WRIBI | vs | XFC_BIG | P | 66.2 |
| WRIBI | vs | XFC_NAT | P | 66.4 |
| **Riparian Characteristics vs WQ** | | | | |
| XCL | vs | WRIBI | + | 60.2 |
| XCL | vs | TSS_MEDIAN | – | 82.8 |
| XCL | vs | TSS MEAN | – | 84.3 |
| XCL | vs | BIBI | + | 64.7 |
| XCL | vs | TSS_10% | – | 82.5 |
| XCS | vs | TSS_MEDIAN | – | 72.8 |
| XCS | vs | TSS MEAN | – | 68.5 |
| XCS | vs | TSS_10% | – | 76.4 |
| XCS | vs | FECAL MEAN | – | 70.9 |
| XCS | vs | FECAL_10% | – | 61.6 |
| XC | vs | WRIBI | + | 50.7 |
| XC | vs | TSS MEDIAN | – | 91.8 |
| XC | vs | TSS MEAN | – | 88.7 |
| XC | vs | TSS_10% | – | 94.7 |
| XC | vs | FECAL MEAN | – | 58.9 |
| XC | vs | FECAL_10% | – | 65.2 |
| XMW | vs | TSS_MEDIAN | – | 58.3 |
| XMW | vs | TSS_MEDIAN | – | 53.8 |
| XMW | vs | TSS_10% | – | 62.5 |
| XMW | vs | FECAL MEAN | – | 76.8 |
| XMW | vs | FECAL_10% | – | 63.5 |

**Table I-3. Correlation Analysis Results (Page 7 of 7)**

| Dependent | vs | Independent | Correlation | $R^2$ |
|---|---|---|---|---|
| XMH | vs | FECAL_10% | – | 51.4 |
| XM | vs | TSS_MEDIAN | – | 73.1 |
| XM | vs | TSS_MEAN | – | 67.8 |
| XM | vs | TSS_10% | – | 80.4 |
| XM | vs | FECAL MEAN | – | 82.8 |
| XM | vs | FECAL_10% | – | 84.7 |
| XGW | vs | TSS_MEDIAN | – | 77.1 |
| XGW | vs | TSS MEAN | – | 72.5 |
| XGW | vs | TSS_10% | – | 81.7 |
| XGW | vs | FECAL MEAN | – | 65 |
| XGW | vs | FECAL_10% | – | 61.2 |
| XG | vs | TSS_MEDIAN | – | 65.8 |
| XG | vs | TSS MEAN | – | 66.7 |
| XG | vs | TSS_10% | – | 60 |
| XWB | vs | TSS_MEDIAN | + | 86.8 |
| XWB | vs | TSS MEAN | + | 84 |
| XWB | vs | TSS_10% | + | 90 |
| XWB | vs | FECAL MEAN | + | 58.5 |
| XWB | vs | FECAL_10% | + | 69.4 |

RSI-1465-04-077

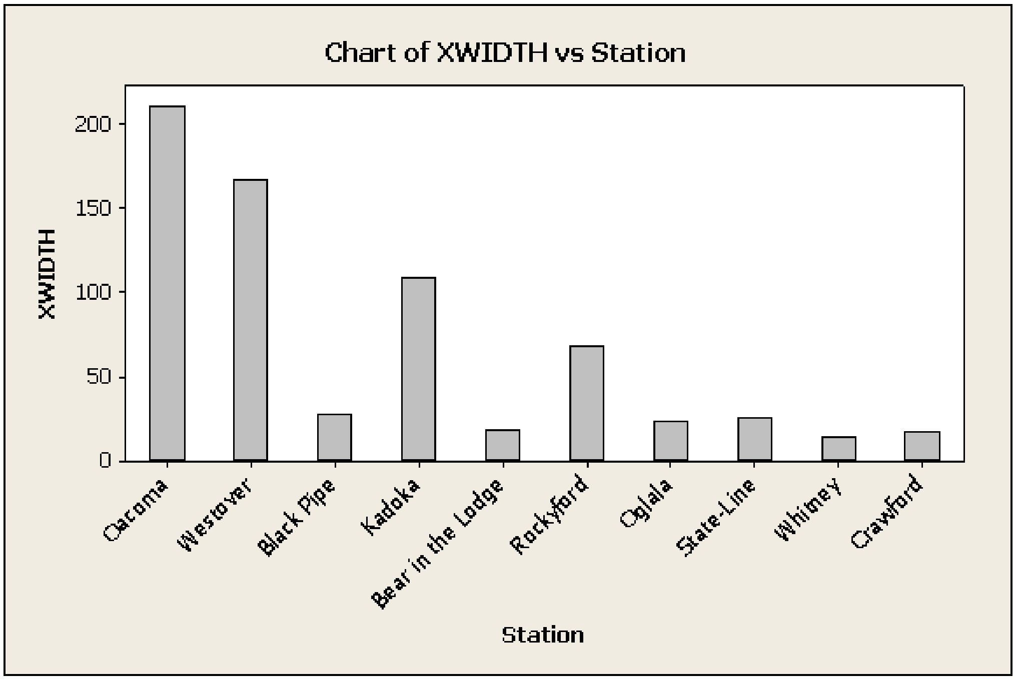



**Figure I-1.** Mean Wetted Widths by Station.

RSI-1465-04-078

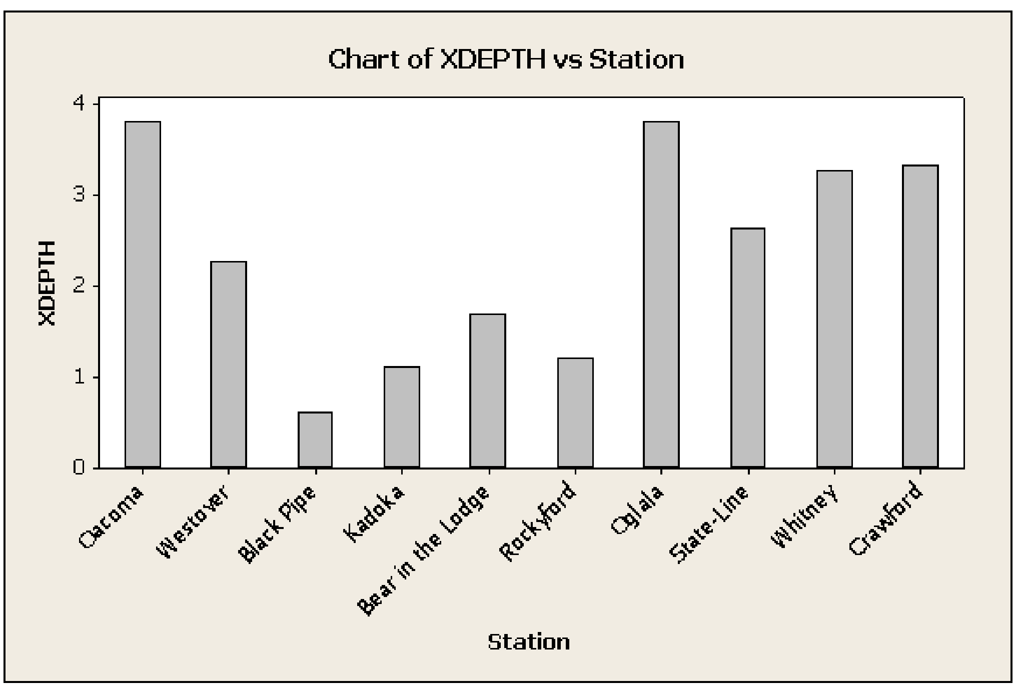



**Figure I-2.** Mean Thalweg Depth by Station.

RSI-1465-04-079

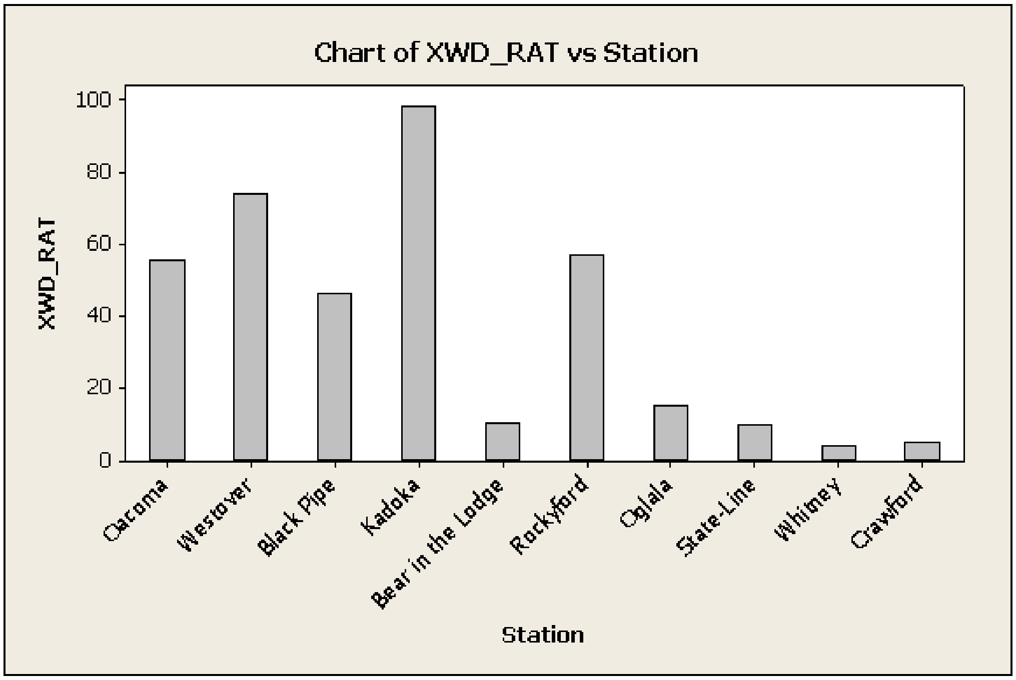



**Figure I-3.** Mean Wetted Width to Depth Ratio by Station.

RSI-1465-04-080

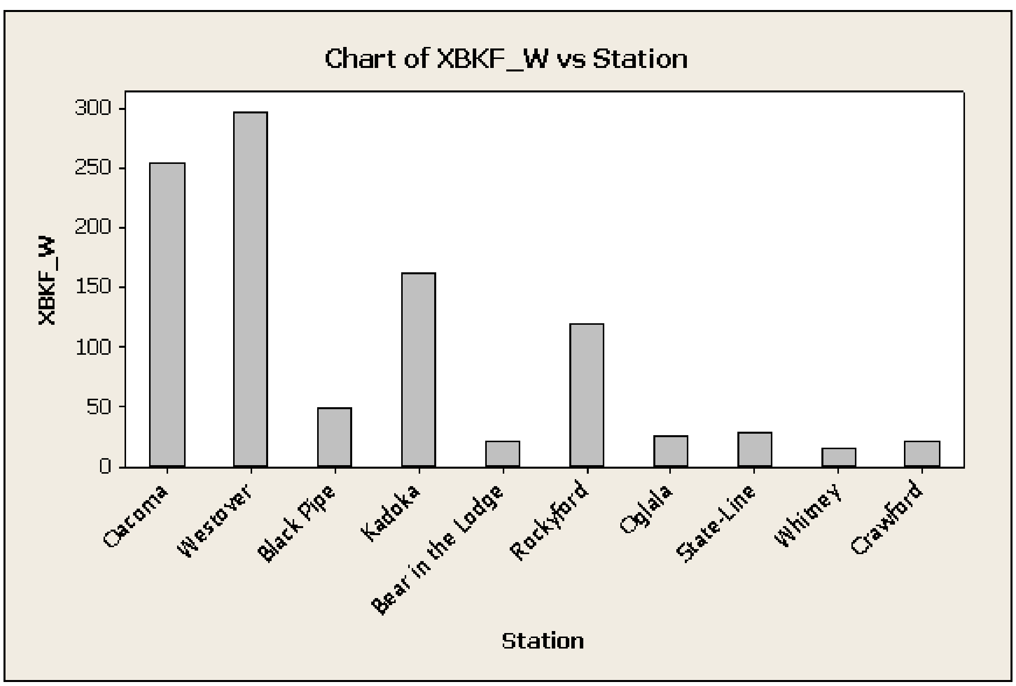



**Figure I-4.** Mean Bankfull Widths by Station.

RSI-1465-04-081

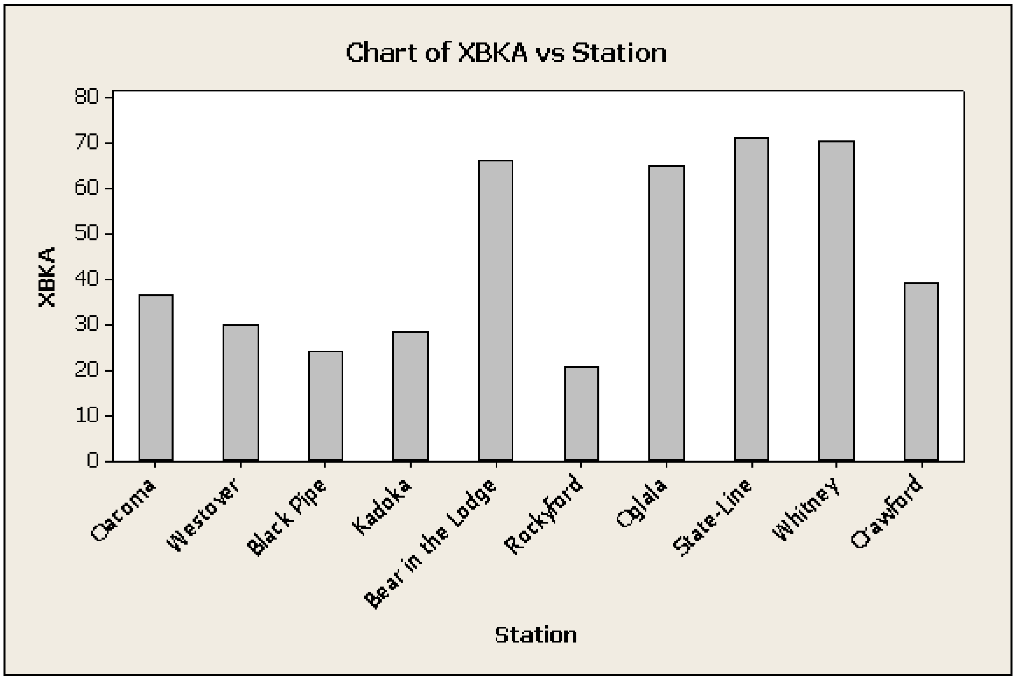



**Figure I-5.** Mean Bank Angle by Station.

RSI-1465-04-082

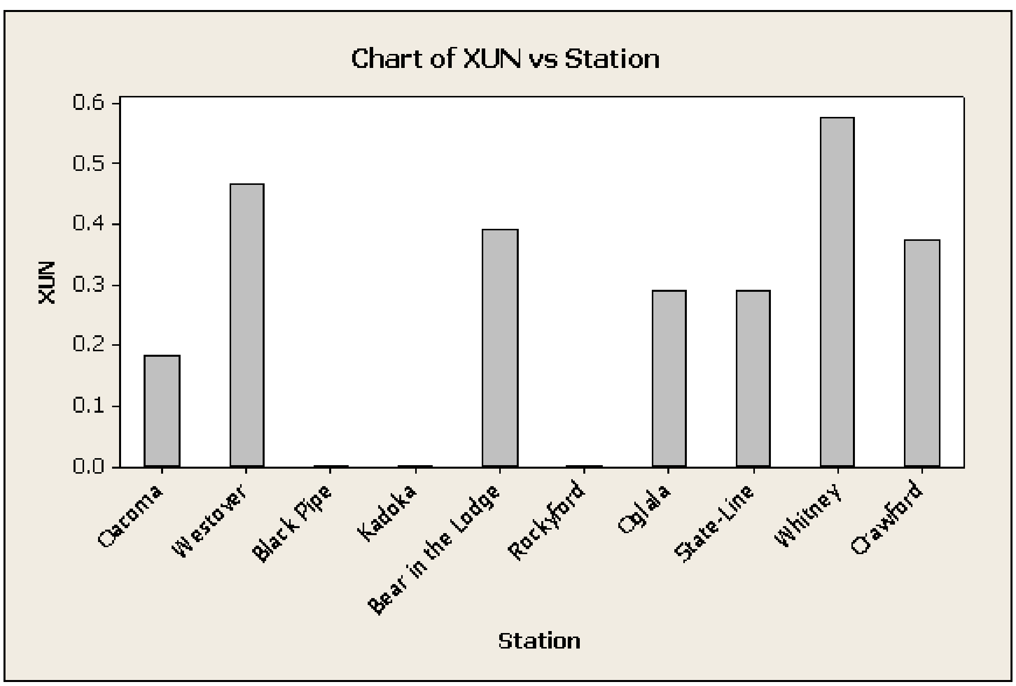



**Figure I-6.** Mean Bank Undercut Distance by Station.

RSI-1465-04-083

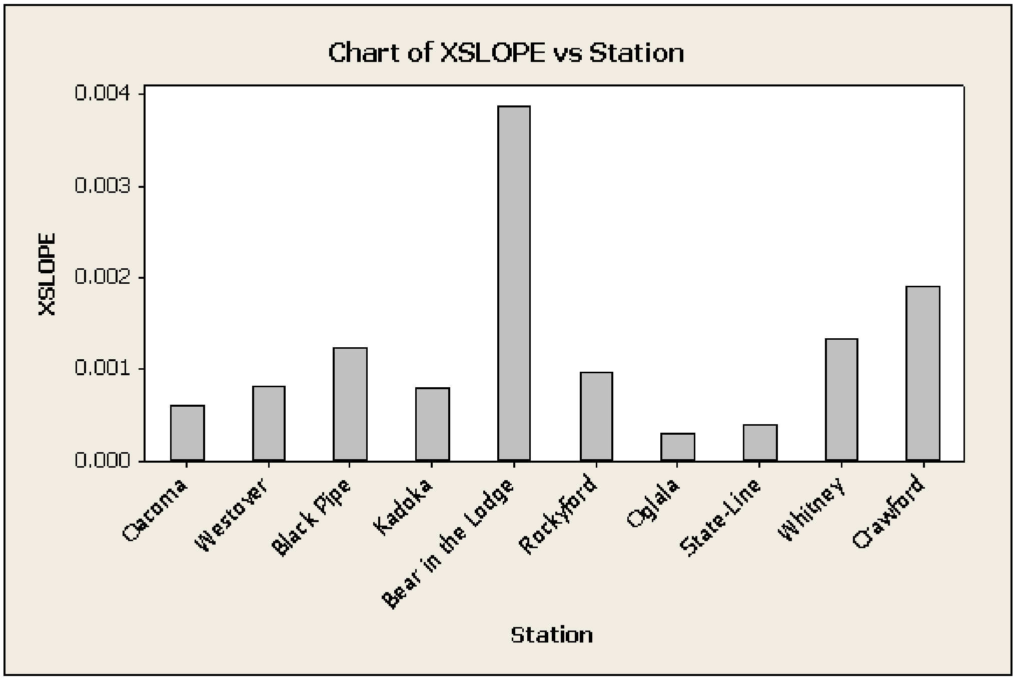



**Figure I-7.** Mean Water Surface Gradient by Station.

RSI-1465-04-084

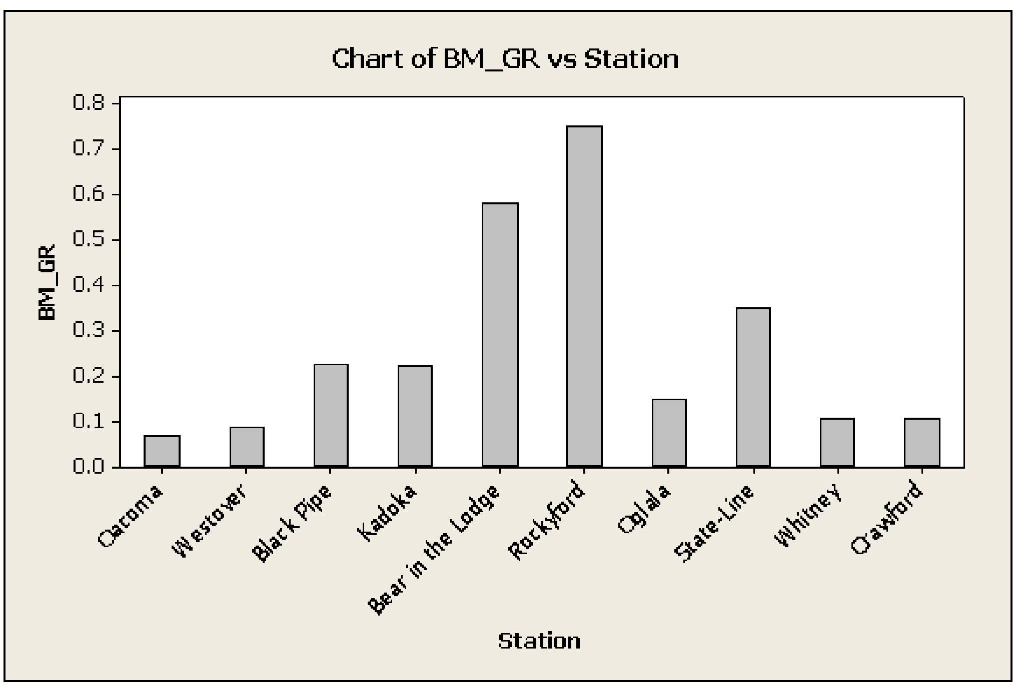



**Figure I-8.** Percent Gravel Found in the Bed Material Samples for Each Station.

RSI-1465-04-085

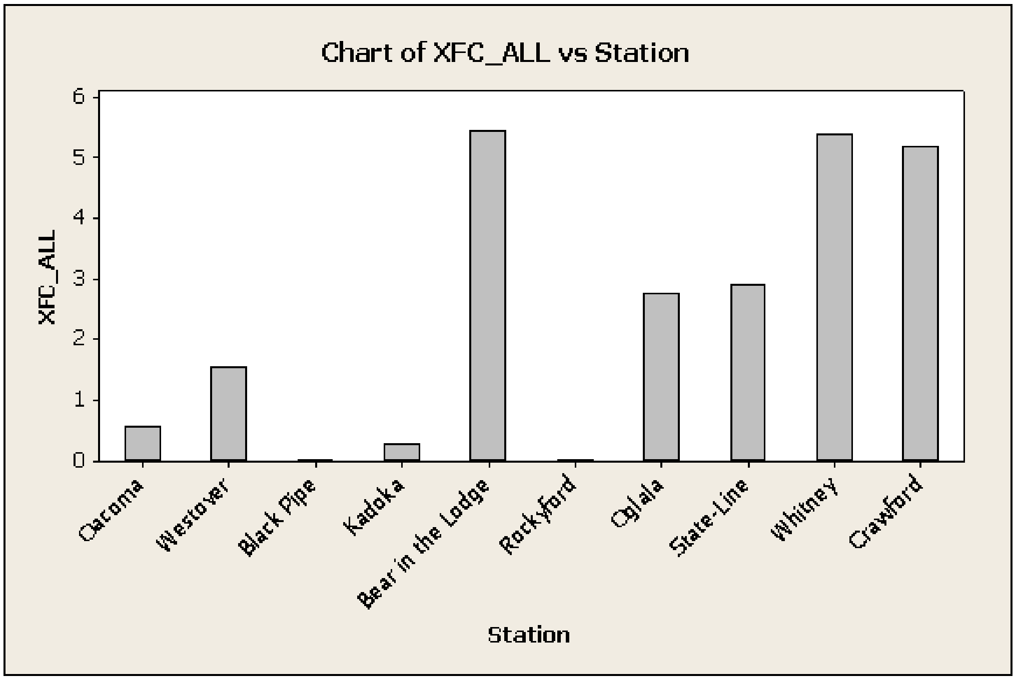



**Figure I-9.** Ranking of the Total in Stream Fish Cover at Each Station.

RSI-1465-04-086

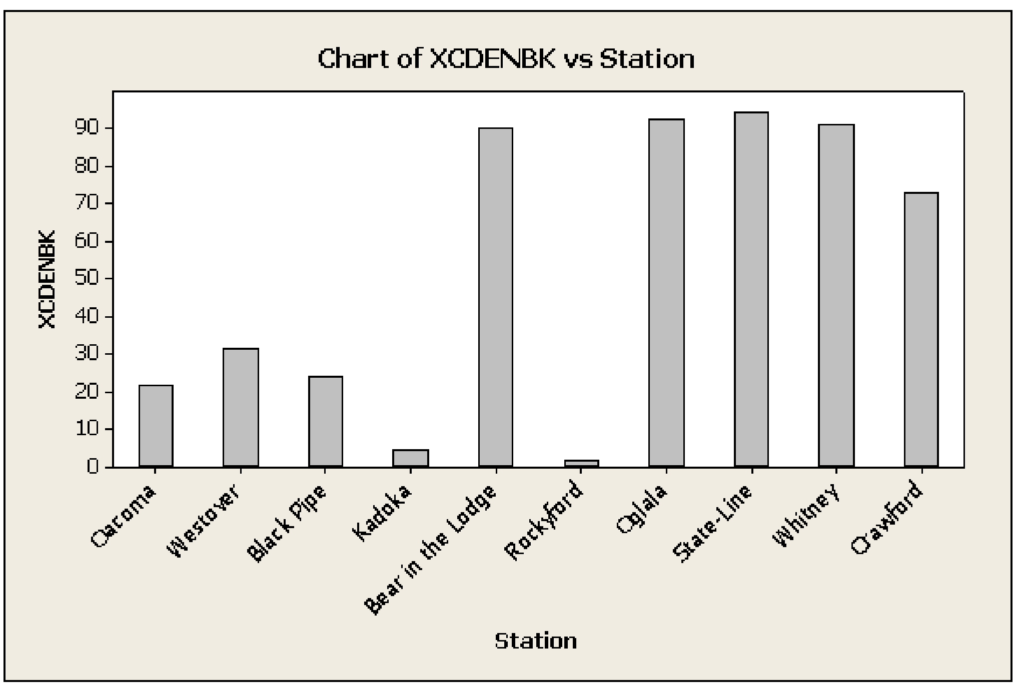



**Figure I-10.** Mean Percent Canopy Density at the Banks for Each Station.

RSI-1465-04-087

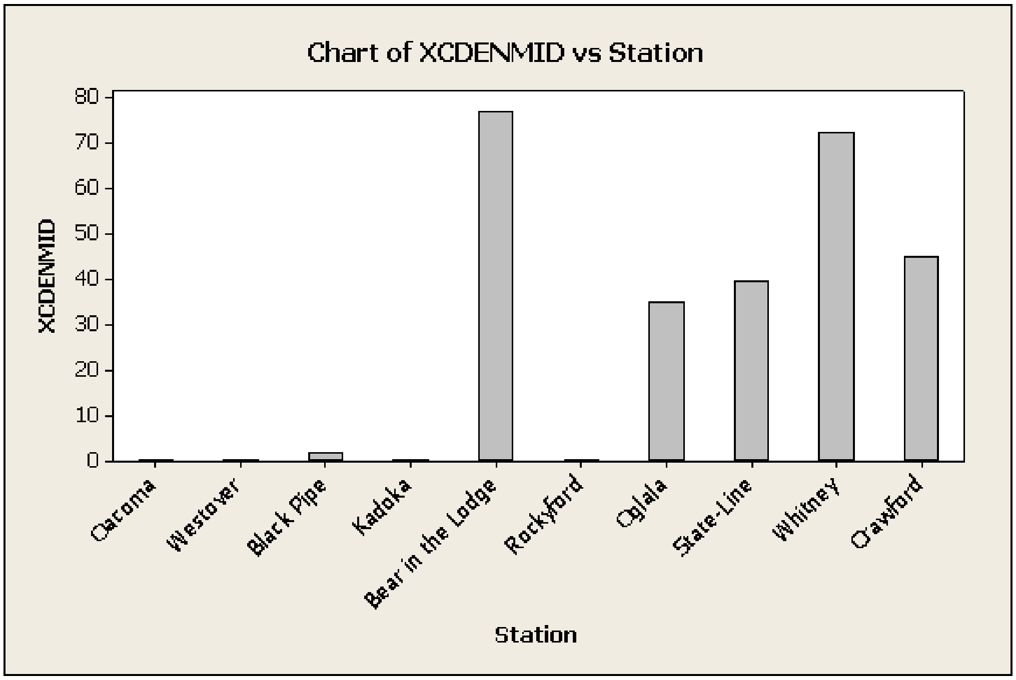



**Figure I-11.** Mean Percent Canopy Density at Mid-Channel for Each Station.

RSI-1465-04-088

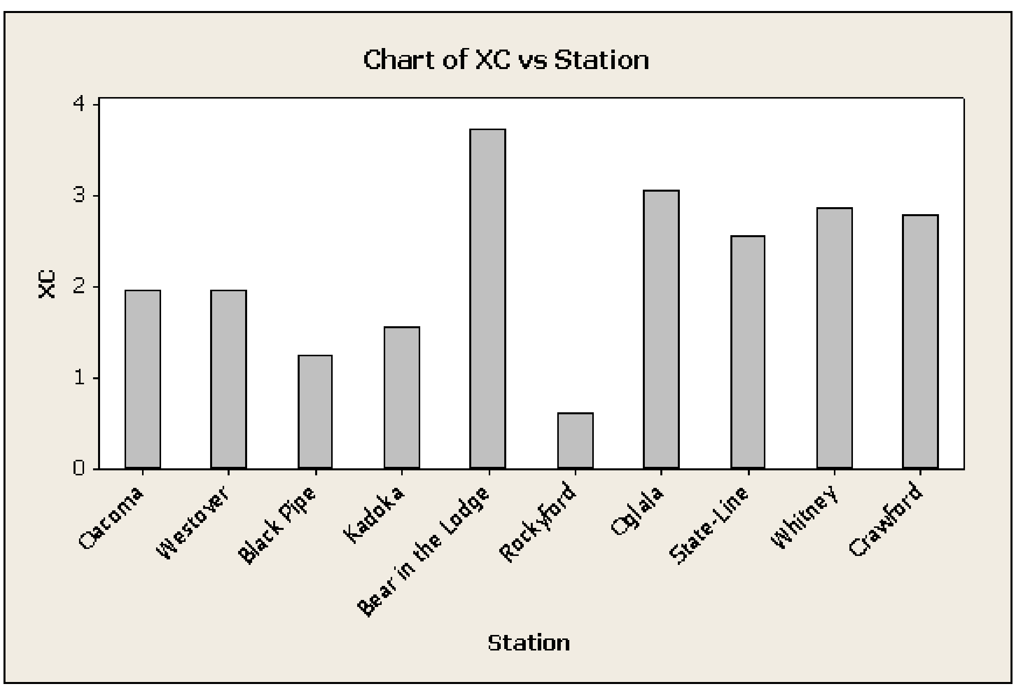



**Figure I-12.** Ranking of Total Canopy Cover at Each Station.

RSI-1465-04-089

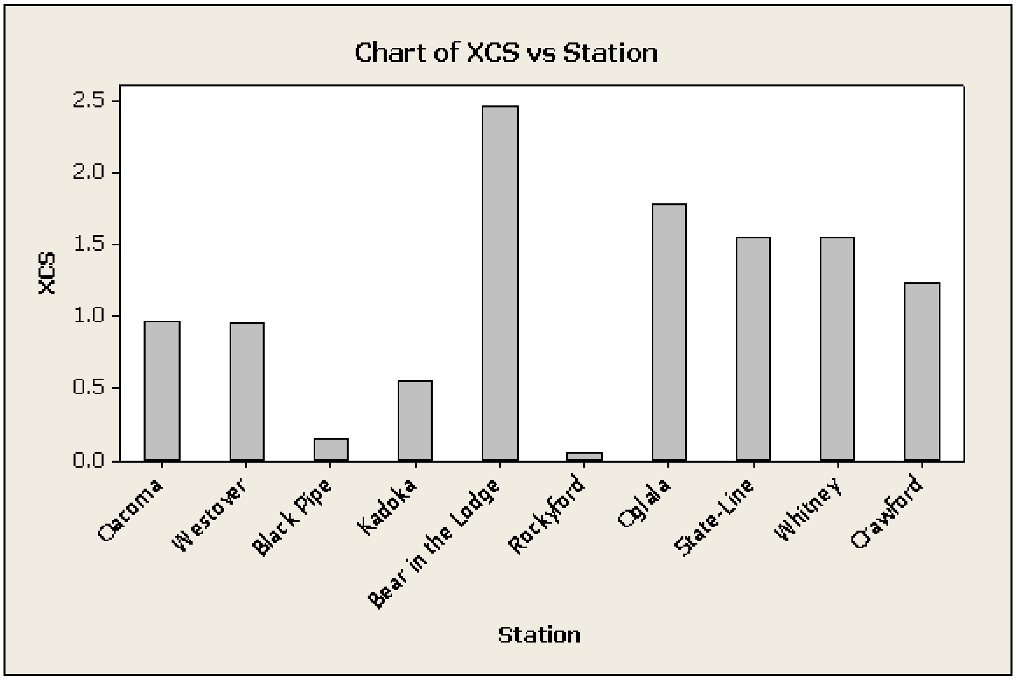



**Figure I-13.** Ranking of Canopy Cover of Small Trees at Each Station.

RSI-1465-04-090

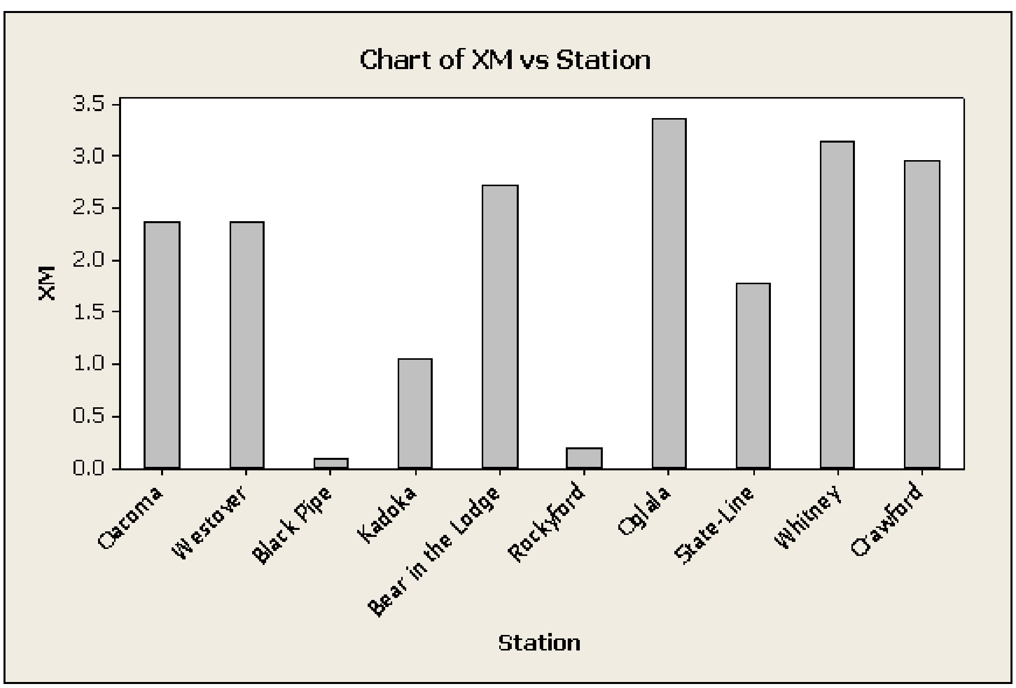



**Figure I-14.** Ranking of Total Understory at Each Station.

# APPENDIX J

# FISHERIES DATA

**Table** 2-1. Fish species collected from the South Dakota portion of the mainstem White River during this study and in other recent (Cunningham et al. 1995; Cunningham 1997) and historic (Baileyand Allum 1962) collections.

| | **Collection period** | | |
|---|---|---|---|
| Species | Current study | Recent collections | Historic collections |
| black bullhead *Ameirus melas* | X | | X |
| brassy minnow *Hybognathus hankinsoni* | | | X |
| channel catfish *Ictalurus punctatus* | X | X | X |
| common carp *Cyprinus carpio* | X | X | |
| emerald shiner *Notropis atherinoides* | X | X | |
| fathead minnow *Pimephales promelas* | X | X | X |
| flathead catfish *Pylodiclis olivaris* | | | X |
| flathead chub *Platygobio gracilis* | X | X | X |
| gizzard shad *Dorosoma cepedianum* | – | X | |
| golden shiner *Notemigonus crysoleucas* | | X | |
| goldeye *Hiodon alosoides* | X | X | |
| green sunfish *Lepomis cyanellus* | X | – | |
| largemouth bass *Micropterus salmoides* | X | | |
| longnose dace *Rhinichthys cataractae* | X | X | X |
| paddlefish *Polyodon spathula* | | | X |
| plains minnow *Hybognathus placitus* | X | | X |

**Table 2-1. Continued.**

| Species | Collection period: Current study | Recent collections | Historic collections |
|---|---|---|---|
| red shiner *Cyprinella lutrensis* | X | X | X |
| river carpsucker *Carpoides carpio* | X | X | |
| sand shiner *Notropis ludibundus* | X | X | X |
| sauger *Stizostedion canadense* | X | | X |
| shorthead redhorse *Moxostoma macrolepidotum* | X | X | |
| stonecat *Noturus flavus* | X | X | |
| stoneroller *Campostoma anomalum* | | | |
| sturgeon chub *Macrhybopsis gelida* | X | X | X |
| western silvery minnow *Hybognathus argyritis* | X | X | X |
| white sucker *Catostomus commersoni* | X | | X |
| pallid sturgeon *Scaphirhynchus albus* | | | 9 |
| shovelnose sturgeon *S. platorynchus* | | | ? |
| **sicklefm chub** *Macrhybopsis meeki* | | | 9 |
| blue sucker *Cycleptus elongates* | | | |
| blue catfish *Ictalurusfurcatus* | | | 9 |
| freshwater drum *Aplodinotus grunniens* | | | |

?= native Missouri River species not historically collected but suspected to have at least seasonally used the White River (Ruelle et al. 1993).

**Table 2-2.** Fish species found in the White River Basin outside the current study area (Bailey and Allum 1962; Bliss and Schainost 1973; NGPC 1988 River Database Query; Cunningham et al. 1995.

| Species | Mainstem NE | Tributaries NE | Little White SD | Little White tributaries SD |
|---|---|---|---|---|
| *bigmouth shiner* *Notropis dorsalis* | X | | | X |
| black bullhead *Ameirus melas* | X | | | |
| black *crappie* *Pomoxis nigromaculatus* | | — | X | X |
| blacknose dace *Rhinichths atratulus* | | — | — | X |
| blacknose shiner *Notropis heterolepis* | | X | | X |
| bluegill *Lepomis macrochirus* | | | X | |
| brassy minnow *Hybognathus hankinsoni* | X | X | | X |
| brook stickleback *Culea inconstans* | | | | X |
| brook trout *Salvelinus fontinahs* | | X | | |
| brown trout *Salmo trutta* | X | X | | |
| *channel catfish* *Ictalurus punctatus* | X | X | X | X |
| *creek chub* *Semotilus atromaculatus* | X | X | X | X |

**Table 2-2. Continued.**

| Species | Mainstem NE | Tributaries NE | Little White SD | Little White tributaries SD |
|---|---|---|---|---|
| *common carp* *Cyprinus carpio* | | | | |
| *common shiner* *Luxilus cornutus* | | X | | |
| fathead minnow *Pimephales promelas* | | X | | X |
| finescale dace *Phoxinus neogaeus* | | | | X |
| flathead chub *Platygobio gracilis* | X | X | X | |
| *golden shiner* *Notemigomus crysoleucas* | | *X* | | X |
| goldeye *Hiodon alosoides* | X | | | |
| grass pickerel *Esox americanus* | | X | | |
| green sunfish *Lepomis cyanellus* | X | X | X | X |
| Iowa darter *Ethostoma exile* | | | | X |
| largemouth bass *Micropterus salmoides* | | X | X | |
| longnose dace *Rhinichthys cataractae* | X | X | X | X |
| mountain sucker *Catostomus platyrhynchus* | | X | | |

**Table 2-2. Continued.**

| Species | Mainstem NE | Tributaries NE | Little White SD | Little White tributaries SD |
|---|---|---|---|---|
| northern pike *Esox lucius* | | | X | |
| Northern redbelly dace *Phoxinus eos* | | | | X |
| pearl dace *Margariscus margarita* | | | | X |
| plains minnow *Hybognathus placitus* | X | | | X |
| plains topminnow *Fundulus sciadicus* | | | | X |
| quillback *Carpoides cyprinus* | X | | | |
| rainbow trout *Oncorhynchus mykiss* | X | X | | |
| *red shiner* *Cyprinella lutrensis* | X | | X | |
| river carpsucker *Carpoides carpio* | X | | | |
| *river shiner* *Notropis orca* | X | | | |
| sand shiner *Notropis* ***ludibundus*** | X | X | X | X |
| **shorthead redhorse** *Moxostoma macrolepidotum* | X | — | X | — |
| stonecat *Noturus flavus* | X | X | X | — |

**Table 2-2. Continued.**

| **Species** | Mainstem NE | Tributaries NE | Little White SD | Little White tributaries SD |
|---|---|---|---|---|
| stoneroller *Campostoma anomalum* | | | | |
| sturgeon chub *Macrhybopsis gelida* | | | X | |
| W. silvery minnow *Hybognathus argyritis* | X | | X | |
| *white crappie* *Pomoxis annularis* | | | X | |
| white sucker *Catostomus commersoni* | X | X | X | X |
| yellow perch *Perca flavescens* | X | X | X | X |

**Table** 2-3. Summary of fishes sampled during 1998 and 1999 on the White River in South Dakota. Relative species composition is expressed as percentage of total individuals sam led.

| Family and species | Mean length (mm) ± SE | Mean weight (g) ± SE | Relative Species composition (%) | Total number of fishes sampled | Reaches where sampled |
|---|---|---|---|---|---|
| Cypnrudae | | | | | |
| common carp | 392 ± 10 | 827 ± 49 | 3 | 119 | 2-4,6 |
| emerald shiner | NA | NA | <1 | 1 | 11 |
| fathead minnow | 41 ± 1 | 1 ± <1 | 6 | 260 | 4,9,10 |
| flathead chub | 71 ± 1 | 6 ± <1 | 44 | 1754 | 1-11 |
| longnose dace | 53 ± 4 | 1 ± <1 | <1 | 6 | 1,3,7 |
| plains minnow | 69 ± 1 | 3 ± <1 | 13 | 520 | 3,4,6-11 |
| Red shiner | 48 ± 2 | NA | <1 | 7 | 1,2,11 |
| sand shiner | 44 ± <1 | 1 ± <1 | 2 | 77 | 1,4,10 |
| W. silvery minnow | 70 ± 3 | 8 ± 3 | 2 | 63 | 5,9-11 |
| sturgeon chub | 61 ± 1 | 2 ± <1 | 4 | 171 | 2-11 |
| Ictaluridae | | | | | |
| black bullhead | 100 ± 8 | 20 -1- 7 | <1 | 17 | 2-4,6 |
| channel catfish | 166 ± 4 | **88** ± 9 | 22 | **888** | 1-11 |
| stonecat | 137 ± 9 | 27 ± 5 | 1 | 33 | 1-3,9 |
| Catostomidae | | | | | |
| river carpsucker | 248 ± 18 | 212 ± 37 | <1 | 11 | 1-3,5,6,10 |
| shorthead redhorse | 256 ± | 149 ± 14 | <1 | 13 | 1,2 |
| white sucker | NA | NA | <1 | 1 | 1 |
| Centrarchidae | | | | | |
| green sunfish | 48 ± 4 | 2 ± 1 | <1 | 7 | 4,6,11 |
| largemouth bass | NA | NA | <1 | 1 | 1 |
| Clupeidae | | | | | |
| goldeye | 359±3 | 347 ± 11 | 1 | 60 | 1-4,6,8,9 |
| Percidae | | | | | |
| sauger | 357±14 | 359 ± 43 | <1 | 12 | 1,2,5,6,8,10 |

NA lengths and weights not collected

**Table** 2-4. White River fish community comparisons between years and among segments using the Morisita-Horn Communi Similarity Index.

| Comparisons | Morisita-Horn Similarity Inde |
|---|---|
| 1998 vs. 1999 | 0.9518 |
| upper vs. middle | 0.8773 |
| middle vs. lower | 0.9648 |
| upper vs. lower | 0.8846 |

-",-,-.-"-

Monsita-Horn Index varies from 0 (no similarity) to 1.0 (complete similarity).

**Table** 2-5. Trophic guild, tolerance for environmental stressors, endemicness, and frequency of occurrence, of fishes collected from the White River, South Dakota during 1998 and 1999.

| Species | Trophic guild | Tolerance | Native or introduced | White River occurence[3] |
|---|---|---|---|---|
| black bullhead | | | N | R |
| channel catfish | | M | N | U |
| common carp | | T | I | C |
| fathead minnow | | T | N | R |
| flathead chub | | M | N | U |
| goldeye | | I | N | C |
| green sunfish | | T | N | R |
| longnose dace | | I | N | R |
| plains minnow | | M | N | C |
| red shiner | | T | N | R |
| river carpsucker | | M | N | C |
| sauger | | M | N | C |
| sand shiner | | M | N | R |
| shorthead redhorse | | M | N | R |
| sturgeon chub | | NA | N | C |
| stonecat | | I | N | R |
| W. silvery minnow | | M | N | R |

Trophic guild: I = insectivore; P = piscivore; 0 = omnivore; H = herbivore (Barbour et al. 1992; Bazata 1991)

[2]Tolerance: I = intolerant; M = moderately tolerant; T = tolerant (Barbour et al. 1992; Bazata 1991)

[3]Frequency of occurence: U = ubiquitous (found at all sites); C = common (found at 6-10 sites); R = rare (found at 2-5 sites); I = incidental (found at 1 site).

NA: Trophic guild and tolerance not reported in literature.

**<u>Table</u> 2-6.** Total hoop net catch from the White River m South Dakota d_uris1999.

| | Site | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | | 2 | 3 | | | | | 8[1] | | | |
| black bullhead | * | | | | | | | | | | |
| channel catfish | 4 | 17 | * | * | * | * | * | * | 2 | * | |
| common carp | 10 | 12 | 17 | 2 | * | 16 | * | 1 | 12 | 2 | 1 |
| goldeye | 1 | * | * | * | * | * | * | * | * | * | * |
| river carpsucker | 1 | * | * | | * | * | * | * | * | * | * |
| sauger | 1 | * | * | * | | * | * | * | * | * | * |
| white sucker | 1 | * | * | * | * | * | * | | * | * | * |

` Sample was from one trap net
[2] Sample was from two trap nets
*Denotes a species that was absent in a sample

**Table 2-7.** Total trap net catch from the White River in South Dakota during 1998 and 1999.

| Species | Year | Site | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 5 | | | 8 | | | 11 |
| black bullhead | **1998** | * | | | | * | * | * | ns | | | |
| | 1999 | * | 1[2] | ns | ns | ns | * | * | * | * | | |
| channel catfish | 1998 | 21['] | 3[1] | 9[2] | 22[2] | 5[2] | 60[2] | | ns | 46[2] | 19[2] | 19[1] |
| | 1999 | 34[2] | 6[2] | ns | ns | ns | 17[2] | 3[2] | 2[1] | 2[2] | 3[2] | 9[2] |
| common carp | 1998 | * | * | 1[2] | * | 1[2] | 2[2] | 4[2] | ns | 4[2] | 6[2] | 2['] |
| | 1999 | 2[2] | * | ns | ns | ns | 62 | 1[2] | * | * | * | * |
| flathead chub | 1998 | 1['] | 2[1] | 4[2] | 1[2] | * | * | * | ns | * | * | * |
| | 1999 | 3[2] | 5[2] | ns | ns | ns | * | 1[2] | | * | 1[2] | |
| goldeye | 1998 | 1['] | * | 122 | * | * | * | * | ns | | | * |
| | **1999** | 1[2] | 1[2] | ns | ns | ns | 1[2] | * | | | | |
| largemouth bass | **1998** | | | | | | | * | ns | | | * |
| | 1999 | 1[2] | * | ns | ns | ns | * | * | * | | | |
| plains minnow | 1998 | * | * | * | * | * | * | * | ns | * | * | * |
| | 1999 | * | * | ns | ns | ns | | * | | | | * |

**Table** 2-7. **Continued.**

| Species | Year | Site | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| river carpsucker | **1998** | | * | | | | * | * | ns | * | | |
| | 1999 | * | * | ns | ns | ns | $1^{2}$ | * | * | * | * | * |
| sauger | 1998 | * | * | $2^{2}$ | * | | $1^{2}$ | * | ns | * | $1^{2}$ | * |
| | 1999 | * | * | ns | ns | ns | $2^{2}$ | $1^{2}$ | * | $3^{1}$ | $1^{2}$ | $1^{2}$ |
| shorthead redhorse | 1998 | $1^{1}$ | $2^{1}$ | * | * | * | * | * | ns | * | * | * |
| | 1999 | $2^{2}$ | $2^{2}$ | ns | ns | ns | | | * | * | * | * |
| stonecat | 1998 | $1^{1}$ | * | $1^{2}$ | * | * | * | * | ns | $1^{2}$ | * | * |
| | 1999 | $3^{2}$ | $6^{2}$ | * | ns | ns | * | * | * | * | | * |
| white sucker | 1998 | * | * | ns | * | * | * | * | ns | * | * | * |
| | 1999 | | * | * | ns | ns | * | * | * | * | * | * |

*Denotes species that was absent in a sample.
[1] Sample was from two trap nets
[2] Sample was from one trap net
ns: Indicates site where trap nets were not used

**Table 2-8.** Catch per unit effort (CPUE, # fish/100 $m^2$) of ubiquitous and common species by reach and year sampled in bag seines in the White River, South Dakota dunn 1998 and 1999.

| | | Reach | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Year | 1 | 2 | 3 | 4 | 4b' | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| channel catfish | 1998 | 4.5 | 2.6 | 1.4 | 1.8 | 5.2 | 0.0 | 3.9 | 2.8 | 2.5 | 0.5 | 0.4 | 1.6 |
| | 1999 | 2.4 | 0.0 | 0.9 | 2.8 | 14.2 | 0.0 | 0.5 | 2.4 | 1.9 | 0.6 | 0.3 | 1.5 |
| flathead chub | 1998 | 2.2 | 6.3 | 14.8 | 3.7 | 92.0 | 4.8 | 4.2 | 3.7 | 1.7 | 2.3 | 3.5 | 3.4 |
| | 1999 | 2.4 | 1.8 | 2.9 | **8.8** | 58 | 5.4 | 3.3 | 5.6 | 1.9 | 0.2 | 0.9 | 3.8 |
| goldeye | 1998 | 0.4 | 0.5 | 0.4 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 1999 | 0.0 | 2.4 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 |
| plains minnow | 1998 | 0.0 | 2.5 | 16.1 | 0.6 | 50.8 | 0.0 | 0.1 | 0.9 | 0.4 | 0.4 | 0.5 | 1.6 |
| | 1999 | 0.0 | 0.0 | 0.3 | 0.1 | 3.1 | 0.0 | 0.3 | 2.2 | 0.3 | 0.0 | 0.0 | 0.0 |
| river carpsucker | 1998 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 1999 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| sturgeon chub | 1998 | 0.0 | 0.1 | 0.8 | 0.4 | 0.0 | 1.6 | 1.2 | 1.3 | 0.7 | 0.1 | 0.4 | 0.0 |
| | 1999 | 0.0 | 0.0 | 0.3 | 0.6 | 0.0 | 0.5 | 0.3 | 1.9 | 0.6 | 0.1 | 0.1 | 0.1 |

Represents samples taken from an isolated spring hole.

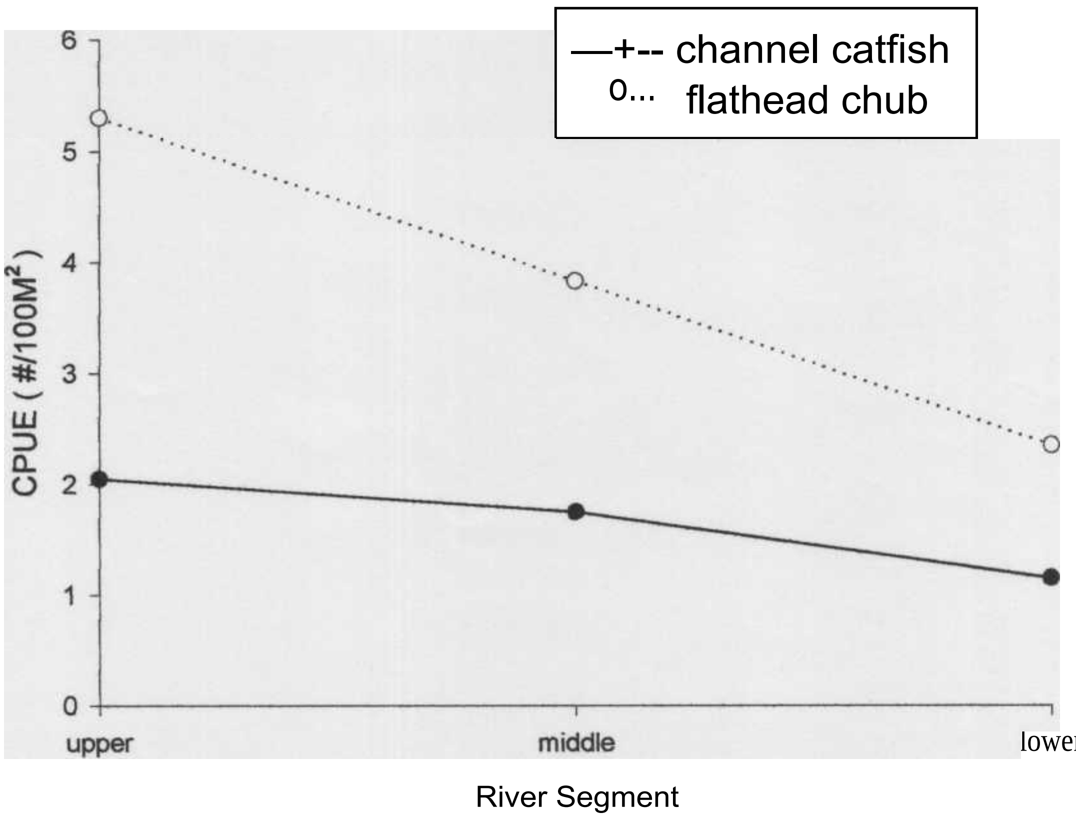



**Figure 2-1.** Longitudinal trends in catch rates of channel catfish and flathead chubs sampled with seines in the White River.

**Table 2-9.** Size structure of channel catfish sampled from the White River during 1998 and 1999. PSD's are reported ± 80% confidence intervals.

| Gear | Year | PSD | Number of stock length **fish** | Number of fish below stock length |
|---|---|---|---|---|
| Seine | 1998 | 33 ± 22 | 12 | 347 |
| | 1999 | 43[A] | 7 | 199 |
| Trap net | 1998 | 21 ± 11 | 33 | 179 |
| | 1999 | 32 ± 17 | 19 | 57 |
| Hoop net | 1999 | 36 [A] | 11 | 12 |

Sample size was too small to calculate confidence intervals.

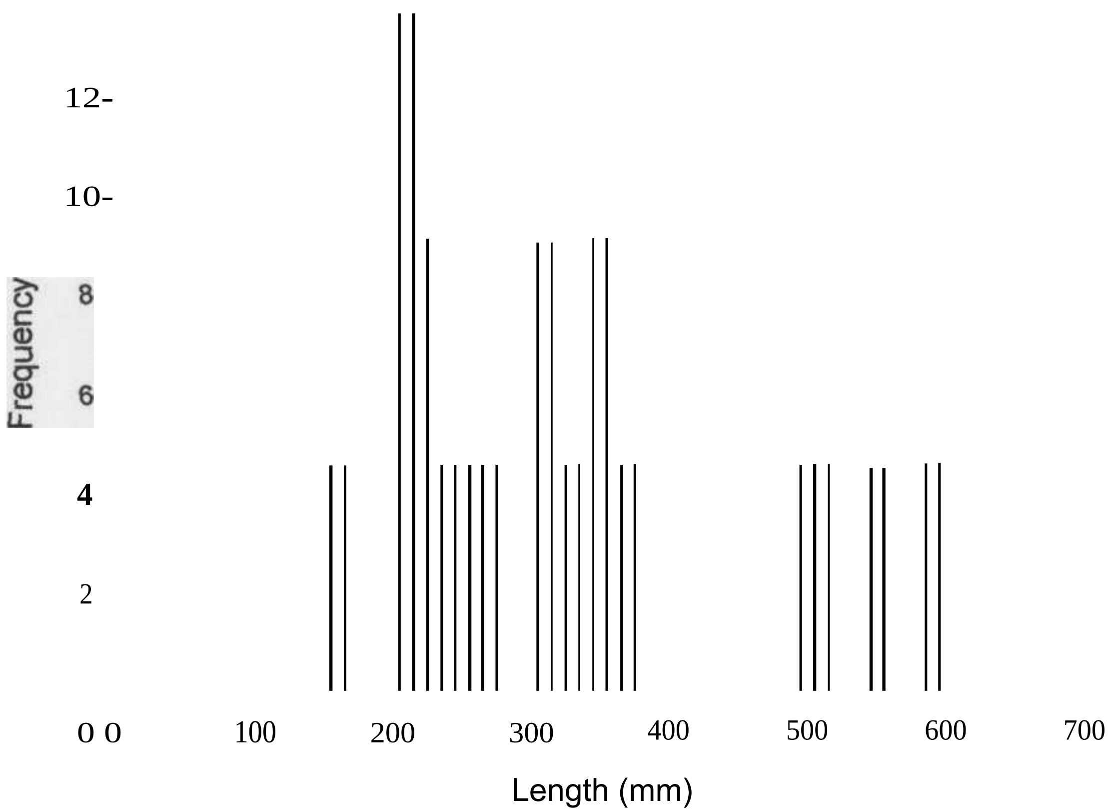
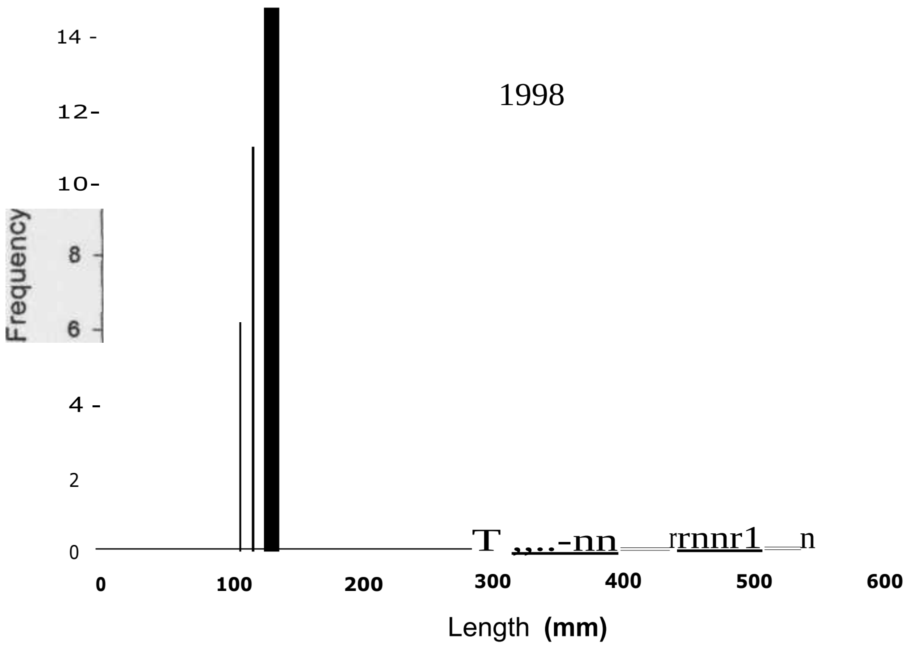



**Figure** 2-2. Length frequency distribution of channel catfish sampled from the White River, South Dakota with hoopnets during 1998.



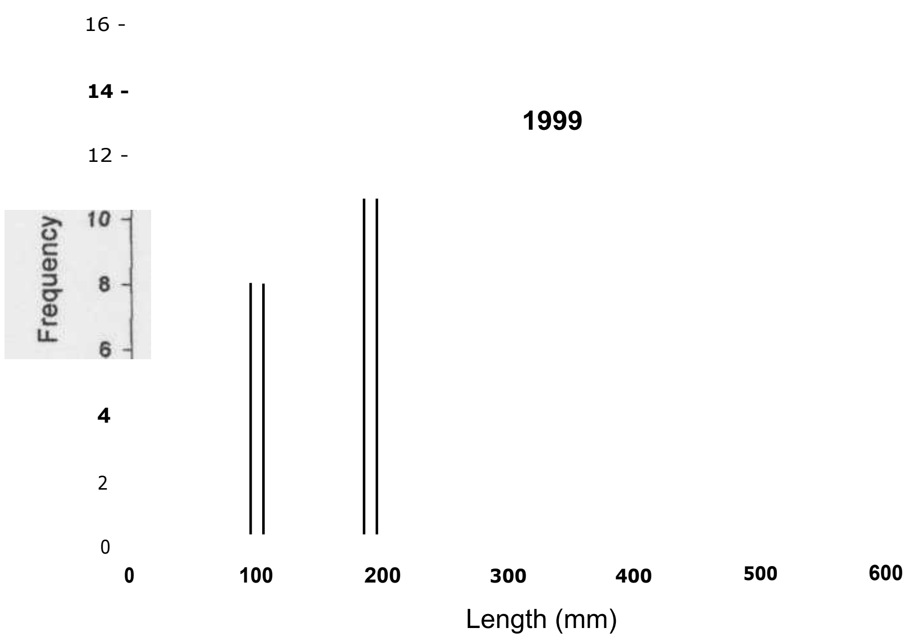




**Figure** 2-3. Length frequency distribution of channel catfish sampled from the White *River, South Dakota with trapnets* during 1998 and 1999.

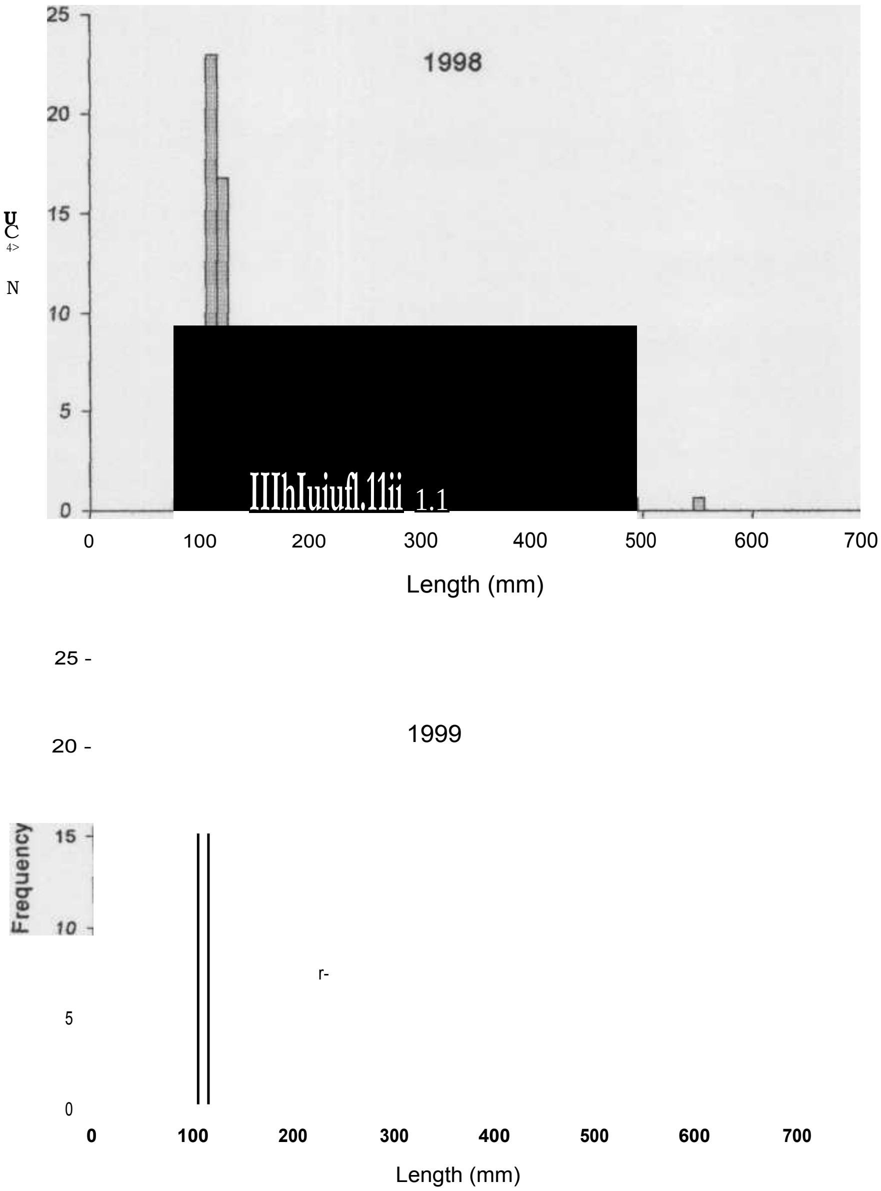



**Figure 2-4.** Length frequency distribution of channel catfish sampled from the White *River, South* Dakota *with seines during 1998 and 1999.*

**Table 2-10.** Mean back calculated total length at ate for channel catfish from various regional lotic systems.

........g

| River and state | | | | | | | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| White, SD (present study) | 77 | 126 | 185 | 242 | 291 | 340 | 385 | 430 | 478 | 508 | 543 | 584 | 601 |
| Belle Fourche, SD (Doorenbos 1998) | 129 | 189 | 230 | 266 | 295 | 316 | 374 | 419 | 467 | 507 | 513 | 562 | 475 |
| James, SD (Kubeny 1992) | 119 | 188 | 252 | 284 | 342 | 407 | 466 | 506 | 559 | 597 | 618 | 690 | |
| Powder, WY (Gerhardt and Hubert 1991) | | | 241 | 265 | 293 | 339 | 390 | 440 | 513 | 580 | 568 | 595 | 619 |
| Tongue, MT (Elser et al. 1977) | | | 257 | 295 | 345 | 388 | 444 | 491 | | | | | |
| Niobrara, NE (Hesse et al. 1979) | | | 183 | 231 | 287 | 303 | 405 | 459 | | | | | |
| Niobrara, NE (Hesses et al. 1979) | 162 | 212 | 235 | 260 | 285 | 315 | 381 | | | | | | |
| Iowa surface, IA (Paragamian 1990) | 102 | 182 | 243 | 292 | 345 | 388 | 449 | 505 | 498 | | | | |
| Powder, WY (Smith and Hubert 1988) | | | 257 | 295 | 345 | 388 | 444 | 491 | 544 | 576 | 595 | 622 | |

# APPENDIX K

# ENDANGERED SPECIES FOUND IN THE WATERSHED

# Table K-1. Endangered Species Found in the Watershed

| Name | County | Last Observed | State Status | Federal Status | Global Rank | State Rank |
|---|---|---|---|---|---|---|
| **Birds** | | | | | | |
| WHOOPING CRANE | 11, 60 | 1996-10-19 | SE | LE | G1 | SZN |
| *Grus Americana* | | | | | | |
| BURROWING OWL | 2, 50, 65 | 1999-07-08 | | | G4 | S3, S4B, SZN |
| *Athene cunicularia* | | | | | | |
| CASSIN'S KINGBIRD | 50, 65 | 1991-07-05 | | | G5 | S2B, SZN |
| *Tyrannus vociferans* | | | | | | |
| COOPER'S HAWK | 39, 60, 65 | 1999-03-19 | | | G5 | S3B, SZN |
| *Accipiter cooperii* | | | | | | |
| FERRUGINOUS HAWK | 27 | 1980-05-08 | | | G4 | S4B, SZN |
| *Buteo regalis* | | | | | | |
| GOLDEN EAGLE | 39, 65 | 1990-07-14 | | | G5 | S3, S4B, S3N |
| *Aquila chrysaetos* | | | | | | |
| KING RAIL | 11 | 1974-07-07 | | | G4, G5 | S1, S2B, SZN |
| *Rallus elegans* | | | | | | |
| LONG-BILLED CURLEW | 27 | 1991-07-23 | | | G5 | S3B, SZN |
| *Numenius americanus* | | | | | | |
| PRAIRIE FALCON | 39 | 1987-07-02 | | | G5 | S3, S4B, S4N |
| *Falco mexicanus* | | | | | | |
| SAGE THRASHER | 65 | Unknown | | | G5 | S2B, SZN |
| *Oreoscoptes montanus* | | | | | | |
| SWAINSON'S HAWK | 39 | 1989-05-19 | | | G5 | S4B, SZN |
| *Buteo swainsoni* | | | | | | |
| **Mammals** | | | | | | |
| BLACK-FOOTED FERRET | 39, 50, 60, 65, 67 | Recent | SE | LE | G1 | S1 |
| *Mustela nigripes* | | | | | | |
| LYNX | 39 | Unknown | | LT | G5 | SA |
| *Lynx canadensis* | | | | | | |
| KIT OR SWIFT FOX | 65 | 2000-08-12 | ST | | G3 | S1 |
| *Vulpes velox* | | | | | | |
| FRINGE-TAILED MYOTIS | 39 | 1999-08-20 | | | G4, G5, T2 | S2 |
| *Myotis thysanodes pahasapensis* | | | | | | |
| LEAST SHREW | 67 | 1932-03 | | | G5 | S3 |
| *Cryptotis parva* | | | | | | |
| PLAINS SPOTTED SKUNK | 45, 60 | 1993-03-25 | | | G5, T4 | S3 |
| *Spilogale putorius interrupta* | | | | | | |
| SPRAGUE'S PIPIT | 65 | 1998-07-15 | | | G4 | S2B, SZN |
| *Anthus spragueii* | | | | | | |
| TOWNSEND'S BIG-EARED BAT | 39 | 1999-08-20 | | | G4 | S2, S3 |
| *Corynorhinus townsendii* | | | | | | |
| **Fish** | | | | | | |
| PALLID STURGEON | 45 | 1998-05-15 | SE | LE | G,1 G2 | S1 |
| *Scaphirhynchus albus* | | | | | | |
| STURGEON CHUB | 39, 41, 45, 50, 60, 65 | 1999-05-16 | ST | | G2 | S2 |
| *Macrhybopsis gelida* | | | | | | |
| PEARL DACE | 60 | 1994-08-20 | ST | | G5 | S2 |
| *Margariscus margarita* | | | | | | |
| PLAINS TOPMINNOW | 11, 39, 60, 65 | 1994-08-20 | | | G4 | S3 |
| *Fundulus Sciadicus* | | | | | | |
| AMERICAN BURYING BEETLE | 60 | 1996-SU | | LE | G2, G3 | S1 |
| *Nicrophorus americanus* | | | | | | |
| NORTHERN MYOTIS | 39 | 1999-08-20 | | | G4 | S3 |
| *Myotis septentrionalis* | | | | | | |
| SILVER-HAIRED BAT | 65 | 1998-07-17 | | | G5 | S4 |
| Lasionycteris noctivagans | | | | | | |
| **Reptiles** | | | | | | |
| LESSER EARLESS LIZARD | 60 | 1967-08-09 | | | G5 | S2 |
| *Holbrookia maculata* | | | | | | |
| NORTHERN PRAIRIE LIZARD | 11, 65 | 1999-06-23 | | | G5 | S2 |
| *Sceloporus undulatus* | | | | | | |
| SHORT-HORNED LIZARD | 2, 27 | 1984-05-27 | | | G5 | S2 |
| *Phrynosoma hernandesi* | | | | | | |
| SIX-LINED RACERUNNER | 65 | 1999-06-23 | | | G5 | S2 |
| *Cnemidophorus sexlineatus* | | | | | | |
| WESTERN BOX TURTLE | 39, 65 | 1987-05-04 | | | G5 | S2 |
| *Terrapene ornata* | | | | | | |
| **Amphibians** | | | | | | |
| PLAINS LEOPARD FROG | 60 | 1971-08-25 | | | G5 | S3, S4 |
| *Rana blairi* | | | | | | |

## Key to Codes Used in Natural Heritage Database Reports

| | |
|---|---|
| FEDERAL STATUS | LE = Listed endangered<br>LT = Listed threatened<br>LELT = Listed endangered in part of range, threatened in part of range<br>PE = Proposed endangered<br>PT = Proposed threatened<br>C = Candidate for federal listing, information indicates that listing is justified. |
| STATE STATUS | SE = State Endangered<br>ST = State Threatened |

An endangered species is a species in danger of extinction throughout all or a significant portion of its range (applied range wide for federal status and statewide for state status).

A threatened species is a species likely to become endangered in the foreseeable future.

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| Global Rank | State Rank | Definition (applied rangewide for global rank and statewide for state rank) |
|---|---|---|
| G1 | S1 | Critically imperiled because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction. |
| G2 | S2 | Imperiled because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range. |
| G3 | S3 | Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors; in the range of 21 of 100 occurrences. |
| G4 | S4 | Apparently secure, though it may be quite rare in parts of its range, especially at the periphery. Cause for long term concern. |
| G5 | S5 | Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery. |

| | | |
|---|---|---|
| GU | SU | Possibly in peril, but status uncertain, more information needed. |
| GH | SH | Historically known, may be rediscovered. |
| GX | SX | Believed extinct, historical records only. |
| G? | S? | Not yet ranked |
| _? | _? | Inexact rank |
| _T | | Rank of subspecies or variety |
| _Q | | Taxonomic status is questionable, rank may change with taxonomy |
| | SZ | No definable occurrences for conservation purposes, usually assigned to migrants |
| | SP | Potential exists for occurrence in the state, but no occurrences |
| | SR | Element reported for the state but no persuasive documentation |
| | SA | Accidental or casual |

Bird species may have two state ranks, one for breeding (S#B) and one for nonbreeding seasons (S#N). Example: Ferruginous Hawk (S3B, SZN) indicates an S3 rank in breeding season and SZ in nonbreeding season.

# APPENDIX L

# WHITE RIVER FECAL COLIFORM BACTERIAL TOTAL MAXIMUM DAILY LOAD DOCUMENT

# TOTAL MAXIMUM DAILY LOAD EVALUATION OF FECAL COLIFORM BACTERIA FOR THE IMPAIRED SEGMENTS OF THE WHITE RIVER

**(From Confluence of Willow Creek to near Oacoma, SD)**

**(HUC 101402)**

**Fall River, Shannon, Pennington, Jackson, Bennett, Jones, Mellette, Todd, Lyman, Tripp Counties, South Dakota**

**South Dakota Department of Environment and Natural Resources**

**January, 2007**

# WHITE RIVER FECAL COLIFORM BACTERIA TOTAL MAXIMUM DAILY LOAD

| | |
|---|---|
| Waterbody Type: | River |
| 303(d) Listing Parameter: | Fecal coliform bacteria |
| Designated Uses: | Warmwater semi-permanent fish propagation waters<br>Limited contact recreation waters<br>Fish and wildlife propagation, recreation, and stock watering<br>Irrigation |
| Size of Impaired Waterbody: | 379 stream miles (in South Dakota) |
| Size of Watershed: | 5,945 square miles (in South Dakota) |
| Water-quality Standards: | Narrative and Numeric |
| Indicators: | Fecal coliform bacteria concentrations |
| Analytical Approach: | Load duration curves and **FLUX** load modeling |
| Location: | HUC Code: 101402 |
| Goal: | Reduce fecal coliform bacteria load above the confluence with the Little White River by 81 percent<br><br>Reduce fecal coliform bacteria load above the confluence with the mouth of the White River by 73 percent |
| Target: | Fecal coliform bacteria concentrations 2000 cfu/100 mL |

# OBJECTIVE

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

# INTRODUCTION

The White River is a natural stream that drains portions of Fall River, Shannon, Pennington, Jackson, Bennett, Jones, Mellette, Todd, Lyman, and Tripp Counties in South Dakota along with portions of Sioux, Dawes, Sheridan and Cherry Counties in Nebraska (Figure C-1). The White River Watershed is approximately 8,500 square miles in South Dakota and approximately 1,440 square miles in Nebraska. Land use in the Watershed is primarily cattle ranching, with some dryland farming.

# PROBLEM IDENTIFICATION

Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals and are used as indicators of waste and the presence of pathogens in waters of the State. In South Dakota water quality standards for fecal coliform are in effect from May 1 through September 30 each year. The beneficial use based criteria for fecal coliform for the White River is limited contact recreation water (2,000 colonies/100ml for any one sample). The White River carries fecal coliform bacteria load that exceeds bacterial use based on thrdegrades the water-quality of the river. According to the 1998, 2002, 2004 and 2006 South Dakota Integrated Report for Surface Water Quality Assessment, the White River from Interior, South Dakota to the mouth of the river near Oacoma, South Dakota failed to support its assigned beneficial uses due to high fecal coliform bacteria. Approximately $1.49 \times 10^{16}$ colony-forming units (cfu)/season of fecal coliform bacteria are transported in the White River from the confluence of Willow Creek to the confluence of the Little White River, as estimated at WQM 11, while approximately $1.96 \times 10^{16}$ cfu/season of fecal coliform bacteria are transported from the confluence of Little White River to the mouth of the river, near Oacoma, as estimated at WQM 12.

The 2006 Integrated Report divides the river into four segments (R6, R7, R8, and R9) based on the location of South Dakota Department of Environment and Natural Resources (SD DENR) Surface Water Quality Program's ambient water-quality monitoring (WQM) sites. Reaches R7, R8, and R9 were identified as impaired due to high fecal coliform concentrations. Based on findings of this project, these reaches were redefined, with only three reaches (R6, R7, and R8) to better reflect geological conditions in the Watershed. The proposed reaches are as follows: (1) from the headwaters to the confluence of Willow Creek 5 miles north of the gage station identified as the White River near Oglala, (2) Willow Creek to the confluence of the Little White River, and (3) the confluence of the Little White River to the mouth of the river near Oacoma, South Dakota. The TMDL summary for the White River is for the proposed reaches R7 and R8. Data collected by SD DENR at WQM 11 and WQM 12 were used to calculate Total Maximum Daily Loads (TMDL's) for these segments of the White River.

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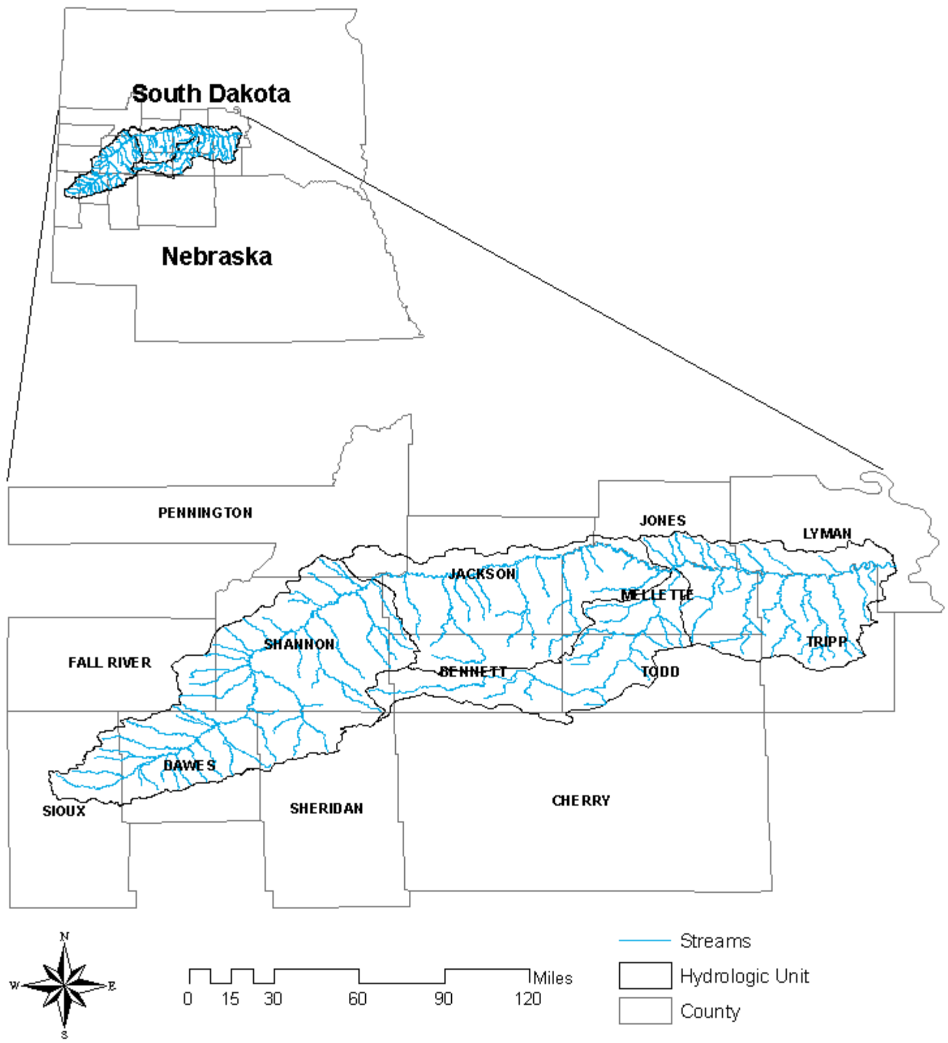


**Figure L-1.** Location of the White River Watershed

# DESCRIPTION OF APPLICABLE WATER-QUALITY STANDARDS AND NUMERIC WATER-QUALITY TARGETS

The White 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 for the river to satisfy its assigned beneficial uses, which are listed below:

- Warm water semi-permanent fish propagation
- Limited contact recreation
- Fish and wildlife propagation, recreation, and stock watering
- Irrigation waters

RSI-1465-10–001

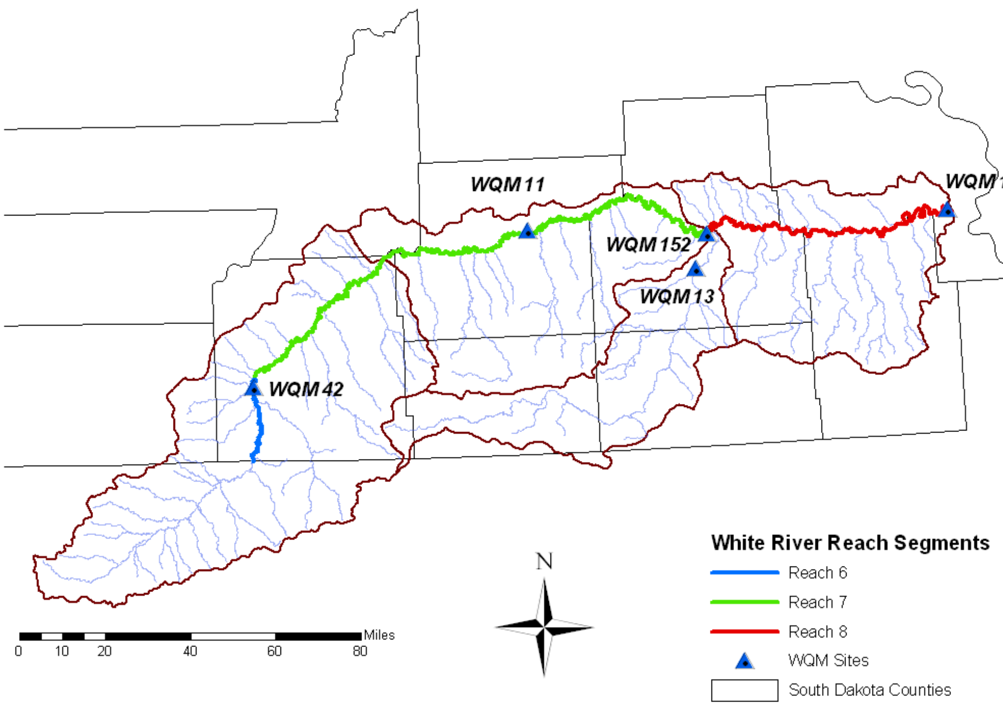


**Figure L-2.** Reach Segments of the White River and Location of Water Quality Monitoring Stations (WQM Sites) on the White River.

Individual parameters, including fecal coliform bacteria concentrations, determine the support of beneficial uses and compliance with water-quality standards. In the case where there is more than one applicable criterion for a water quality constituent, the most stringent criteria is used. For limited contact recreation waters, the 30-day geometric mean (based on a minimum of five samples obtained during separate 24-hour periods for any 30-day period) concentration of fecal coliform bacteria samples should not exceed 1,000 cfu/100 ml or a daily maximum concentration of 2000 cfu/100 ml. Fecal coliform bacteria concentrations in the White River have been found to exceed the daily maximum fecal coliform standard.

# POLLUTANT ASSESSMENT

## POINT SOURCES

Several small municipalities are located within the White River Watershed, including Manderson, Pine Ridge, Oglala, Wounded Knee, Porcupine, Kyle, and Interior. Manderson, Wounded Knee, Wanblee, Potato Creek, and Interior are the only municipalities within watershed segments of the White River listed as impaired, that have point-source discharge permits for wastewater treatment effluent. All other municipalities within the impaired watersheds have non-discharge wastewater treatment facilities.

## NONPOINT SOURCES

Fecal coliform bacteria source tracking in the White River indicated that nonpoint sources of fecal coliform bacteria include sources from domestic livestock and wildlife within the watershed. In Reach 6 and Reach 7, domestic wildlife were identified as the dominant source (47 percent and 59 percent respectively). Wildlife contributions accounted for roughly one third of the fecal loading in both Reach 6 and Reach 7 (36 percent for both). However wildlife contributions become the dominant source in the downstream reach, Reach 8 (49 percent). Domestic livestock account for 37 percent of the loading in Reach 8. Human sources accounted for the lowest percentage of the loading in all three reaches (18, 6, and 14 percents for Reaches 6, 7, and 8 respectively). Human sources of fecal coliform bacteria in the White River most likely come from a combination of point sources and non-point sources, such as failing septic systems.

# TMDL AND ALLOCATIONS

## TOTAL MAXIMUM DAILY LOAD (TMDL)

A TMDL is defined as the total amount of pollution a waterbody can assimilate and still maintain water-quality standards. A TMDL includes the sums of the waste load allocations from point sources; the load allocations from nonpoint sources, including natural background sources; and a margin of safety to account for sources of uncertainty.

A TMDL was calculated for the proposed listed segments of the White River. **FLUX**, a program developed by the U.S. Army Corps of Engineers, was used to estimate the current fecal coliform loads at WQM 11 and WQM 12. To determine the TMDL for the listed segment, the mean seasonal flow was multiplied by the standard for fecal coliform, 2000 cfu/100 ml and dividing by the number of days in the season. This was done for WQM 42, WQM 11, and WQM 12. A TMDL was not calculated for WQM 152 due to its limited dataset. Additionally, a TMDL was calculated for the Little White River, which enters the White River between Reach 7 and Reach 8. The TMDL for the Little White River was calculated at WQM 13, using the fecal coliform standard of 2000 cfu/100 mL in the same manner as the other WQM stations. Currently both the Little White River and Reach 6 of the White River are meeting their TMDL's.

A goal of 81 percent reduction of the seasonal fecal coliform load was set for Reach 7 of the White River based on loading found at WQM 11. The load estimate for Reach 7 was calculated as $1.49 \times 10^{16}$ or an average daily load of $9.73 \times 10^{13}$. The TMDL for Reach 7 was set at $1.85 \times 10^{13}$. A goal of 65 percent reduction of the seasonal fecal coliform load was set for Reach 8 of the White River based on loading found at WQM 12. The load estimate for Reach 8 was calculated as $1.96 \times 10^{16}$ or an average daily load of $1.28 \times 10^{14}$. The TMDL for Reach 8 was set at $4.48 \times 10^{13}$. These goals will meet or exceed the required reductions for each listed segments of the White River. TMDL allocations are shown in Table C-1 for Reach 7 and Table C-2 for Reach 8. Upstream allowable loads based on TMDL's for the contributing reaches were accounted for in TMDL allocations. Load allocations and needed percent reduction are discussed further in the Load Allocation section of this document.

**Table L-1. TMDL for Reach 7 of the White River (cfu/day)**

| Reach 7, White River | |
|---|---|
| **Upstream Contributing TMDL** | 2.98E+12 |
| **Load Allocation (LA)** | 1.34E+13 |
| **Waste Load Allocation (WLA)** | 2.20E+11 |
| **Margin of Safety (MOS)** | 1.85E+12 |
| **Total Maximum Daily Load (TMDL)** | 1.85E+13 |

**Table L-2. TMDL for Reach 8 of the White River (cfu/day)**

| Reach 8, White River | |
|---|---|
| **Upstream Contributing TMDL** | 2.63E+13 |
| **Load Allocation (LA)** | 1.38E+13 |
| **Waste Load Allocation (WLA)** | 0 |
| **Margin of Safety (MOS)** | 4.48E+12 |
| **Total Maximum Daily Load (TMDL)** | 4.48E+13 |

## WASTELOAD ALLOCATIONS (WLA)

The WLA portion of the TMDL identifies the portion of the loading capacity allocated to existing and future point sources. There are five permitted point sources (Wounded Knee, Manderson, Potato Creek, Interior, and Wanblee) for fecal coliform in the White River Watershed, contributing to Reach 7 of the River. There are no permitted point sources contributing to Reach 8 of the River. Each of the permitted systems in the Watershed is a lagoon system designed to be zero discharge. However they are permitted to discharge if needed. Discharge flow rates were calculated assuming that the lagoons could discharge two feet of depth in one day; multiplying the surface area by 2 feet. An exponential decay rate was applied to each WLA, using the equation: $C = C_o * e^{(K*X/U)}$

where:

C = concentration of fecal coliform bacteria at confluence
Co = concentration of fecal coliform bacteria at discharge
K = Decay coefficient
X= distance along axis of flow
U = Flow Velocity

The fecal standard of 2000 cfu/100mL was used as the concentration at the point of discharge. Flow velocity was estimated assuming velocity was equal to flow rate (flow through a 1 foot square channel), which incorporates an implicit factor of safety, since natural channels are rarely equal to one foot square in cross section. Distance was estimated from a GIS river shapefile, which also incorporates an implicit factor of safety, since the shapefile under-estimated stream length due to the sinuous stream channel. A decay coefficient of 0.51 was used for these calculations. Based on discharge and decay rate estimates, the point source discharge facilities in the White River Watershed contributing to Reach 7 can discharge approximately $2.20 \times 10^{11}$ cfu/day of fecal coliform.

## LOAD ALLOCATIONS (LA)

The LA portion of the TMDL identifies the portion of loading capacity allocated to existing and future nonpoint sources. Natural background sources are included in the nonpoint source load allocation to represent the portion of the loading capacity attributed to wildlife. The LA was calculated as the remaining load available towards the TMDL after accounting for the upstream allowable TMDL and the WLA contributing to each reach. For Reach 7, the upstream allowable TMDL is for the upstream reach of the White River (Reach 6), as calculated at WQM 42. For Reach 8, the upstream allowable TMDL's are for Reach 7 of the White River as calculated at WQM 11, and the Little White River, as calculated at WQM 13. Reductions of fecal coliform loading need to come from the LA portion of the TMDL, since the upstream TMDL's and WLA's are set by the water quality standard.

Based on the estimated seasonal loading at WQM 11, a reduction of $1.21\times10^{16}$ cfu/season (81 percent) is required to meet the water-quality standard for Reach 7, above the confluence of the Little White River. Based on the results of Bacterial Source Tracking (BST) performed at WQM 11, it was estimated that roughly 58 percent of the fecal coliform load comes from domestic livestock, 36 percent comes from wildlife sources, and 6 percent comes from human sources. Human sources of fecal coliform in Reach 7 could come from point sources accounted for in the WLA, from point sources from the upstream contributing watershed accounted for in the TMDL for Reach 6, or from non-point sources, such as failing septic systems.

Based on the estimated seasonal loading at WQM 12, a reduction of $1.27\times10^{16}$ cfu/season (65 percent) is required to meet the water-quality standard for Reach 8. Based on the results of BST performed at WQM 12, it was estimated that roughly 50 percent of the fecal coliform load comes from wildlife sources, 37 percent comes from domestic livestock, and 13 percent comes from human sources. Human sources of fecal coliform in Reach 8 could come from point sources in upstream watersheds, accounted for in the TMDL's for Reach 7 or the Little White River, or from non-point sources, such as failing septic systems.

The required reductions of fecal coliform concentrations may be achieved through the implementation of BMPs, including filter strips, riparian buffer strips, and riparian zone rehabilitation. These practices should be effective in reducing fecal loading from overland sources, either from cattle or wildlife. Also BMPs traditionally used for cattle sources of fecal coliform, such as fencing and exclusion, off-site watering, and rotational grazing, should be implemented.

## MARGIN OF SAFETY

Substantial uncertainty is often inherent in estimating fecal coliform loads from non-point sources. To account for uncertainty in the TMDL calculations, a portion of the available fecal coliform loading capacity was not allocated.  Ten percent of the TMDL was reserved as the margin of safety, a required component of the TMDL.

## FOLLOW-UP MONITORING

Future monitoring will be necessary to determine whether or not the proposed implementation actions have had an impact on water quality in the White River Watershed. Once an implementation project is completed, post-implementation monitoring will be necessary to ensure that the TMDL was reached.  At a minimum, monthly monitoring will continue for WQM 11, WQM 152, and WQM 12.  Additional bacteria source tracking may be necessary to better understand the sources of fecal coliform bacteria.  Currently it appears as if livestock are the major source of fecal loading to the middle reach of the White River.  A shift in fecal source occurs in the lower reach of the river, towards Oacoma, with sources from wildlife becoming more dominant.  Investigation of fecal coliform lifespan and transport rates is necessary in the White River, in order to understand the potential effects implementation might have on fecal coliform loading.  Watershed modeling of fecal coliform bacteria should coincide with any further monitoring the White River.

## PUBLIC PARTICIPATION

Efforts were taken to gain public education, review, and comment during development of the TMDL, including local newspaper articles, and two general public meetings.  The general public meetings provided an opportunity to present assessment results and to receive input from the stakeholders.  The comments/findings from these public meetings were taken into consideration in the development of the White River TMDL.  Based on comments received at these meetings, additional work on a separate project was initiated to allocate fecal loadings from source animal groups.  Comments received also led to samples being collected from prairie dog communities to add prairie dogs as a classification source group.

## IMPLEMENTATION PLAN

Currently no implementation plan has been initiated in the White River Watershed. Communication occurred through out this project with several Conservation Districts along with the Black Hills RC&D.  It is expected that upon approval of this TMDL, one of these groups or a partnership between several or all of these groups will take action to begin implementation within the White River Watershed.