2001 – 2002

GOOSE CREEK WATERSHED ASSESSMENT

FINAL REPORT

July 2003

<u>Prepared For</u>:
The Goose Creek Drainages Advisory Group

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FORWARD

The Goose Creek watershed is the livelihood for much of Sheridan County, Wyoming because it provides the natural resources that drive the urban, agricultural, recreational, and wildlife opportunities for this region of Wyoming. Protection of this resource is critical to maintain the quality of life enjoyed by not only citizens in the watershed, but also for all those who visit this area for recreational, aesthetic, and economic offerings provided by resources within the watershed. Sheridan was settled around the Goose Creeks and today they remain accessible to over 27,000 county residents throughout the year. Local citizens and visitors of all ages commonly recreate on these streams, especially in city parks and along recreational pathways. Kendrick, Emerson, Washington, and Thorne-Rider parks all have direct access to these waterways. Due to their high use, easy access, and direct contact with the public it is essential that these waterways are of highest quality.

Big and Little Goose Creeks were placed on the 1998 list of impaired waterbodies for fecal coliform bacteria based on data collected by the United States Geological Survey (USGS) and the Wyoming Department of Environmental Quality (WDEQ). Seven tributaries were added to the list in 2000 as a result of additional monitoring by WDEQ that identified fecal coliform levels violating Wyoming Water Quality Standards. The sampling conducted by USGS and WDEQ did not adequately identify the magnitude of fecal coliform contamination nor determine the ability of these waterbodies to support the applicable beneficial uses, such as agriculture, industry, municipal, protection of fish and wildlife, recreation, scenic value, and aquatic life use.

To address these impairments, the Sheridan County Conservation District (SCCD), Sheridan County Commissioners, and the City of Sheridan submitted a joint proposal for an assessment project to conduct a more complete evaluation of the watershed and its uses and to maintain local control of watershed improvements. The Goose Creek Drainages Advisory Group (GCDAG) was formed to provide oversight for the assessment and included representatives from each of the three sponsors as well as other local interests.

This assessment spanned two years as a collaborative effort among rural and urban interests. The Goals of the Assessment were to

- conduct a comprehensive watershed assessment to identify impaired segments of Goose, Big Goose, and Little Goose Creeks; and
- provide information and education to the affected interests and general public to encourage public involvement in future planning and improvement efforts.

Approximately 17 stream miles of Little Goose, 13 miles of Big Goose, and 3.5 stream miles of Goose Creek were assessed. Sample sites were selected based on a review of the historical data and sampling sites (including WDEQ and USGS), availability, and access. GCDAG members contacted individual landowners for their permission prior to establishing a sample site. There were 46 total sample sites with 5 stations on Goose Creek, 15 stations on Big Goose Creek, and 17 stations on Little Goose Creek. In addition, there was one station each on eight tributaries and one storm drain near Coffeen Avenue. The tributaries sampled included: Soldier Creek, Beaver Creek, Park Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek.

ACKNOWLEDGEMENTS

The Sheridan County Conservation District, the Sheridan County Commission, and the City of Sheridan would like to thank the following individuals, organizations, and agencies for their support and cooperation offered during the Goose Creek Watershed Assessment.

Thanks go to Goose Creek watershed landowners and users, especially those that allowed access for monitoring. SCCD employees, supervisors, associate supervisors, and volunteers provided monitoring support, technical assistance, and aided with Final Report preparation. The majority of project funding, and activity coordination, and information/education efforts were managed by Mrs. Carrie Rogaczewski. Much of the field work, data management, and report construction were conducted by Mr. Jason Nehl. Mr. Jerry Forster and fellow NRCS employees provided many hours of field assistance, technical guidance, and document preparation. Project oversight and management were provided by Mr. Brian Lovett and others from WDEQ. WDEQ also provided current and historical data for the watershed. The USGS provided substantial water quality and stream discharge data and allowed the use of discharge monitoring equipment. Fisheries data for the watershed were provided by the Wyoming Game and Fish Department (WGFD). Special thanks go to Mr. Kurt King for macroinvertebrate and habitat assessment training, technical assistance, and Final Report assistance.

Ms. Jackie Flowers and additional City of Sheridan personnel provided project guidance, surveying assistance, and the use of laboratory titration equipment. Bruce Yates, County Engineer, and contracted consultants also provided project guidance during the assessment. The primary advisory group (GCDAG) consisted of members representing Sheridan County, the City of Sheridan, the SCCD, and other local interests. These members included Mr. Brad Waters, Ms. Ky Dixon, Mr. Scott Severs, Mr. Tom Pilch, Mr. Jack Landon, and Mr. Bill Doughty.

The Wyoming Association of Conservation Districts provided funding support for construction of the Sampling and Analysis Plan (SAP). Inter-Mountain Laboratories, Inc. and Aquatic Biology Associates, Inc. assisted with SAP review, provided technical guidance, and analyzed water quality and macroinvertebrate samples. Mr. Bob Bode, New York State Department of Conservation Division of Water Stream Biomonitoring Unit, allowed reprinting of stream benthic macroinvertebrate photos.

The WDEQ and the EPA are acknowledged and thanked for providing the mechanism necessary to conduct this watershed assessment with funding through Section 319 of the Clean Water Act.

EXECUTIVE SUMMARY

Big and Little Goose Creeks originate in the Big Horn Mountains west of Sheridan, Wyoming and pass through several ranches, rural sub-divisions, and through the towns of Big Horn and Sheridan. Near the center of Sheridan, Big and Little Goose Creek join to form Goose Creek. Each of these streams is classified by the WDEQ as Class 2AB – Coldwater Fisheries and are closely tied to local agriculture, recreational uses, and drinking water supplies.

The USGS has collected quarterly water quality samples within the Goose Creek watershed for several years. During the course of this sampling, a number of fecal coliform samples were found to have elevated concentrations of bacteria. The WDEQ used data collected by the USGS during the 1993 through 1997 water years to place Big and Little Goose Creek on the 1998 Section 303(d) list of impaired waters.

In 1998 and 1999, the WDEQ implemented a more detailed monitoring program on Big and Little Goose Creeks following their placement on the 1998 303(d) list. The objective of the monitoring program was to determine the geometric means for fecal coliform bacteria at various stream locations during a 30-day period within the recreation season (Rogaczewski and Smith, 1999). Results of the WDEQ sampling revealed elevated fecal coliform bacteria concentrations on Goose Creek, Big Goose Creek, and Little Goose Creek which exceeded Wyoming Water Quality Standards. Violation of these standards resulted in a non-attainment designation of beneficial use for Recreation and Human Consumption. This violation subsequently triggered the Federal Clean Water Act requirement for establishment of a Total Maximum Daily Load (TMDL) restriction. The purpose of a TMDL is to restore compliance of the waterbody with Water Quality Standards.

The 1998 and 1999 sampling conducted by WDEQ did not adequately identify the potential sources and magnitude of fecal coliform contamination. Moreover, sampling and supporting analyses to determine attainment of the other beneficial uses applicable to these waterbodies (e.g. agriculture, protection and propagation of fish and wildlife, industry, scenic value, and aquatic life use) was inadequate both in the number of parameters monitored and in the frequency of sampling.

At the time when the Goose Creeks Watershed Assessment was initiated in 2000, Beaver Creek, Big Goose Creek, Goose Creek, Jackson Creek, Kruse Creek, Little Goose Creek, Park Creek, Rapid Creek, Sackett Creek, and Soldier Creek were placed on Table A of Wyoming's 303(d) list for fecal coliform bacteria impairments as a result of WDEQ's 1998 and 1999 monitoring. Additionally, Goose Creek was listed on Table B of the 303(d) list for ammonia, fecal coliform, and chlorine as part of the Sheridan Waste Water Treatment Plant's routine NPDES permit renewal.

To address these impairments and prevent TMDL regulation, the GCDAG was formed as a collaborative partnership among the Sheridan County Conservation District, the Sheridan County Commission, and the City of Sheridan. Additional rural, urban, and locally interested parties also serve on this committee. In July 2000, the GCDAG received $217,500 in federal Clean Water Act Section 319 funding, which was disseminated through WDEQ, to design and implement a comprehensive watershed assessment. These federal dollars were required to be matched with $145,000 in non-federal cash or services. The match responsibility was divided among the three sponsors.

During 2000, the GCDAG (in consultation with WDEQ) laid plans for conducting this comprehensive assessment of the Goose Creek Watershed. The design included collecting credible chemical, physical, biological, bacteriological, and habitat information on Goose Creek, Big Goose Creek, Little Goose Creek and on eight tributaries within the watershed. By collecting these credible data, GCDAG would be able to evaluate attainment of beneficial uses applicable to each waterbody and define temporal (seasonal) and spatial (among sample stations) changes in water quality to identify impaired segments. Completion of this comprehensive watershed assessment would be the technical basis for future watershed planning and implementation efforts.

During April 2001, SCCD initiated the monitoring program which included collecting pH, water temperature, conductivity, dissolved oxygen, total residual chlorine, fecal coliform, turbidity, alkalinity, biochemical oxygen demand, chloride, hardness, sulfate, ammonia, total nitrate nitrogen, phosphorus, and total suspended solids samples. In total, 46 monitoring stations were utilized on Goose Creek, Big Goose Creek, Little Goose Creek, and the eight tributaries. Five stations were installed on Goose Creek, 15 on Big Goose Creek, 18 on Little Goose Creek, and each of the eight tributaries were monitored at a single, lower station located near its mouth. Fecal coliform and turbidity samples collected five times during each of the months April, May, August, and October to comply with WDEQ's fecal coliform monitoring protocol. Continuous temperature recorders were used to monitor water temperatures at 15-minute intervals at the lowermost Goose Creek station, three Big Goose Creek stations, and three Little Goose Creek stations. Benthic macroinvertebrate samples were collected and habitat assessments were conducted at 19 sites on Goose Creek, Big Goose Creek, and Little Goose Creek during September. Year 2001 monitoring concluded during October.

Year 2002 monitoring was similar to the previous year's monitoring with a few exceptions. BOD samples were not taken during 2002 since approximately 96% of all 2001 samples were analyzed as non-detectable and did not warrant further monitoring. *E. coli* samples were collected once during April, May, and October, and five times during August to coincide with fecal coliform monitoring. The *E. coli* samples were collected in anticipation of WDEQ changing the pathogen indicator standard from fecal coliform to *E. coli* in 2004. Fecal coliform samples were collected at three sites during April and September while disturbing stream bed sediment with a rake. This sampling was conducted to determine if higher fecal coliform concentrations were present in the sediment and to determine if the bacteria could survive through the winter months. Thirteen pesticides and herbicides were monitored during a single June monitoring event at three sites located on Goose Creek, Big Goose Creek, and Little Goose

Creek. During 2002, an additional three continuous temperature recorders were installed to monitor water temperatures on Soldier Creek, Beaver Creek, and Jackson Creek. Year 2002 monitoring concluded during October.

The Goose Creek Watershed Assessment (GCWA) identified pollutants affecting Goose Creek, Big Goose Creek, Little Goose Creek and the eight primary tributaries. There were no significant pollutants identified from point source discharges, therefore the majority of pollutants affecting water bodies were from non-point sources. The assessment provided potential sources for pollutants and discussed land use associations with fecal coliform bacteria and certain water quality parameters.

Water quality within the three major waterbodies, Goose Creek, Big Goose Creek, and Little Goose Creek, generally improved from downstream to upstream with few exceptions. The water in Big Goose Creek and Little Goose Creek leaving the BHNF was of very high quality with rare occurrences of high fecal coliform concentrations. After leaving the mountain foothills, fecal coliform concentrations and water temperatures in Big Goose Creek and Little Goose Creek increased while traveling through the agricultural, rural, and suburban areas south and west of Sheridan, Wyoming. Land uses and population densities along these streams steadily increase toward Sheridan which is reflected in changes to water quality. Water quality in lower Big Goose Creek, lower Little Goose Creek, and Goose Creek was of lesser quality. In contrast, water quality appeared to improve with several water quality parameters at the lowermost station (GC1) located near Acme, Wyoming. Comparisons of current WDEQ, GCWA, and USGS fecal coliform data to historic USGS data on lower Goose Creek indicate bacteria concentrations have declined significantly since the 1970's and early 1980's. This decline appears to correspond with the timing of facility upgrades made at the Sheridan Waste Water Treatment Plan (WWTP) in 1983 and 1984.

Goose Creek sites throughout Sheridan (GC2, GC3, GC5, and GC6) exceeded the fecal coliform standard on at least one occasion. The lowermost site, GC1, did not have a geometric mean that exceeded 200 CFU/100 mL during this assessment. Lower Big Goose Creek sites BG1 through BG4 each exceeded the fecal coliform standard during the assessment while sites BG5 through BG18 (not including the tributary sites) had geometric means less than 200 CFU/100 mL. Little Goose Creek proper sites LG1 through LG4 and LG6 through LG12 also exceeded the fecal coliform standard. Sites LG5 and LG13 through LG22 (not including the tributary sites) never violated the standard during this assessment. Current and historic WDEQ and USGS fecal coliform monitoring generally revealed higher fecal coliform concentrations on Goose Creek, Big Goose Creek, and Little Goose Creek than those found during the 2001-2002 GCWA. During 1998 and 1999 monitoring, WDEQ found fecal coliform impairments on upper Goose Creek throughout Sheridan, on Big Goose Creek from it's mouth to the canyon, and on Little Goose Creek from it's mouth to the canyon. Lower fecal coliform concentrations found during the GCWA may be attributable to below normal discharge observed while collecting these samples. Sampling conducted during the Project suggested that higher bacteria populations are present within bed sediment which may be re-suspended during higher flows.

Monitoring stations that were found during the assessment to exceed the fecal coliform standard also exceeded WDEQ's proposed *E. coli* standard of 126 CFU/100 mL for Full Body Contact recreational waters (WDEQ, 2002). Of the 19 sites monitored during August 2002, 10 stations exceeded the proposed *E. coli* standard and existing fecal coliform standard. However, of these 10 stations, Goose Creek site GC2 exceeded only the *E. coli* standard and site BG1 exceeded only the fecal coliform standard. Paired fecal coliform and *E. coli* samples collected throughout the watershed during 2002 should provide sufficient baseline data for future references operating under the new regulations which will use *E. coli* as the indicator of bacterial pathogens.

Water temperatures in Goose Creek, lower Big Goose Creek, and lower Little Goose Creek were often found to exceed the 20°C instream limit set forth in the Wyoming Water Quality Standards. Instantaneous measurements with field meters occasionally recorded temperatures in excess of 20°C, however, the time at which these samples were taken often did not correspond with the actual daily high water temperatures. Continuous water temperature data collected at Goose Creek site GC1, Big Goose Creek sites BG2 and BG6, and Little Goose Creek sites LG2 and LG8 showed routine daily exceedences of the maximum instream temperature standard from May until September. Moreover, each of these sites observed periods when water temperatures never cooled below 20°C. These continuous water temperature data, when evaluated with benthic macroinvertebrate data and historic fisheries data, suggest most lower reaches of the watershed are more accurately represented as warm-water fisheries. Continuous temperature data and 2001 – 2002 instantaneous temperature measurements suggest the entire length of Goose Creek, Big Goose Creek from it's mouth to the canyon, and Little Goose Creek from it's mouth to the canyon regularly exceed the water temperature standard.

Three dissolved oxygen measurements did not meet Wyoming Water Quality Standards. DO measurements less than 5.0 mg/L were taken at Goose Creek site GC1, Big Goose Creek site BG5, and Park Creek site BG13. However, these measurements only represented 0.14% of all GCWA dissolved oxygen samples taken and were taken at or near the lowest discharges recorded during the Project. In general, DO throughout the watershed was good to excellent.

Based on mean Wyoming Stream Integrity Index (WSII) values derived from current and historic benthic macroinvertebrate sampling, the entire reach of Goose Creek from its headwaters in Sheridan at the confluence of Big Goose Creek and Little Goose Creek, to its confluence with the Tongue River, had either fair or poor biological condition. It should be noted however, that aquatic life use support in the Placheck Pit, a former surface coal mine pit constructed in the main Goose Creek channel, was unknown due to lack of sampling. Two rainbow trout, a cold water game fish species, were collected in gillnet samples from the Placheck Pit by Wyoming Water Resources Research Institute (WWRRI) in 1977. The rainbow trout were probably stocked or transients from upstream Goose Creek or downstream Tongue River and were apparently able to survive in the cooler water temperature refuge afforded by the pit. Brown trout were collected in 62% of samples from Goose Creek and the 2 rainbow trout collected only from the Placheck Pit suggested the Pit may support cold water aquatic life use. It should also be noted that when Brown trout were collected in Goose Creek, they were never abundant and ranged from only 1 fish to 3 fish per sample. This observation indicated brown trout populations were marginal at Goose Creek sample stations.

Although biological condition based on benthic macroinvertebrate populations improved downstream of Sheridan between Goose Creek station GC1A and GC1, the lower biological condition values indicated non-support of the narrative WDEQ water quality standard for aquatic life use for all of Goose Creek, with perhaps the exception of the Placheck Pit.

As indicated by mean WSII values derived from current and historic benthic macroinvertebrate sampling, Big Goose Creek appears to attain aquatic life use from station BG18 in the canyon on the T-T Ranch downstream to station BG4 located at Normative Services. It should be noted that although aquatic life use support occurs through the reach from station BG18 to BG4, water quality and habitat stressors appeared to negatively affect biological condition at stations BG15, BG14, BG8 and BG4, but not to the degree to result in non-attainment of aquatic life use. It was proposed that the reach from station BG18 to downstream station BG14 be described as fully supporting, but threatened for aquatic life use support; and the reach from station BG10 to downstream station BG4 be described as fully supporting, but threatened for aquatic life use support. Biological condition was reduced between station BG4 and BG2 in Sheridan indicating non-support of aquatic life use within this stream reach. Further, it is likely the stream reach from station BG2 to the confluence with Little Goose Creek in Sheridan did not support aquatic life use.

Little Goose Creek appears to support aquatic life use from upstream station LG22 downstream to station LG10 based on WSII values derived from current and historic benthic macroinvertebrate sampling. Biological condition at station LG10 indicated marginal aquatic life support during 2001 sampling, but non-support for samples collected in 1998 and 2002. Biological condition decreases and aquatic life use was not supported at each consecutive station downstream from station LG10 into Sheridan. This observation was supported by fisheries data that found a shift from cold water fish species to more non-game and warm water game species from the Highway 87 bridge downstream to the Woodland Park bridge near Little Goose Creek station LG7 for this Project. Biological condition continues to decline from station LG7 downstream to station LG2A in Sheridan and non-support of aquatic life use is indicated.

Additional evaluation of the biological condition data using the “weight of evidence” approach described in WDEQ (2002b) by incorporating chemical, physical, and biological data in addition to consideration of soils, geology, hydrology, climate, geomorphology, and stream succession, supported the finding that Little Goose Creek did not support aquatic life use from station LG10 downstream to station LG2A. It is probable the stream reach from station LG2A downstream to the Big Goose Creek confluence did not support aquatic life use. Further, the biological condition at station LG10 indicated full support for aquatic life, but there was a downward trend indicating potential non-support in the near future. It was recommended that the stream reach from station LG18 to downstream station LG10 be described as fully supporting, but threatened for aquatic life use support. The factors that are most likely to contribute to lowered aquatic life support are water temperature, turbidity, nutrients, channel modifications, and stream discharge.

Stream discharges observed during the Project were significantly less than normal for the watershed as a result of the continuing drought affecting North-Central Wyoming. In summary, discharge during 2001 and 2002 was 31% and 29% of normal at USGS Station No. 06305700 (Goose Creek Near Acme), 44% and 57% of normal at USGS Station No. 06301500 (West Fork Big Goose Creek Near Big Horn, and 42% and 55% of normal at USGS Station No. 06303500 (Little Goose Creek in Canyon), respectively. Discharge quantities normally affect most water quality parameters, macroinvertebrate communities, fisheries production, and riparian habitat. Stream dewatering and irrigation return flows probably had a greater impact on overall water quality during 2001-2002 than during normal years due to the drought and increased demand for supplemental watering. However, stream dewatering has likely affected water quality in this watershed for several decades.

Water quality in the eight tributaries was generally of lesser quality than Goose Creek, Big Goose Creek, and Little Goose Creek. Each of the tributaries, except Beaver Creek, exceeded the fecal coliform standard during the assessment. However, Beaver Creek nearly exceeded the standard on several occasions and did exceed WDEQ's proposed *E. coli* standard of 126 CFU/100 mL during August 2002. Soldier Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek also exceeded the proposed *E. coli* standard during August 2002. *E. coli* samples were not collected from Park Creek during August 2002 because the stream was dry.

Soldier Creek had fecal coliform concentrations greater than 200 CFU/100 mL during each of the months of May and August, 2001 and 2002. Jackson Creek had fecal coliform geometric means greater than 200 CFU/100 mL during three months of the assessment. Park Creek, McCormick Creek, and Sackett Creek exceeded the fecal coliform standard during two months each. The fecal coliform standard was exceeded during one month only at Rapid Creek and Kruse Creek.

Continuous temperature data collected from Soldier Creek, Beaver Creek, and Jackson Creek during 2002 provided nearly identical results. Beaver Creek and Jackson Creek each exceeded 20°C during 45 days during 2002. Soldier Creek only exceeded the temperature standard during 34 days, however, the data logger was partially buried in stream sediment during much of June and these data were not included. Since daily average temperatures were nearly identical for these three streams during 2002, it is estimated that Park Creek, Rapid Creek, McCormick Creek, Kruse Creek, and Sackett Creek would have yielded similar results.

The Coffeen Avenue storm drain (site LG3) generally had very poor water quality. However, the volume of water from this storm drain entering Little Goose Creek was only about 35 gpm (0.08 cfs) on average. Conductivity, total sulfate, total chloride, total nitrate nitrogen, and total hardness were highest at this site during the GCWA. This storm drain also had fecal coliform geometric means greater than 1,100 CFU/100 mL during both August 2001 and August 2002. Although site LG3 was the only urban storm drain monitored during this assessment, historic data collected by WDEQ and others have shown that several other Sheridan storm drains discharge similar water quality and may collectively have a significant impact on local water quality.

None of the eight individual tributaries and one storm drain monitored during this Project appeared to have a drastic impact on the water quality of Goose Creek, Big Goose Creek, and/or Little Goose Creek. Poorer tributary water quality was usually offset by their relatively low flow contributions and subsequent dilution into the larger streams. However, the combined effect of all tributary waters, storm drains, irrigation returns, and non-point sources of various pollutants did have a profound effect on the water quality of the main streams when proceeding from upstream to downstream. Water quality in Big Goose Creek and Little Goose Creek steadily decreases towards and through Sheridan, and was not be attributed to solely to single sources.

Evaluation of historic and current monitoring data indicated full support for agricultural, industrial, scenic value, and wildlife beneficial uses and the applicable Wyoming narrative water quality criteria. There were no historic, current, or anecdotal information to suggest non-attainment of the Wyoming beneficial use for fish consumption. Beneficial uses for Class 2AB streams within the watershed are defined in Section 4 of this Final Report and are as follows:

1. Agriculture;
2. Fisheries;
3. Industry;
4. Drinking water;
5. Recreation;
6. Scenic value;
7. Aquatic life other than fish;
8. Wildlife; and
9. Fish consumption.

WDEQ standards and/or beneficial uses should not be the sole means by which water quality is measured, or improvement strategies are planned. Existing standards may not adequately reflect the impacts of some parameters on overall ecosystem quality. Public expectations uncovered through a local planning process should provide direction at least equal to that provided by the regulatory standards.

During June 2003, the SCCD received Clean Water Act 319 federal funding to initiate local watershed planning and implementation to address water quality impairments identified within the Goose Creek watershed. In Wyoming, TMDL development for listed streams is usually identified as a low priority if a local watershed planning program is in place. This process will follow the assessment and commence during the fall of 2003.

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LIST OF ACRONYMS USED IN THIS DOCUMENT

ABA	Aquatic Biology Associates, Inc.
ANL	Argonne National Laboratories
APHA	American Public Health Association
BG	Big Goose Creek
BHNF	Big Horn National Forest
BLM	Bureau of Land Management
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
BURP	Beneficial Use Reconnaissance Program
CBM	Coal-Bed Methane
cfs	Cubic Feet per Second
CFU/100 mL	Colony Forming Units per 100 Milliliters
COC	Chain of Custody
DO	Dissolved Oxygen
DQO	Data Quality Objective
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
FC	Fecal Coliform Geometric Mean
GC	Goose Creek
GCDAG	Goose Creek Drainages Advisory Group
GCWA	Goose Creek Watershed Assessment
gpm	Gallons per Minute
GPS	Global Positioning System
HBI	Hilsenhoff Biotic Index
HUC	Hydrologic Unit Code
IML	Inter-Mountain Laboratories, Inc.
LG	Little Goose Creek
MDL	Minimum Detection Limit
mg/L	Milligrams per Liter
N/A or NA	Not Applicable
NAWQA	National Water-Quality Assessment Program
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Units
PIP	Project Implementation Plan
ppm	Parts Per Million
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RPD	Relative Percent Difference
S.U.	Standard Units

SAP	Sampling and Analysis Plan
SAWS	Sheridan Area Water Supply
SCC	Sheridan County Commission
SCCD	Sheridan County Conservation District
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TNTC	Too Numerous To Count
TRC	Total Residual Chlorine
TSS	Total Suspended Solids
ug/L	Micrograms per Liter
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
WACD	Wyoming Association of Conservation Districts
WBCI	Wyoming Biological Condition Index
WDA	Wyoming Department of Agriculture
WDEQ	Wyoming Department of Environmental Quality
WEST	Western EcoSystems, Inc.
WEV	Weighted Embeddedness Value
WGFD	Wyoming Game and Fish Department
WMP	Watershed Management Plan
WRDS	Water Resources Data System
WSII	Wyoming Stream Integrity Index
WWRC	Wyoming Water Resources Center
WWRRI	Wyoming Water Resources Research Institute
WWTP	Waste Water Treatment Plant
YSI	Yellow Springs Instruments

1. INTRODUCTION

1.1 STATEMENT OF NEED

Big and Little Goose Creeks originate in the Big Horn Mountains west of Sheridan, Wyoming and pass through the Big Horn National Forest (BHNF), several ranches, rural sub-divisions, and through the towns of Big Horn and Sheridan. Near the center of Sheridan, Big and Little Goose Creek join to form Goose Creek. Each of these streams are classified by the Wyoming Department of Environmental Quality (WDEQ) as Class 2AB – Coldwater Fisheries and are closely tied to local agriculture, recreational uses, and drinking water supplies.

Accessible to over 27,000 Sheridan County residents, these streams and their tributaries are used extensively throughout the year. Local citizens of all ages commonly recreate on these streams, especially in Sheridan's city parks and along recreational pathways. Sheridan was settled around these streams and today they remain highly accessible – Big Goose Creek flows through Kendrick Park, Little Goose Creek flows through Emerson and Washington Parks, and Goose Creek passes by Thorne-Rider Park. Due to their extensive use, easy access, and direct contact with the public it is essential that these waterways are of highest quality.

The United States Geological Survey (USGS) has collected quarterly water quality samples within the Goose Creek watershed for several years. During the course of this sampling, a number of fecal coliform samples were found to have elevated concentrations of bacteria. The WDEQ used data collected by the USGS during the 1993 through 1997 water years to place Big and Little Goose Creek on Table A of the 1998 Section 303(d) list of impaired waters.

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The 1998 and 1999 sampling campaign conducted by WDEQ did not adequately identify the potential sources and magnitude of fecal coliform contamination. Moreover, sampling and supporting analyses to determine attainment of the other beneficial uses applicable to these waterbodies (e.g. agriculture, protection and propagation of fish and wildlife, industry, scenic value, and aquatic life use) was inadequate both in the number of parameters monitored and in the frequency of sampling.

At the time when the Goose Creeks Watershed Assessment (GCWA) was initiated in 2000, Beaver Creek, Big Goose Creek, Goose Creek, Jackson Creek, Kruse Creek, Little Goose Creek, Park Creek, Rapid Creek, Sackett Creek, and Soldier Creek were placed on Wyoming's 303(d) list (Table A) for fecal coliform bacteria impairments as a result of WDEQ's 1998 and 1999 monitoring. Additionally, Goose Creek was listed on Table B of the 303(d) list for ammonia, fecal coliform, and chlorine as part of the routine National Pollutant Discharge Elimination System (NPDES) permit renewal for the Sheridan Waste Water Treatment Plant (WWTP).

To address these impairments and prevent TMDL regulation, the Goose Creek Drainages Advisory Group (GCDAG) was formed as a collaborative partnership among the Sheridan County Conservation District (SCCD), the Sheridan County Commission (SCC), and the City of Sheridan. Additional rural, urban, and locally interested parties also serve on this committee. In July 2000, the GCDAG received $217,500 in federal Clean Water Act Section 319 funding, from the United States Environmental Protection Agency (EPA). The grant, which was disseminated through WDEQ, allowed the GCDAG to design and implement a comprehensive watershed assessment. The federal dollars were required to be matched with $145,000 in non-federal cash or services. The match responsibility was divided among the three sponsors.

During 2000, the GCDAG (in consultation with WDEQ) laid plans for conducting the GCWA. The design included collecting credible chemical, physical, biological, bacteriological, and habitat information on Goose Creek, Big Goose Creek, Little Goose Creek, and on eight tributaries within the watershed. By collecting these credible data, GCDAG would be able to evaluate attainment of beneficial uses applicable to each waterbody and define temporal (seasonal) and spatial (among sample stations) changes in water quality to identify impaired segments. Completion of this GCWA would be the technical basis for future watershed planning and mitigation efforts.

2. PLANNED PROJECT GOALS AND RELATED TASKS

Project goals and tasks for this assessment were prescribed in the August 16, 1999 Request for Project Funding (by Section 319 of the Clean Water Act) and in the February 2000 Project Implementation Plan (PIP) (SCCD, 2000a). The specific goals of the project were to:

- Conduct a comprehensive watershed assessment to identify impaired segments of Goose, Big Goose, and Little Goose Creeks; and

- Provide information and education to the affected interests and general public to encourage public involvement in the planning and mitigation efforts.

The goals and necessary tasks described in this Section are the result of a collaborative effort among representatives of the SCCD, the SCC, and the City of Sheridan.

2.1 GOAL 1

Goal 1 was to conduct a comprehensive watershed assessment to identify impaired segments of Big Goose, Little Goose, and Goose Creek. This goal was completed as planned as discussed in Sections 6 and 8 of this Final Report.

2.1.1 TASK 1

Task 1 directed SCCD to provide Project Administration for this assessment in consultation with the GCDAG. General responsibilities in this category included preparation of a PIP, project accounting, ordering supplies, reimbursement applications, organization of GCDAG meetings, maintenance of project records, and preparation of progress, status, and final reports. This task was completed as planned.

2.1.2 TASK 2

Task 2 required SCCD to compile and evaluate current data (less than 5 years old) and historical data (more than 5 years old). Historical data would be used to aid in developing a monitoring plan to include sample locations and parameters monitored. Potential sources of historical data would include local, state, and federal resource agencies and other watershed stakeholders. SCCD was required to create a historical database and provide a summary of this data in the Final Report. This task was completed as planned. Current and historical data for the watershed are discussed in Section 5 of this Final Report.

2.1.3 TASK 3

Task 3 required SCCD, under the direction of the GCDAG, to prepare and distribute a Sampling and Analysis Plan (SAP) that could be used to direct all monitoring activities for this assessment. A Quality Assurance Project Plan (QAPP) would be required to supplement the SAP and provide standards for Quality Assurance/Quality Control (QA/QC) measures. This task also required obtaining landowner permission for sampling access, maintaining sample sites, and acquiring the necessary monitoring equipment to conduct the assessment. This task was completed as planned and is discussed in Section 6.

2.1.4 TASK 4

Task 4 required the SCCD – coordinated sampling team, under the direction of GCDAG, to collect and analyze samples for presentation of chemical, physical, bacteriological, biological, and habitat data. This would include field preparations, sample collection, on-site analyses (for field parameters), and lab analyses. Sampling techniques would comply with WDEQ sampling protocol as described in the SAP. Photopoints would be required at each sample station and meteorological data would be obtained for the project. This task was completed as planned. Sections 6 and 8 address Task 4 requirements in detail.

2.1.5 TASK 5

Task 5 required SCCD to create and maintain an electronic database for data obtained during the assessment. Data would be subjected to QA/QC requirements and analyzed to determine impaired stream segments. Monitoring results would be compared to Wyoming Water Quality Standards for determinations of beneficial use attainment. This task was completed as planned and these activities are described in Sections 6, 7, and 8.

2.2 GOAL 2

Goal 2 was to provide information and education to the affected interests and general public to encourage public involvement in future planning and mitigation efforts. This goal was accomplished as described in Section 2.2.1.

2.2.1 TASK 6

Task 6 required GCDAG to coordinate the dissemination of information through this assessment project, the Goose Creek Watershed Awareness Information and Education Project, and the Sheridan County Animal Feeding Operations Improvements Project. A public meeting, conducted by GCDAG, was held in November 2000 to introduce the project to the public. Initially, the GCDAG proposed multiple public meetings to keep the public updated, however the project received a lot of media attention and the GCDAG decided to wait until there were data to be presented before having additional meetings. All GCDAG meetings were open to the public. In addition, SCCD personnel provided several updates and presentations to various groups, including local engineering companies, the Basin Advisory Group for the Powder/Tongue River Basins, the Wyoming Association of Conservation Districts (WACD), and others.

SCCD personnel used the Enviroscape Model and other educational resources to demonstrate the effects of non-point source pollution on watersheds to local schools and interested parties.

A semi-annual newsletter describing the assessment process and findings was not completed specifically for this project. However, updates were included in all of the SCCD newsletters, which are distributed to Sheridan County residents in May and November each year. The GCWA received a lot of public attention and media resources were heavily used. The public was kept up to date through several newspaper articles, regional television and local radio news stories, appearances on Public Pulse, a local radio talk show, and other available resources. This task was completed, with the above mentioned modifications, as planned.

3. DESCRIPTION OF PROJECT AREA

3.1 THE GOOSE CREEK WATERSHED

The majority of surface waters forming Goose Creek originate in the Big Horn Mountains south and west of Sheridan, Wyoming with additional tributaries joining from the foothills and plains in the lower reaches of the watershed. The two main tributaries to Goose Creek, Big and Little Goose Creek, flow from the Big Horn Mountains and join in Sheridan, Wyoming. Goose Creek then meanders north before entering the Tongue River near Acme, Wyoming.

The Goose Creek watershed has an approximate drainage area of 415 square miles and is identified by hydrologic unit code (HUC) 10090100-010. Map A-1 shows the Goose Creek watershed as it is located primarily in Sheridan County, Wyoming and Map A-2 provides a larger-scale view of the watershed identifying local communities, highways, and landmarks.

3.2 GOOSE CREEK

Goose Creek forms at the confluence of Big Goose Creek and Little Goose Creek near downtown Sheridan, Wyoming. More precisely, the confluence occurs south of the Dow Street and Alger Street intersection. Goose Creek then flows in a northerly direction from this confluence to its intersection with the Tongue River near Acme, Wyoming.

Goose Creek is a 5^{th} order stream (Strahler, 1957) located within the Great Plains Ecoregion (Omernik and Gallant, 1987). Because ecoregions are regions of relative homogeneity with respect to ecological systems (Hughes, 1995), the change from one ecoregion to another indicates that normal changes in environmental, ecological, and water quality characteristics are expected along the longitudinal gradient of the Goose Creek drainage. Goose Creek is predominantly a low gradient, meandering “C” type channel (Rosgen, 1996). Goose Creek is considered by the Wyoming Game and Fish Department (WGFD) to be a Class 5 trout fishery, which means it is a very low production trout water and is not likely to sustain a trout fishery (WGFD, 1991).

The predominant geology within the Goose Creek floodplain is alluvium and colluvium comprised of clay, silt, sand, and gravel (USGS, 1985). The meandering character of the creek combined with these geological characteristics naturally provide greater potential for clay and silt introduction and deposition in the creek. Because of the greater natural potential of siltation in the creek, it is even more important for local land users to practice wise soil and water conservation practices and employ Best Management Practices (BMP’s) where appropriate.

Soils along Goose Creek, as described by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), are primarily of the general

Haverdad-Zigweid-Nuncho group, which are very deep, loamy and clayey soils, typically found in floodplains, alluvial fans, and terraces. Another general group, the Nuncho-Platsher-Samday group, comprises a smaller area adjacent to and west of Goose Creek located north of Sheridan. This group is broadly classified as shallow and deep clayey soils found on terraces, hills, and alluvial fans (NRCS, 1998).

Land uses vary longitudinally along Goose Creek. From Acme upstream to Sheridan, the adjacent lands are predominantly used for agriculture including irrigated and non-irrigated hay meadows, wildlife habitat, and range land. Figure 3-1 at the end of this section is viewed from the east side of Goose Creek looking south and west at Sheridan and the Big Horn Mountains. Range lands, riparian areas (Goose Creek), Highway 338, and irrigated hay lands are shown in the foreground. Historically, the area around Acme was developed to extract coal by surface and underground mining methods. During reclamation of an inactive mine, a portion of Goose Creek upstream from Acme was channelized and the banks were reinforced to prevent further channel erosion. More recently, coal bed methane development has occurred between Acme and Sheridan, but the majority of this development to date lies outside the Goose Creek watershed. The northern portion of Sheridan could be classified as a lightly industrial area to include the Sheridan WWTP, a concrete plant, a sawmill, a livestock sale facility, a Veterans Administration hospital, and other small businesses. The uppermost segment of Goose Creek flows mainly through Sheridan’s residential, recreational, and retail business areas. In these upper reaches, the majority of Goose Creek has been channelized (straightened) to protect Sheridan from larger flooding events.

Irrigation of hay meadows, pasture land, and residential areas constitutes a great demand on surface waters within the watershed. Most irrigation diversions take surface water from Big and Little Goose Creeks and their associated tributaries. The Grinnell Livestock Company Ditch is the only major diversion that takes water from Goose Creek. Located approximately 1/4 mile downstream from the Sheridan WWTP, this diversion distributes surface waters to irrigated lands located between Highway 338 and Goose Creek north of Sheridan.

3.2.1 SOLDIER CREEK

The headwaters for Soldier Creek are in the BHNF near Walker Mountain at an elevation of about 8,000 feet. Soldier Creek is a 4th order stream (Strahler, 1957) with a total drainage area of approximately 33.3 square miles. The stream enters Goose Creek from the west approximately 1,000 feet upstream from the Fort Road bridge. The WGFD has designated Soldier Creek as a Class 5 trout fishery, which means it is a very low production trout water and is not likely to sustain a trout fishery (WGFD, 1991).

Several intermittent streams (Hammel, Warriner, and Hultz Draws) enter Soldier Creek along its course and several diversions remove water for irrigation of hay meadows and pastures. The PK and Alliance ditches divert water from Big Goose Creek for use in the Soldier Creek and Wolf Creek (Tongue River) watersheds.

The upper Soldier Creek watershed overlays several geologic formations, but alluvium and colluvium deposits, located adjacent the channel, are most prolific. Shales and light colored sandstones from the Fort Union Formation are predominant in the lower portions of the watershed. Thick coal seams are also commonly found in the Fort Union Formation (USGS, 1985).

Soils in the upper Soldier Creek watershed consist primarily of the Tolman-Cloud Peak-Starley association indicating steep slopes with shallow to moderately deep loamy soils located on mountain slopes, ridges, and hills (NRCS, 1998). In the middle reaches of the watershed, the Trimad-Trivar-Abac association is present on nearly level to steep mountain toe slopes, terraces, and alluvial fans. These soils are generally shallow and very deep loamy soils. The Haverdad-Zigweid-Nuncho association is present in the lower portion of the watershed with very deep loamy and clayey soils on level to gently sloping alluvial fans, terraces and floodplains.

Land uses vary greatly from the upper to lower reaches of the watershed. In the upper areas, wildlife habitat, cattle grazing, and recreation are the main uses on the BHNF. Ranches with range lands and irrigated hay lands dominate the watershed from the BHNF boundary to Sheridan. The lowermost portion of Soldier Creek passes through the Downer Addition located northwest of Sheridan. In 2002, the USDA-Rural Utilities Service obtained funding to provide approximately 150 properties in the Downer Addition with public water and sewer systems. The properties operated on private wells and septic systems prior to these improvements installed during the summer of 2002.

3.3 BIG GOOSE CREEK

Big Goose Creek is the largest tributary to Goose Creek with headwaters forming in the Cloud Peak Wilderness at elevations approaching 11,000 feet. Big Goose Creek forms at the confluence of East Fork Big Goose Creek and West Fork Big Goose Creek approximately 2 miles southwest of the BHNF boundary. The creek flows from this confluence in a northeasterly direction to its confluence with Little Goose Creek in downtown Sheridan. At the mouth of Big Goose Creek, the watershed area is approximately 203 square miles. Rapid Creek, Park Creek, and Beaver Creek are the major tributaries to Big Goose Creek studied within the Project area.

After the confluence of the East and West Forks, Big Goose Creek becomes a 5^{th} order stream (Strahler, 1957). As the creek exits Big Goose Canyon, it enters a transition zone from the Big Horn Mountain foothills to the Great Plains. The creek transforms from a higher gradient and confined “B” type channel in the canyon to a lower gradient, meandering “C” type channel in the plains (Rosgen, 1996). Additionally, the creek exits the Middle Rockies Ecoregion and enters the Great Plains Ecoregion (Omernik and Gallant, 1987).

Within Big Goose Canyon, the creek flows through mostly plutonic rocks (quartz diorite to quartz monzonite). However, the creek also flows over relatively narrow formations consisting of dolomite, limestone, and sandstone before entering alluvium and colluvium deposits near the canyon mouth. Alluvium and colluvium is the predominant geology of the Big Goose Creek channel from the lower reach of the canyon throughout the plains to Sheridan (USGS, 1985).

Soils in the canyon are of the Tolman-Cloud Peak-Starley grouping, indicating shallow and moderately deep, loamy soils, which are present on moderate to very steep slopes. Soil types from the canyon to near the town of Beckton are of the Trimad-Trivar-Abac grouping indicating shallow to very deep, loamy soils found on mountain toe slopes, dip slopes, terraces, terrace escarpments, and alluvial fans. From the town of Beckton to the confluence with Little Goose Creek, the soils are of the Haverdad-Zigweid-Nuncho grouping containing very deep loamy and clayey soils found on alluvial fans, terraces, and floodplains (NRCS, 1998).

Land uses along Big Goose Creek range from wilderness and BHNF lands on the upper watershed to highly urban lands in the lower watershed. Land use intensifies with an increasing population density as Big Goose Creek flows east to Sheridan. In general, the main land uses between Sheridan and the BHNF boundary are irrigated hayland, non-irrigated hayland, wildlife habitat, and cattle grazing. However, many rural subdivisions have been constructed along Big Goose Road and along County Road 87 near Beaver Creek. As Big Goose Creek enters Sheridan, it flows through residential areas and Kendrick Park before meeting Little Goose Creek. Figure 3-2 shows Big Goose Creek with portions of Kendrick Park in the background. Segments of lower Big Goose Creek within Sheridan have also been channelized for flood control purposes.

WGFD classifies Big Goose Creek above USGS Station Number 06302000 in the canyon as a Class 2 trout fishery, which is considered to be a very good trout water of statewide importance (WGFD, 1991). From this USGS station downstream to the Rapid Creek confluence, Big Goose Creek is a Class 3 trout fishery and considered important trout waters of regional importance. Between Rapid Creek and Beaver Creek, Big Goose Creek is a Class 4 - low production trout water of local importance, but is thought to be generally incapable of sustaining substantial fishing pressure. Downstream from Beaver Creek to the Little Goose Creek confluence, the stream is considered a Class 5 trout fishery having very low production and is often incapable of sustaining a trout fishery.

Several water sources have been appropriated on Big Goose Creek. Many irrigation ditches withdraw water from Big Goose Creek and are described in the Big Goose Creek site descriptions in Section 6.2. The City of Sheridan and the Fort Mackenzie Veterans Administration also withdraw water from the canyon for domestic water supplies. An 1882 adjudication allows the city 16 cubic feet per second (cfs) of Big Goose Creek water and serves as the city’s primary water supply. Of the 16 cfs, up to 3 cfs may be used by the Fort per city ordinance Number 94 (1903). Twin Lakes Reservoir, located on the BHNF, provides the city with approximately 2,967 acre-feet of secondary storage water by permit. In addition, the Sheridan Area Water Supply (SAWS) has water rights of 7.14 cfs of direct stream flow with a 1989 priority date. SAWS also has right to stored water in Twin Lakes Reservoir (408 acre-feet), Park Reservoir (180 acre-feet), and Dome Lakes Reservoir (20.92 acre-feet). When released, there is a 10% loss of flow between the reservoirs and the diversion in Big Goose Canyon (City of Sheridan, 2001).

3.3.1 BEAVER CREEK

The headwaters for Beaver Creek originate in the BHNF at an elevation of approximately 7,600 feet. At the confluence with Big Goose Creek, Beaver Creek is a 3rd order stream (Strahler, 1957) having a drainage area of 13.2 square miles. The entire length of Beaver Creek has been designated a Class 5 trout fishery, which means it is a very low production trout water, often incapable of sustaining a trout fishery (WGFD, 1991).

Most of the Beaver Creek watershed lies in the Fort Union Formation known to have shales and light-colored sandstones interbedded with thick coal seams (USGS, 1985). Soils in the upper portion of the watershed are of the Tolman-Cloud Peak-Starley grouping, which are shallow and moderately deep loamy soils found on steep mountain slopes, ridges, and hills. In the foothills of the Big Horn Mountains, soils within this watershed are defined under the Trimad-Trivar-Abac association as shallow and very deep loamy soils found on mountain toe slopes, terraces, and alluvial fans. The Nuncho-Platsher-Samday grouping, found in the lower reaches of the watershed, is generally shallow to very deep clayey soils found on terraces, hills, and alluvial fans. Near the confluence with Big Goose Creek, very deep loamy and clayey soils of the Haverdad-Zigweid-Nuncho grouping are found typically on alluvial fans, terraces, and floodplains (NRCS, 1998).

Land uses in the upper watershed consist primarily of wildlife habitat above the BHNF boundary. Below the BHNF, ranches use the land for cattle grazing and irrigated hay meadows. Lower in the watershed, west of the Beaver Creek Hills, smaller ranches and rural subdivisions dominate the landscape. The Big Goose and Beaver Ditch diverts water from Rapid Creek and supplies many landowners in the Beaver Creek watershed with irrigation water.

3.3.2 PARK CREEK

Park Creek has a drainage area of 6.5 square miles making it the smallest tributary to Big Goose Creek studied within the Project area. Park Creek's headwaters are found at an elevation of about 7,800 feet approximately two miles east of Walker Mountain. The creek is a 3rd order stream (Strahler, 1957) and has been designated by WGFD as a Class 5 trout fishery throughout its length. A Class 5 trout fishery is a very low production trout water, often incapable of sustaining a trout fishery (WGFD, 1991).

The predominant geologic formation found within the watershed is the Cody Shale, which consists of gray shales, gray siltstones, and gray sandstones. Less common are alluvium and colluvium deposits located adjacent to the stream channel (USGS, 1985).

Soils in the upper Park Creek watershed are generally of the Tolman-Cloud Peak-Starley grouping, which are shallow to moderately deep loamy soils found on steep mountain slopes, ridges, and hills. The lower portion of the watershed consists mainly of the

Trimad-Trivar-Abac association. These soils are shallow to very deep loamy soils found on nearly level to steep mountain toe slopes, dip slopes, terraces, terrace escarpments, and alluvial fans (NRCS, 1998).

Land uses in the Park Creek watershed are generally cattle grazing, irrigated hay meadows, and wildlife habitat. A small area of the watershed lies within the BHNF, but is not readily accessible for recreation purposes. The Alliance and PK Ditches divert water from Big Goose Creek, pass through Park Creek, and continue into the Soldier Creek watershed.

3.3.3 RAPID CREEK

The largest tributary to Big Goose Creek within the project area is Rapid Creek. This creek has a drainage area of 16.6 square miles and originates at an elevation of approximately 8,200 feet two miles northeast of Park Reservoir. Rapid Creek evolves into a 3rd order stream (Strahler, 1957) before entering Big Goose Creek southwest of Beckton, Wyoming. The WGFD classifies the entire length of Rapid Creek as a Class 4 trout fishery (WGFD, 1991). Class 4 trout fisheries are defined as low production trout waters with local fisheries importance, but are generally incapable of sustaining substantial fishing pressure.

Upper Rapid Creek overlies plutonic rocks consisting mainly of quartz diorite and quartz monzonite. Farther downstream, the Cody Shale is present having gray shales, gray siltstones, and gray sandstones. The lower reaches of the watershed overlie the Lance Formation, which is a buff-colored sandstone with drab-green shales (USGS, 1985).

Soils in the upper portions of the watershed are generally of the Tolman-Cloud Peak-Starley grouping, which are shallow to moderately deep loamy soils found on steep mountain slopes, ridges, and hills. Lower in the watershed, soils of the Trimad-Trivar-Abac association are found. These soils are shallow to very deep loamy soils found on nearly level to steep mountain toe slopes, dip slopes, terraces, terrace escarpments, and alluvial fans (NRCS, 1998).

Watershed uses on the BHNF include recreation, wildlife habitat, and cattle grazing. Ranches with irrigated hay meadows and pasture lands are found on Rapid Creek below the BHNF boundary. These ranches generally provide good wildlife habitat.

The Big Goose and Beaver Ditch removes water from the East Fork Big Goose Creek about 1 mile below Park Reservoir and delivers it to Rapid Creek near its headwaters. Rapid Creek is then used as an irrigation conduit for this water until it is diverted from Rapid Creek less than 1 mile below the BHNF boundary. The Big Goose and Beaver Ditch then supplies irrigation water to landowners in Rapid and Beaver Creek watersheds. Near the mouth of Rapid Creek, Big Goose Creek water enters Rapid Creek via Ditch Number 9. Rapid Creek carries this water for a short distance before the ditch again recaptures the water and diverts it northeast parallel to Big Goose Creek.

3.4 LITTLE GOOSE CREEK

The East and West Forks join forming Little Goose Creek approximately ½ mile above the BHNF boundary. The headwaters of the East Fork form at over 10,000 feet in the Cloud Peak Wilderness and the West Fork originates in the BHNF east of Bighorn Reservoir. As Little Goose Creek leaves the BHNF, it flows east through a steep-walled canyon before turning north towards Big Horn and Sheridan. Many small tributaries enter the creek along its path to Sheridan; however, Sackett Creek, Jackson Creek, Kruse Creek, and McCormick Creek are the only tributaries studied in the GCWA.

After the confluence of the East and West Forks, Little Goose Creek becomes a 4^{th} order stream (Strahler, 1957). As Little Goose Creek exits the canyon, it enters a transition zone from the Big Horn Mountain foothills to the Great Plains. The creek transforms from a higher gradient and confined "B" type channel in the canyon to a lower gradient, meandering "C" type channel in the plains (Rosgen, 1996). In addition, the creek exits the Middle Rockies Ecoregion and enters the Great Plains Ecoregion (Omernik and Gallant, 1987).

From the BHNF boundary to the Highway 87 bridge crossing, Little Goose Creek is classified by WGFD as a Class 3 trout fishery (WGFD, 1991). From the bridge crossing downstream to Sheridan, the stream rating is lowered to a Class 5 trout fishery. Class 3 streams are important trout waters designated as fisheries of regional importance. Class 5 streams are very low production trout waters, which are often incapable of sustaining a trout fishery.

On the upper portion of the watershed, Little Goose Creek and its tributaries flow over predominantly plutonic rocks consisting of quartz diorite to quartz monzonite. As the creek enters the canyon, it begins to flow over several formations consisting of dolomite, limestone, sandstone, siltstone, claystone, shale, and depositional formations. Approximately 4 miles south of Big Horn, the creek enters a floodplain consisting of alluvium and colluvium that continues to its confluence with Big Goose Creek (USGS, 1985).

Soils in and above Little Goose Canyon are of the Tolman-Cloud Peak-Starley grouping indicating shallow and moderately deep, loamy soils that are present on moderate to very steep slopes. Soil types from the canyon to near the Bradford-Brinton Memorial are mainly of the Nuncho-Platsher-Samday grouping with lesser amounts of the Trimad-Trivar-Abac also present. The Nuncho-Platsher-Samday grouping consists mainly of shallow to very deep clayey soils found on terraces, hills, and alluvial fans. The Trimad-Trivar-Abac grouping indicate shallow to very deep, loamy soils found on mountain toe slopes, dip slopes, terraces, terrace escarpments, and alluvial fans. From near the Bradford-Brinton Memorial to the Big Goose Creek confluence, the soils are primarily of the Haverdad-Zigweid-Nuncho association containing very deep loamy and clayey soils found on alluvial fans, terraces, and floodplains. Minor reaches of the Nuncho-Platsher-Samday grouping are also found within this lower section (NRCS, 1998).

Land uses along Little Goose and Big Goose Creeks are very similar, but Little Goose Creek has a higher population density along its lower reaches. After leaving the BHNF and the Little Goose Canyon, the land use on this watershed is predominantly agricultural-- irrigated hayland, non-irrigated hayland, cattle grazing, and wildlife habitat. Near the town of Big Horn, more rural sub-divisions and urban areas are found. Downstream from Big Horn is a resort golf course and several larger subdivisions. Between Big Horn and Sheridan, the land is predominantly developed into small acreage parcels and is interspersed with smaller areas of agricultural land. Little Goose Creek flows through much of Sheridan, including business areas, residential areas, and recreational areas before meeting Big Goose Creek. The majority of Little Goose Creek through Sheridan has been channelized for flood control and development purposes. The lowermost reach of Little Creek has been placed in a concrete lined channel. The entrance to this channel is shown in Figure 3-3.

Little Goose Creek is a highly appropriated waterbody with irrigation ditches taking water from Little Goose Canyon to Sheridan. A more detailed description of the major diversions within this reach is provided with the Little Goose Creek sample site descriptions (Section 6.2). Above the BHNF boundary, two diversions route water from the Big Goose watershed into the Little Goose watershed. The Mountain Supply Ditch (a.k.a. Peralta Ditch) diverts Bighorn Reservoir water from Cross Creek into Willow Creek--a tributary to the West Fork Little Goose Creek. Bighorn Reservoir has a storage capacity of 4,627 acre-feet and is wholly appropriated to shareholders of the Little Goose watershed. The second ditch, the Park Reservoir Diversion Ditch, diverts water from Park Reservoir into Willow Creek. Park Reservoir contains 10,362 acre-feet of water when full; approximately 60% of this water is appropriated to Little Goose Creek shareholders.

3.4.1 McCORMICK CREEK

McCormick Creek is a relatively small watershed—with a drainage area of 6.4 square miles—that forms in the hills along Highway 87 north of Banner, Wyoming. Near the intersection of Highways 87 and 335, McCormick Creek enters Little Goose Creek. McCormick Creek is a 3^{rd} order stream (Strahler, 1957) and Class 5 trout fishery (WGFD, 1991). Class 5 fisheries are very low production trout waters, which are often incapable of sustaining a trout fishery.

The predominant geologic formation of the McCormick Creek watershed is the Main Body of the Wasatch Formation, which is comprised of red to gray and brown sandstones and mudstones with conglomerate lenses (USGS, 1985). Most soils within the watershed are of the Moskee-Hargreave grouping typically found on level to strongly sloping hillslopes and alluvial fans (NRCS, 1998). These are loamy soils with moderate to very deep profiles. Near the Little Goose Creek confluence, the soil type changes to the Haverdad-Zigweid-Nuncho association typically found on nearly level and gently sloping alluvial fans, terraces, and floodplains. These are categorized as very deep loamy and clayey soils.

Land uses on the watershed are mainly pasture land, irrigated hay land, and wildlife habitat; however, rural residences are more common in lower reaches of the watershed. The East Side Ditch diverts water from Little Goose Creek south of Big Horn and passes through the middle of the McCormick Creek watershed.

3.4.2 KRUSE CREEK

Kruse Creek begins on the north side of Moncreiffe Ridge west of Banner, Wyoming at an approximate elevation of 5,800 feet. The East Fork of Kruse Creek and Lee Creek enter before Kruse Creek joins Little Goose Creek near the intersection of Highways 87 and 335. Kruse Creek is a 3rd order stream (Strahler, 1957) with a total watershed area of 8.8 square miles. The WGFD considers the entire length of Kruse Creek to be a Class 5 trout fishery (WGFD, 1991). Class 5 streams are very low production trout waters often incapable of sustaining a trout fishery.

The main body of the Wasatch formation underlies the majority of the watershed. This formation is known to have red to gray and brown sandstones and mudstones with conglomerate lenses (USGS, 1985). In the area of Moncreiffe Ridge, soils are of the Agneston-Granile-Rock Outcrop grouping, which are moderate to very deep loamy soils found on steep mountain slopes (NRCS, 1998). Further north and downstream, a narrow band of the Norbert-Savage-Savar grouping is found. These are shallow to very deep clayey soils normally found on nearly level to steep hills, terraces, and alluvial fans. The predominant soil type, the Moskee-Hargeave association, is found in the central reaches of the watershed. These are moderately to very deep loamy soils found on hillslopes and alluvial fans. Near the Little Goose Creek confluence, the very deep, loamy soils of the Haverdad-Zigweid-Nuncho association are found on gently sloping alluvial fans, terraces, and floodplains.

Land uses in the watershed are generally irrigated hay land, pasture land, wildlife habitat, livestock grazing, and include a number of small acreage rural residences. A feedlot and a State Bird Farm are also located within the watershed. The East Side Ditch takes water from Little Goose Creek and diverts it through the Kruse Creek drainage. The Meade-Coffeen Ditch diverts Piney Creek water through Tunnel Hill, across upper Prairie Dog and Meade Creeks, and into the Kruse Creek watershed.

3.4.3 JACKSON CREEK

Jackson Creek forms just above the BHNF boundary at an elevation of about 7,200 feet. After passing through Big Horn, the creek enters Little Goose Creek north of the town approximately ½ mile. It is a 3rd order stream (Strahler, 1957) with an approximate drainage area of 10.3 square miles. Jackson Creek is considered by WGFD to be a Class 5 trout fishery, which is a very low production trout water probably incapable of sustaining a trout fishery (WGFD, 1991).

The Kingsbury Member of the Wasatch Formation underlies much of the upper and middle Jackson Creek watershed. This formation is a conglomerate of Paleozoic clasts interbedded with sandstones and claystones. Lower Jackson Creek flows over alluvium and colluvium (USGS, 1985).

Soils in the upper Jackson Creek watershed are of the Tolman-Cloud Peak-Starley grouping, which consists of loamy soils found on steep mountain slopes, ridges, and hills. The Trimad-Trivar-Abac soils are located in the mid- to upper portions of the watershed and include shallow to deep loamy soils found on mountain toe slopes, dip slopes, terraces, terrace escarpments, and alluvial fans. Soils in the middle and lower reaches of the watershed are mainly of the Nuncho-Platcher-Samday grouping to include shallow and very deep clayey soils found on terraces, hills, and alluvial fans (NRCS, 1998).

Land uses on the upper Jackson Creek watershed are mainly wildlife habitat, livestock grazing, and irrigated hay land. Lower in the drainage, rural subdivisions, the town of Big Horn, and irrigated hay lands are found. A small gravel mining operation is also present within the drainage. Landslides have occurred on hillslopes west of Highway 335 possibly as the result of saturating the gravel-shale contact zones. The Colorado-Colony Ditch is a major diversion that diverts water near Little Goose Canyon and passes through the Jackson Creek watershed.

3.4.4 SACKETT CREEK

Sackett Creek has a drainage area of approximately 3.4 square miles making it the smallest tributary studied in the GCWA. The headwaters originate at elevations up to 5,650 feet on the north side of Moncreiffe Ridge. The creek then meanders through foothills and plains before entering Little Goose Creek near the northeast corner of Big Horn.

Sackett Creek is a 3rd order stream (Strahler, 1957) and is designated by WGFD as a Class 5 trout fishery (WGFD, 1991). Class 5 trout streams are very low production trout waters, often incapable of sustaining a trout fishery.

The Moncreiffe and Kingsbury Conglomerate Members of the Wasatch Formation, consisting of clasts interbedded with sandstones and claystones, are present in the upper areas of the watershed. Near the middle of the stream reach, the thick shale and light colored sandstone bed of the Fort Union Formation are present. Lower in the reach, alluvium and colluvium are found adjacent to the channel down to the Little Goose Creek confluence.

Soils near the headwaters are of the Agneston-Granile-Rock Outcrop association, which consists of deep, loamy soils found on steep mountain slopes. The stream then passes through a narrow strip of the Norbert-Savage-Savar grouping. These are shallow to very deep clayey soils found on hills, terraces, and alluvial fans. Further downstream, the Moskee-Hargreave is present on nearly level to strongly sloping hillslopes and alluvial fans. These are normally moderate to very deep loamy soils. Near the town of Big Horn, the deep, loamy Haverdad-Zigweid-Nuncho soils overlie alluvial fans, terraces, and floodplains.

Land uses on the watershed are primarily wildlife habitat, livestock pasture, and irrigated hayland. Smaller acreage properties and rural residential areas become more common lower in the watershed near Big Horn.

3.5 LAND USES

As mentioned previously, the Goose Creek watershed comprises approximately 415 square miles, or 265,600 acres. Of this, about 115,000 acres are BHNF (43%); 9,900 acres are State lands and Military Reservations (4%); 4,000 acres are managed by the Bureau of Land Management (BLM) (2%); and 136,700 acres are privately owned (51%).

The BHNF is a multiple-use area and provides for various types of recreation, seasonal cattle grazing, wildlife habitat, and logging. Land use of privately owned lands is quite diverse. Small and large ranches own the majority of private lands—these ranches generally include pasture lands for cattle grazing, irrigated hay and crop lands, and corrals for short to long term feeding. An example of a diversion structure used to route irrigation water to hay lands is shown in Figure 3-4. Cattle grazing in a riparian area typical of the upper watershed are shown in Figure 3-5. Many private lands in rural areas continue to be sub-divided and developed as the Sheridan area continues to grow at a rapid pace. Urban areas include the towns of Sheridan and Big Horn. However, numerous rural subdivisions also exist within the watershed and tend to be most common along the lower reaches of the major drainages. The area also provides year-round habitat for small and big game, furbearers, waterfowl, game birds, and song birds. Figure 3-6 shows an example of big game found in habitat provided on private lands.

Streams and reservoirs within the watershed are highly appropriated and provide a crucial resource to ranches, subdivisions, and urban areas. Established diversions from these waterbodies to the end-users have created a complex web of water delivery systems where inter-drainage waters are often mixed and co-mingled. Many of the delivery and application systems operate at very low efficiencies losing much of the water to infiltration, seeps, and evaporation.

3.6 POINT SOURCE DISCHARGES

There are 12 existing NPDES permits within the Goose Creek watershed. The Sheridan WWTP (Permit Number WY0020010) and the Bighorn Mountain KOA sewage treatment plant (Permit Number WY0026441) have obtained NPDES permits, allowing the discharge of treated effluent to Goose Creek. Fidelity Exploration has obtained five discharge permits for coalbed methane waters within the Goose Creek watershed and are as follows: Acme CBM Project A (Permit Number WY0038628), Acme CBM Project C (Permit Number WY0038644), Acme CBM Project D (Permit Number WY0038652), Wrench Ranch (Permit Number WY0047066), and Wrench Ranch – Beatty Gulch (Permit Number WY0047074). Additional NPDES permits for coalbed methane facilities are expected in the future.

Two NPDES permits are currently in use on Big Goose Creek for Sheridan's public drinking water supply. Permit Number WY0035661 has been issued for the Pre-Treatment Plant near Big Goose Canyon and Permit Number WY0001392 was issued for the Treatment Plant near Gillispie Draw. The Joint Powers Board has been issued Permit Number WY0036480 for eight pressure relief valves on the SAWS system. Six of these valves are located in the Big Goose Creek drainage and two are located in the Little Goose Creek watershed.

Located along Little Goose Creek, the Powderhorn Golf Club has obtained NPDES Permit Number WY0036251 for the discharge of treated effluent from the Powderhorn's WWTP. In the Kruse Creek drainage, Garber Agri-Business has received an NPDES permit for storm waters captured from a feedlot for discharge onto irrigated haylands. K&H Construction, LLC has obtained Permit Number WY0039420 for a single discharge point into Jeffries Draw.

The City of Sheridan has a storm drain system with numerous discharge points to Goose Creek, Big Goose Creek, and Little Goose Creek. These drains generally convey storm waters from streets, parking areas, and residential areas to the creeks. Currently, the City of Sheridan is not required to permit or treat water from these drains under existing storm water regulations. However, it is likely that municipalities of this size will be regulated in the future.

Figure 3-1. **A view of land uses typically found along lower Goose Creek. Rangelands are shown in the foreground; the Goose Creek riparian corridor and Highway 338 are shown in the center; and irrigated hay lands, the north end of Sheridan, and the Big Horn Mountains are shown in the background.**

Figure 3-2. **An example of land use on lower Big Goose Creek. Big Goose Creek is shown in the foreground and portions of Kendrick Park are shown in the background.**

Figure 3-3. **View of lower Little Goose Creek entering the concrete lined channel in downtown Sheridan.**

Figure 3-4. **An example of an irrigation diversion structure used to route stream waters to irrigated hay lands.**

Figure 3-5. **Cattle grazing within a riparian area. This is a common land use in the upper, rural portions of the Goose Creek watershed.**

Figure 3-6. **An example of wildlife habitat in the upper Goose Creek watershed.**

4. STREAM LISTINGS, CLASSIFICATIONS, AND STANDARDS

4.1 STREAM LISTINGS

Section 303(d) of the Clean Water Act requires states to identify waters that are not supporting their designated uses, and/or need to have a TMDL established to support their uses. TMDL's are regulatory actions intended to induce changes within a watershed to achieve compliance with the waterbody's designated uses. In Wyoming, WDEQ encourages local watershed planning and implementation through voluntary efforts. WDEQ assigns a low priority for TMDL development to waterbodies with an active local planning effort and improvement effort in place. Streams found on 303(d) lists published by WDEQ are organized as follows:

- Table A. Waterbodies requiring TMDL's, for which there are credible data that indicate the reach does not support all its designated uses. These are considered impaired.

- Table B. Waterbodies requiring Waste Load Allocations and/or TMDL's in the two years following publication due to the routine NPDES renewal process for permits containing Waste Load Allocations.

- Table C. Waterbodies requiring watershed plans or TMDL's, for which there are data indicating trends away from supporting beneficial use and where there are improvement plans or other corrective actions in progress. These are considered threatened.

- Table D. Waterbodies removed from the previous 303(d) lists of waterbodies requiring TMDL's.

In 1998, Big Goose Creek and Little Goose Creek were listed on Table A for fecal coliform exceedences based on USGS data from Station Numbers 06305500 and 06304500, respectively. However, Big Goose Creek was incorrectly listed as Station Number 06305500, which is located on Goose Creek near the Sheridan WWTP. Goose Creek was listed on Table B in 1998 for ammonia, fecal coliform, and total residual chlorine as a result of the Sheridan WWTP NPDES permit renewal. Rapid Creek was placed on the 1998 Table D list for previous flow and siltation impairments (WDEQ, 1998).

In 2000, WDEQ placed Beaver Creek, Big Goose Creek, Goose Creek, Jackson Creek, Kruse Creek, Little Goose Creek, Park Creek, Rapid Creek, Sackett Creek, and Soldier Creek on the 303(d) Table A list for fecal coliform impairments. Credible data collected by WDEQ and/or USGS during 1998 and 1999 were the basis for these listings. Goose Creek also appeared on Table D because the Sheridan WWTP had completed its NPDES permit renewal (WDEQ, 2000).

In 2002, Table A listed the same streams for fecal coliform as did the 2000 303(d) list. However, Goose Creek was again placed on Table B for ammonia, fecal coliform, and total residual chlorine because of the routine renewal of the Sheridan WWTP NPDES permit (WDEQ, 2002).

4.2 STREAM CLASSIFICATIONS AND BENEFICIAL USES

During June 2001, WDEQ revised the Wyoming Surface Water Classification List to include subdivisions within the four existing classifications (WDEQ, 2001b). These subdivisions more specifically designated beneficial uses for surface waters and are shown in Table 4-1.

Table 4-1. June 21, 2001 Surface Water Classifications

Surface Water Classifications *Prior* to June 21, 2001	Surface Water Classifications *After* June 21, 2001
Class 1	Class 1
Class 2	Class 2AB
	Class 2A
	Class 2B
	Class 2C
Class 3	Class 3A
	Class 3B
	Class 3C
Class 4	Class 4A
	Class 4B
	Class 4C

After the June 21, 2001 revision, the following streams studied within the project area were deemed Class 2AB:

- Goose Creek;
- Soldier Creek;
- Big Goose Creek;
- Park Creek;
- Rapid Creek;
- Little Goose Creek;
- Kruse Creek;
- Jackson Creek; and
- Sackett Creek.

As defined in Chapter 1 – Wyoming Surface Water Quality Standards, Class 2AB waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either “cold water” or “warm water” depending on the predominance of cold water or warm water species present. Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are protected for that use (WDEQ, 2001a).

The June 21, 2001 classification list deemed Beaver Creek as a Class 3B waterbody. Class 3B waters are tributary waters including adjacent wetlands that are not known to support game fish populations or drinking water supplies and where those uses are not attainable. Class 3B waters are intermittent and ephemeral streams with sufficient hydrology to normally support and sustain communities of aquatic life including invertebrates, amphibians, or other flora and fauna that inhabit waters of the State at some stage of their life cycles. In general, Class 3B waters are characterized by frequent linear wetland occurrences or impoundments within or adjacent to the stream channel over its entire length (WDEQ, 2001a).

McCormick Creek has not been classified in the Wyoming Surface Water Classification List or in the WGFD's "Streams and Lakes Inventory" database. By default, Chapter 1, Appendix A would define McCormick Creek as a Class 3A, 3B, or 3C stream (WDEQ, 2001a).

The beneficial uses that are protected on Wyoming waters are listed and described in WDEQ's Water Quality Standards. The objectives of the Wyoming water pollution control program are designed to serve the interests of the state and achieve the related goals, objectives, and policies of the Federal Act (WDEQ, 2001a). The objectives of the Wyoming program are to provide, wherever attainable, the highest possible water quality commensurate with the following uses:

- Agriculture. For purposes of water pollution control, agricultural uses include irrigation or stock watering.
- Fisheries. The fisheries use includes water quality, habitat conditions, spawning and nursery areas, and food sources necessary to sustain populations of game and non-game fish. This does not include the protection of exotic species which are designated "undesirable" by the WGFD or the U.S. Fish and Wildlife Service with their appropriate jurisdictions.
- Industry. Industrial use protection involves maintaining a level of water quality useful for industrial purposes.
- Drinking water. The drinking water use involves maintaining a level of water quality that is suitable for potable water or intended to be suitable after receiving conventional drinking water treatment.
- Recreation. Recreational use protection involves maintaining a level of water quality which is safe for human contact. It does not guarantee the availability of water for any recreational purpose.
- Scenic value. Scenic value use involves the aesthetics of the aquatic systems themselves (odor, color, taste, settleable solids, floating solids, suspended solids, and solid waste) and is not necessarily related to general landscape appearance.
- Aquatic life other than fish. This includes water quality and habitat necessary to sustain populations of organisms other than fish in proportions which make up diverse aquatic communities common to waters of the state. This does not include the protection of insect pests or exotic species which are designated "undesirable" by the WGFD or the U.S. Fish and Wildlife Service with their appropriate jurisdictions.
- Wildlife. The wildlife use protection of water quality to a level which is safe for contact and consumption by avian and terrestrial wildlife species.

- Fish consumption. The fish consumption involves maintaining a level of water quality that will prevent any unpalatable flavor and/or accumulation of harmful substances in fish tissue.

Except for Class 1, waters are classified according to their designated uses. Class 1 waters are specially designated waters for which the existing water quality is protected regardless of the uses supported by the water. Table 4-2 shows the uses designated for each surface water classification.

Table 4-2. Surface Water Classes and Use Designations (WDEQ, 2001b)

Class	Drinking Water	Game Fish	Non-Game Fish	Fish Consumption	Other Aquatic Life	Recreation	Wildlife	Agriculture	Industry	Scenic Value
1*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	Yes	Yes	Yes	Yes	Yes
2AB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2A	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
2B	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2C	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3A	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3B	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3C	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4A	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4B	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4C	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes

* Class 1 waters are not protected for all uses in all circumstances. For example, all waters in the National Parks and Wilderness areas are Class 1, however, all do not support fisheries or other aquatic life uses (e.g. hot springs, ephemeral waters, wet meadows, etc.).

4.3 WATER QUALITY STANDARDS

Wyoming's surface waters are protected through application of narrative (descriptive) and numeric water quality standards described in Wyoming Water Quality Rules and Regulations, Chapter 1 (WDEQ, 2001a). For Class 2AB waters, the Human Health values for "Fish and Drinking Water" listed in Appendix B of Chapter 1 apply. The "acute" and "chronic" values for Aquatic Life apply to all Class 1, 2, and 3 waters. Table 4-3 provides a summary of relevant standards for the GCWA. Table 4-3 provides a reference for the applicable water quality standard and a brief summary of the standard. Please refer to Chapter 1 *in* WDEQ (2001a) for specific details regarding water quality standards.

A listing of additional chemical, biological, and habitat parameters for which there are no established Wyoming surface water quality numeric standards is also provided in Table 4-3.

These parameters are included since they provide additional information for use in determining attainment of beneficial uses applicable to the waterbodies within the Project area.

Table 4-3. Narrative and Numeric Wyoming Surface Water Quality Standards Applicable to Waterbodies within the Project Area (from WDEQ, 2001)

NARRATIVE STANDARDS – Chapter 1		
Parameter	Reference	Standard / Description
Settleable Solids	Section 15	Shall not be present in quantities that could degrade aquatic life habitat, affect public water supplies, agricultural or industrial use, or affect plant and wildlife.
Floating and Suspended Solids	Section 16	Shall not be present in quantities that could degrade aquatic life habitat, affect public water supplies, agricultural or industrial use, or affect plant and wildlife.
Taste, Odor, and Color	Section 17	Substances shall not be present in quantities that would produce taste, odor, or color in: fish flesh, skin, clothing, vessels, structures, or public water supplies.
Ammonia	Section 21 (a)	In Class 3 waters, concentrations shall not affect aquatic life or designated uses. In Class 1 and 2 waters, Appendix C provides pH and temperature dependent numeric criteria.
Turbidity	Section 23	For cold water fisheries and drinking water supplies, discharge shall not create increase of 10 NTU's.
Dissolved Oxygen	Section 24	In Class 3 waters, levels shall not be depleted to harm aquatic life or designated uses. For Class 2AB waters, refer to Appendix D (5.0 mg/L for early life stages, 4.0 mg/L for other life stages).
Temperature	Section 25	Discharge shall not increase temperature by more than 2 degrees F; maximum allowable temperature is 68 degrees F/20 degrees C (cold water fisheries).
pH	Section 26, Appendix B	Discharge shall not change pH to levels harmful to aquatic life or to be less than 6.5 or greater than 9.0 standard units.
Fecal Coliform Bacteria	Section 27	Geometric mean of 5 samples obtained during separate 24 hour periods within a 30 day period shall not exceed 200 organisms per 100 mL.
Oil and Grease	Section 29	Shall not exceed 10 mg/L or cause visible deposits, or impair human, animal, plant, or aquatic life.
Total Dissolved Gases	Section 30	Concentration below dams shall not exceed 110% of saturation for gases at the existing pressures.
Biological Criteria	Section 32	Class 1, 2, and 3 waters shall not have concentrations of substances that adversely affect aquatic life.

Table 4-3. (Continued)

NUMERIC STANDARDS – Chapter 1, Appendix B			
Parameter	Aquatic Life – Acute Value (µg/L)	Aquatic Life – Chronic Value (µg/L)	Human Health – Fish & Drinking Water (µg/L)
Antimony			14
Arsenic	340	150	7
Beryllium			4
Cadmium	4.3	2.2	5
Chromium (III)	569.8	74.1	100 (total)
Chromium (VI)	16	11	100 (total)
Copper	13.4	9	1000
Cyanide (free)	22	5.2	200
Lead	64.6	2.5	15
Mercury	1.4	0.77	0.050
Nickel	468.2	52	100
Selenium	20	5	50
Silver	3.4		
Thallium			1.7
Zinc	117.2	118.1	5000
Barium			2000
Chloride	860000	230000	
Chlorine – total residual	19	11	
Fluoride			4000
Iron		1000	300
Manganese	3110	1462	50
Nitrite + Nitrate (as N)			10000

ADDITIONAL PARAMETERS AND RECOMMENDED STANDARDS		
Parameter	Reference	Standard / Description
Total Phosphorus	EPA (1977), USGS (1999)	EPA: Should not exceed 0.05 mg/L for a stream entering a lake or reservoir (i.e. Tongue River Reservoir), USGS: National background level in undisturbed watersheds is 0.10 mg/L.
Sulfate	WDEQ (1993)	Groundwater: 200 mg/L agriculture; 250 mg/L drinking water; 3000 mg/L livestock; 250 mg/L EPA secondary drinking water
Alkalinity	EPA (1986)	Minimum 20 mg/L
Hardness	Sawyer (1960) in EPA (1986)	Concentrations greater than 300 mg/L may be considered unsuitable for industrial use.
Habitat	King (1993): Stribling et al. (2000)	Habitat condition no less than 50 percent of reference; total habitat score >100 to qualify as reference

5. HISTORICAL AND CURRENT DATA SOURCES

5.1 HISTORICAL DATA AND DATA SOURCES

Collection, compilation, and evaluation of historical data provided a long-term perspective for water quality within the Project area. Historical data played an important role in the development of an effective monitoring and assessment plan. These data were used to develop a cost-effective monitoring plan by providing information to:

1. Identify gaps in previous monitoring, sampling parameters, sampling frequency, and sampling locations;

2. Select representative sampling stations;

3. Select proper sampling parameters;

4. Allow comparison of current data collected during the project to historical data; and

5. Assist development of post-project monitoring recommendations.

Historical data for the purposes of this project were defined as data that were greater than five years from the start of this project. Since the GCWA monitoring was initiated during 2001, data collected before January 1, 1996 were considered historical data. However, some historical databases also contained some current data. For simplicity, these databases were left as a single historical database and may be found in Appendix B.

The following sources have provided historical data within the project area:

- United States Geological Survey;
- United States Forest Service;
- Wyoming Department of Environmental Quality;
- Wyoming Game and Fish Department;
- Environmental Protection Agency;
- Argonne National Laboratory;
- Wyoming Water Resources Center – Wyoming Water Resources Data System; and
- Wyoming Water Resources Research Institute.

Table 5-2, provided at the end of this Section, lists historical (and current) sampling stations, station descriptions, data source, site location, and provides references to maps and data tables found in the appendices of this report.

5.1.1 USGS DATA

During August and October, 1978, the USGS collected two samples near the mouth of Goose Creek; these data are provided in Table B-2. A more permanent monitoring station was established upstream from this site in 1983 (Station Number 06305700). Station Number 06305700 – Goose Creek near Acme, Wyoming was established downstream from the Highway 339 bridge crossing over Goose Creek and is still in use today. GCWA site GC1 was also located at this USGS station. Chemical, physical, and bacteria data have been collected at Station Number 06305700 since 1983 and are presented in Table B-3. Monthly and daily discharge data for this site are presented in Table P-1 and Figure P-1.

USGS Station Number 06305500 is located on Goose Creek near the Sheridan WWTP. An extensive set of water quality data have been collected at this site from 1964 to present and are provided in Tables B-4 through B-7. Discharge data were collected at this site from 1941 through 1984 and are located in Table P-2 and Figure P-2. GCWA site GC2 was located near this USGS station.

Water quality data have been collected at Station Number 06302000 since 1987 and are presented in Table B-8. Monthly and daily discharge data (1930 through 2000) for this site can be found in Table P-4 and Figure P-4. This station was located on Big Goose Creek near the mouth of Big Goose canyon and was also the location for GCWA site BG18. Station Number 06302000 was removed by the USGS during the fall of 2002. A new monitoring site, Station Number 06301850, was established further upstream above the PK Ditch inlet during 2002. A comparison of 2002 discharge data from Station Number 06301850 to average daily discharge data from Station Number 06302000 is shown in Figure 8-23.

Table B-9 provides chemical, physical, bacteria, and organic water quality data collected at USGS Station Number 06304500 from 1979 through 1998. This station is located on Little Goose Creek in Sheridan, Wyoming near the Broadway Street and Dow Street intersection. Site LG2 used in the GCWA was located near this USGS monitoring station.

USGS collected benthic macroinvertebrates on July 30, 1977 at Goose Creek USGS Station Number 06305500 (USGS, 1977). The location was apparently downstream of Fort Road and possibly upstream of the Sheridan WWTF discharge outfall. As such, this location was probably located in between Goose Creek stations GC2 and GC3 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table J-6. No macroinvertebrate community metric list was presented and SCCD did not calculate metrics because data were not comparable to current Project data due to unknown sampling and analytical methods used.

5.1.2 USFS DATA

The United States Forest Service (USFS) collected water quality data on Big Goose Creek at USGS Station Number 06302000 from 1968 through 1976. Chemical, physical, and bacteria data were collected during this period and are provided in Table B-10. As mentioned in Section 5.1.2, this was also the location of GCWA monitoring site BG18. The USFS also collected similar water quality data for Little Goose Creek at USGS Station Number 06303500 from 1970 through 1976. This station is located in Little Goose canyon above the Peralta Ditch inlet. USFS data for this station are presented in Table B-11. The uppermost GCWA monitoring site on Little Goose Creek (LG22) was located at the County Road 77 bridge crossing approximately 2 stream miles downstream from this USFS/USGS site.

5.1.3 WDEQ DATA

From May 1993 to April 1994, the WDEQ collected monthly water quality samples at seven locations on Goose Creek, Big Goose Creek, and Little Goose Creek and at four storm drain locations in the vicinity of Sheridan, Wyoming. WDEQ, in cooperation with the City of Sheridan, performed this "Salt Monitoring Project" to determine if street snow, which was stockpiled near the creeks, had any measurable effect on water quality. Chemical, physical, and bacteria data were collected for the project and are summarized in Tables B-12 through B-22.

WDEQ also collected water quality samples near the Big Horn Coal Company mine in 1973 and 1974. Exact locations for these sample sites were unclear, however, they were collected on Goose Creek near the town of Acme. Data from this monitoring were accessed from WWRC and are found in Tables B-23 and B-24.

WDEQ collected benthic macroinvertebrates in 1994 at Big Goose Creek station NGPI21 for the Sheridan Salt Monitoring Project. This station was the same as Big Goose Creek station BG2 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table J-1 and the macroinvertebrate community metric list is presented in Appendix Table K-1. Both WDEQ data and current Project data were comparable since samples were collected at the same station using the same sampling and analysis methods.

WDEQ collected benthic macroinvertebrates in 1994 at Goose Creek station NGPI19 for the Sheridan Salt Monitoring Project. The station was located near the north Sheridan city limit just upstream of the bridge near the Wyoming Highway Department Port of Entry. This station was located between Goose Creek stations GC2 and GC1B for the current Project. The macroinvertebrate taxa list is presented in Appendix Table J-5 and the macroinvertebrate community metric list is presented in Appendix Table K-1. Although both WDEQ data and current Project data were collected using the same sampling and analysis methods, the data may not be directly comparable because samples were collected at different locations. Data for WDEQ station NGPI19 may be used to evaluate temporal trends and changes in benthic community composition along the longitudinal gradient of Goose Creek.

Little Goose Creek station NGPI20, located upstream of the Brundage Lane bridge was sampled by WDEQ for benthic macroinvertebrates in 1994. Samples were collected at the same location as LG5 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table J-8 and the macroinvertebrate community metric list is presented in Appendix Table K-1. Both WDEQ data and current Project data were comparable since the same sampling and analysis methods were used. WDEQ collected macroinvertebrates in 1994 at Little Goose Creek station NGPI26 located downstream of the Coffeen Avenue bridge and below a large storm drain discharge. The samples were collected at the same location as LG2A for the current Project. The macroinvertebrate taxa list is presented in Appendix Table J-7 and the macroinvertebrate community metric list is presented in Appendix Table K-1. Both WDEQ data and current Project data were comparable since the same sampling and analysis methods were used.

5.1.4 WGFD DATA

A single water quality sample taken by WGFD in 1938 near the Sugar Factory Outlet was found and is presented in Table B-26. These data were accessed from the WWRC. Further research by SCCD located the document listing the water quality sample result entitled *Preliminary report on Little Goose Creek* prepared September 8, 1938 by Mr. Eugene E. Bjorn. Mr. Bjorn investigated the sugar factory sewage outlet in Sheridan. One station was sampled upstream of the sugar factory and one station was sampled downstream of the sugar factory. Eight fish were collected at the lower station and sixteen fish were collected at the upper station. Common suckers (probably white suckers), Red Horse suckers (now known as Northern Redhorse sucker) and long-nose dace (also known as Longnose dace) were reported by Mr. Bjorn. This record represents the first known fish population-based study to investigate water pollution in the Project area. Mr. Bjorn wrote "It is reported that during the factory run the creek is colored by factory pollution for a distance of 50 miles, which includes part of Big Goose Creek [now known as Goose Creek]". It should be noted that the distance the sugar factory pollution traveled downstream was not directly based on Mr. Bjorn's observations, but due to anecdotal conversations with a landowner. A chicken hatchery located about 100 yards from the sugar factory was investigated, "But no evidence of this pollution could be detected" from the chicken hatchery. The chicken hatchery is now gone, but the old sugar factory building remains although it is no longer in operation and has no discharge.

WGFD fishery and habitat surveys began in earnest in 1958 when biologists initiated a survey of the Tongue River drainage including Big Goose Creek, Little Goose Creek and Goose Creek. It should be noted that Goose Creek was referred to as Big Goose Creek during these early surveys and in some surveys into the early 1990's. Results from the Tongue River drainage surveys were published in 1964 (WGFD, 1964). WGFD continued to conduct fish and habitat surveys and it is these data that comprise the bulk of the historical fishery data presented in Appendix O.

Other investigators conducted fish survey work in the Project area. A study by Wesche and Johnson (1979) was conducted in the latter 1970's. The study was related to baseline environmental assessment at Goose Creek and the Tongue River in the vicinity of the Big Horn Coal Mine. Results of their fishery work are presented in Appendix Tables O-6 through O-8. Patton (1994) sampled single sites on Goose Creek (Appendix Table O-4), Big Goose Creek (Appendix Table O-10) and Little Goose Creek (Appendix Table O-27) to determine change in distribution of fish species in the Missouri River basin over the years.

Current and historical fish sampling results since 1958 were compiled into 47 individual data sets presented in Appendix O. The data provide a good historical perspective for general distribution of game species. However, absolute presence/absence data and relative contribution of non-game species presented in sampling results contained an unknown degree of bias because many historical fish surveys concentrated on capture of game (trout) species. Further, the small size and often high density of smaller minnows (long-nose dace and others) precluded good capture efficiency. Although presence/absence data for game fish species appeared reliable, changes in trout abundance that may have occurred through the years could not be determined due to differing sampling effort and variable capture efficiencies.

The description of the historical fish sampling sites was generally sufficient to associate the sites to current Project sampling sites. This allowed the fish data to be incorporated into the discussion of water quality, benthic macroinvertebrate and habitat quality data collected during the current Project where appropriate. The fishery data is evaluated and discussed in Section 8.23.

5.1.5 EPA DATA

Water samples taken by EPA on Little Goose Creek near Sheridan are summarized in Table B-25. An exact sampling location was not found; these data were accessed from the WWRC.

EPA STORET data for the Goose Creek watershed were obtained from WDEQ. However, these databases contained USGS data identical to those found in Tables B-3 through B-9. These data were not presented again in additional tables.

5.1.6 ANL DATA

The Argonne National Laboratory (ANL) collected water quality samples at two Goose Creek sites during 1975. However, the sites are improperly described to be south of Acme on Big Goose Creek instead of Goose Creek. These data were provided by WWRC and are summarized in Tables B-27 and B-28.

5.1.7 WWRC DATA

The Wyoming Water Resources Center – Wyoming Water Resources Data System (WWRC) can be accessed from the Internet at the following website: www.wrds.uwyo.edu/. However, the WWRC does not certify the quality of data contained in the database because of the numerous sources providing the data with differing quality assurance procedures. Data retrieved for the Goose Creek watershed often did not contain the necessary information to provide detailed sampling locations. Therefore, water quality comparisons from these data to current water quality data must be conducted with some caution. WWRC data can be found in Tables B-29 through B-81.

5.1.8 WWRRI DATA

The Wyoming Water Resources Research Institute (WWRRI) collected benthic macroinvertebrate samples at two Goose Creek stations in 1976 (Wesche, 1977). One location (WWRRI-1) was reported to be below the Bighorn Mine and immediately upstream of Acme (just upstream of the confluence with the Tongue River). Three Surber samples using an unknown net mesh size were collected in July and October. The macroinvertebrate taxa list is presented in Appendix Table J-2. No macroinvertebrate community metric list was presented and SCCD did not calculate metrics because data were not comparable to current Project data due to different sampling methods used. The second location (WWRRI-2) was sited about 200 meters above the Placheck Pit (at the Bighorn Mine). This station was located downstream about ¼ to ½ mile from the Goose Creek station GC1 for the current Project. Three Surber samples with unknown net mesh size were collected in July and October. The macroinvertebrate taxa list is presented in Appendix Table J-4. No macroinvertebrate community metric list was presented and SCCD did not calculate metrics because data were not comparable to current Project data due to different sampling methods used.

WWRRI collected samples at a Goose Creek station located upstream of Bighorn Mine (WWRRI-3) on consecutive days from August 9 through August 23, 1978 (Gore and Johnson, 1979). An unknown number of Hess samples with unknown net mesh size were collected daily. This station was located an unknown distance downstream from the Goose Creek station GC1 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table J-3. No macroinvertebrate community metric list was presented and SCCD did not calculate metrics because data were not comparable to current Project data due to different sampling methods used.

5.2 CURRENT DATA AND DATA SOURCES

For the purposes of this project, current data includes data collected on or after January 1, 1996. The majority of current water quality data collected for this project are located in Appendix C, however, Yellowstone River Basin – National Water Quality Assessment Program (NAWQA) data collected by the USGS are presented in Appendix D and current benthic macroinvertebrate data collected by other sources have been summarized in Appendix L and Appendix M. As described in Section 5.1, some lengthy historical databases also contained current data. These databases were not split into separate historical and current databases, but remain as a single historical database to be found in Appendix B. Additionally, four historical water quality samples collected by WDEQ during macroinvertebrate sampling in 1994 are presented in the current data Appendix Table C-7.

The following sources have provided current data within the project area:

- United States Geological Survey;
- Wyoming Department of Environmental Quality; and
- Western EcoSystems, Inc.

5.2.1 USGS DATA

During June 2000, the USGS conducted synoptic water quality sampling at 24 stations within the Goose Creek watershed. These samples include fecal coliform and *E. coli* data and are shown in Table C-2. The 1999 and 2000 water quality data for Big Goose Creek USGS Station Number 06302200 are provided in Table C-3. This station is at the same location as site BG14 used in this assessment. Current USGS water quality data can also be found in historical data Table B-3 for Goose Creek, Table B-8 for Big Goose Creek, and Table B-9 for Little Goose Creek.

In 1998, the USGS initiated a NAWQA investigation on the Yellowstone River Basin with one sample station located on Goose Creek (USGS Station Number 06305700). These data have been summarized in Appendix D. Table D-2 summarizes bed sediment trace metal analysis data, Table D-3 provides liver trace metal analysis for carp and white sucker, Table D-4 provides whole-body organics analysis for carp and white sucker, and Table D-5 contains bed sediment organics analysis. USGS Station Number 06305700 is located with site GC1 for the GCWA.

5.2.2 WDEQ DATA

In 1998 and 1999, the WDEQ implemented a monitoring project that focused primarily on collecting additional fecal coliform bacteria data for Goose Creek, Big Goose Creek, and Little Goose Creek and their associated tributaries. Water quality data from this project have been summarized in Tables C-4 through C-6. Table C-4 presents data collected from Goose Creek, Table C-5 provides Big Goose Creek (and tributary) data, and Table C-6 shows Little Goose Creek (and tributary) data. Site locations and monitoring data from this project were used to construct a monitoring plan for the GCWA. Table 5-1 shows common sampling sites used in the 1998 – 1999 WDEQ monitoring project and the 2001 – 2002 GCWA.

Table 5-1. Common Monitoring Stations Used in the 1998 – 1999 WDEQ Monitoring Project and the 2001 – 2002 Goose Creeks Watershed Assessment

1998-1999 WDEQ Monitoring Site	Corresponding GCWA Site
Above Sheridan WWTF	GC3
Below Sheridan WWTF	GC2
BGH1	BG1
BGH2	BG4
BGH3	BG10
BGH4	BG14
BGH5	BG18
Below Beaver Creek	BG8
County Highway 81	BG11
Beaver Creek	BG9
Park Creek	BG13
Rapid Creek	BG16
LGH1	LG4
LGH2	LG5
LGH3	LG7
LGH4	LG10
LGH5	LG18
LGH6	LG21
LGH7	LG22
South of Big Horn	LG20
Kruse Creek	LG11
Sackett Creek	LG19
Jackson Creek	LG17

WDEQ collected benthic macroinvertebrates at five Goose Creek stations in 1998. The five stations and relation to Goose Creek stations sampled during the current Project include:

- WDEQ Goose Creek station NGP22 was sited at the Big Horn Mine downstream of current Project station GC1 and just upstream of the confluence with the Tongue River. The macroinvertebrate taxa list is presented in Appendix Table L-43 and the macroinvertebrate community metric list is presented in Appendix Table M-5.

- Duplicate benthic macroinvertebrate samples were reported for WDEQ Goose Creek station NGP21 located below the Big Horn Mountain KOA discharge outfall. This is the same station as GC1A for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-44 for duplicate 1 and Appendix Table L-45 for duplicate 2. The macroinvertebrate community metric list for each duplicate sample is presented in Appendix Table M-5.

- WDEQ Goose Creek station NGPI50 was sited upstream of the Big Horn Mountain KOA discharge outfall. This is the same station as GC1B for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-46 and the macroinvertebrate community metric list is presented in Appendix Table M-4.

- WDEQ Goose Creek station NGPI19 was sited downstream of the Sheridan WWTF discharge outfall. This station appeared to be about 1/4 mile downstream from station GC2 for the current Project. Although both WDEQ data and current Project data were collected using the same sampling and analysis methods, the data may not be directly comparable because samples were collected at different locations. Data for WDEQ station NGPI19 may be used to evaluate temporal trends and changes in benthic community composition along the longitudinal gradient of Goose Creek. The macroinvertebrate taxa list is presented in Appendix Table L-47 and the macroinvertebrate community metric list is presented in Appendix Table M-5.

- WDEQ Goose Creek station NGPI51 was sited just upstream from the Fort Road bridge and upstream of the Sheridan WWTF discharge outfall. This station is the same as Goose Creek station GC3 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-48 and the macroinvertebrate community metric list is presented in Appendix Table M-4.

With the exception of WDEQ station NGPI19, both WDEQ data and current Project data were comparable for Goose Creek stations since the same stations were sampled and the same sampling and analysis methods were used.

WDEQ collected benthic macroinvertebrates at four Big Goose Creek stations in 1998. The four stations and their relation to Big Goose Creek stations sampled during the current Project include:

- WDEQ Big Goose Creek station NGPI21 was sited upstream of the footbridge near West Works Street and Elk Street in Sheridan. This is the same station as station BG2 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-49 and the macroinvertebrate community metric list is presented in Appendix Table M-4.

- WDEQ Big Goose Creek station NGPI49 was located at Normative Services west of Sheridan. This is the same station as BG4 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-50. The macroinvertebrate community metric list for each duplicate sample is presented in Appendix Table M-4.

- WDEQ Big Goose Creek station NGPI50 was sited downstream from the Beckton road bridge. This station is near BG14 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-51 and the macroinvertebrate community metric list is presented in Appendix Table M-4.

- WDEQ Big Goose Creek station MRCI48 was sited in the Big Goose Creek canyon on the T-T Ranch near USGS gage station number 06302000. This station is near BG18 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-52 and the macroinvertebrate community metric list is presented in Appendix Table M-4.

Both WDEQ data and current Project data were comparable for Big Goose Creek stations since the same stations were sampled and the same sampling and analysis methods were used. Water quality data collected during these sampling events are presented in Table C-7.

WDEQ collected benthic macroinvertebrates at one Little Goose Creek station in 1996 and five Little Goose Creek stations 1998. Little Goose Creek station MRC38 was located in the foothills of the Little Goose Creek canyon and was sampled in both 1996 and 1998. WDEQ station MRC38 was identified as a reference station indicating that water quality, biological condition and habitat were among the best for Middle Rockies ecoregion foothill streams in Wyoming (Jessup and Stribling, 2002). This is the same station as Little Goose Creek station LG22 for the current Project. The macroinvertebrate taxa list for the WDEQ samples collected in 1996 and 1998 are presented in Appendix Table L-61 and Appendix Table L-58, respectively. The macroinvertebrate community metric lists for samples collected in 1996 and 1998 are presented in Appendix Table M-5. The remaining WDEQ benthic macroinvertebrate samples collected from Little Goose Creek in 1998 and their relation to Little Goose Creek stations sampled during the current Project include:

- WDEQ Little Goose Creek station NGPI26 was located downstream of the Coffeen Avenue bridge and below a storm drain discharge. WDEQ also sampled this location in 1994 (see Section 5.1.3). The samples were collected at the same location as LG2A for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-53 and the macroinvertebrate community metric list is presented in Appendix Table M-5.

- WDEQ Little Goose Creek station NGPI36 was located just upstream of the Coffeen Avenue bridge in Sheridan about 200 yards upstream of WDEQ Little Goose Creek station NGPI26. The macroinvertebrate taxa list is presented in Appendix Table L-54. The macroinvertebrate community metric list for each duplicate sample is presented in Appendix Table M-5.

- WDEQ Little Goose Creek station NGPI20 was located upstream of the Brundage Lane bridge. WDEQ also sampled this location in 1994 (see Section 5.1.1). Samples were collected at the same location as LG5 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-55 and the macroinvertebrate community metric list is presented in Appendix Table M-5.

- Duplicate samples were collected by WDEQ at Little Goose Creek station NGPI52 located upstream of the Highway 87 bridge. This station is at Little Goose Creek station LG10 for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-56 for duplicate 1 and Appendix Table L-57 for duplicate 2. The macroinvertebrate community metric list for each duplicate sample is presented in Appendix Table M-6.

Both WDEQ data and current Project data, with the exception of WDEQ station NGPI36, were comparable since the same stations were sampled and the same sampling and analysis methods were used. The Project did not have a sample station located at WDEQ station NGPI36. Water quality data collected during the Little Goose Creek sampling events is provided in Table C-7.

WDEQ collected benthic macroinvertebrates at four stations on Soldier Creek in 1999. No macroinvertebrate samples were collected from Soldier Creek during the current Project. The WDEQ benthic macroinvertebrate samples collected from Soldier Creek include:

- WDEQ Soldier Creek station NGP64 was located just upstream of the confluence with Goose Creek in Sheridan. Current Project water quality sample station GC4 was located at this location. The macroinvertebrate taxa list is presented in Appendix Table L-62 and the macroinvertebrate community metric list is presented in Appendix Table M-6.

- WDEQ Soldier Creek station NGP63 was located just upstream of the County Road 330 bridge west of Sheridan. The macroinvertebrate taxa list is presented in Appendix Table L-63. The macroinvertebrate community metric list for each duplicate sample is presented in Appendix Table M-6.

- WDEQ Soldier Creek station MRC77 was located on the PK Ranch. Although the station number indicates this station was located in the Middle Rockies ecoregion, the location was in the Northwestern Great Plains ecoregion. The macroinvertebrate taxa list is presented in Appendix Table L-64 and the macroinvertebrate community metric list is presented in Appendix Table M-6.

- WDEQ Soldier Creek station MRC78 was located in the Big Horn Mountain foothills. The sample location was identified as the "upper" station on Soldier Creek. The macroinvertebrate taxa list is presented in Appendix Table L-65 and the macroinvertebrate community metric list for each duplicate sample is presented in Appendix Table M-6.

Water quality data collected during the 1999 macroinvertebrate sampling on Soldier Creek are presented in Table C-7.

5.2.3 WEST Data

Western EcoSystems, Inc. (WEST) collected benthic macroinvertebrate samples in 1997 at two stations on Little Goose Creek in response to an oil spill from a road surfacing project on Coffeen Avenue in Sheridan (Johnson et al., 1997). One station (WEST-1) was sited downstream of the Coffeen Avenue bridge and below a storm drain that discharged an unknown amount of oil from the road project to Little Goose Creek. This station was the same as WDEQ Little Goose Creek station NGPI26 sampled in 1994 and 1998 (see Section 5.1.1 and Section 5.2.1). The samples were collected at the same location as LG2A for the current Project. The macroinvertebrate taxa list is presented in Appendix Table L-59 and the macroinvertebrate community metric list is presented in Appendix Table M-5. The second station (WEST-2) was located just upstream of the Coffeen Avenue bridge in Sheridan about 100 to 200 yards upstream of the point of the stormdrain discharge to Little Goose Creek. This station was the same as WDEQ Little Goose Creek station NGPI36 sampled in 1998. The macroinvertebrate taxa list is presented in Appendix Table L-60 and the macroinvertebrate community metric list is presented in Appendix Table M-5. Water quality data collected in conjunction with WEST macroinvertebrate sampling are provided in Table C-7.

WEST data, WDEQ station NGPI26 data, and current Project data collected at station LG2A were comparable since the same stations were sampled and the same sampling and analysis methods were used. The current Project did not have a sample station located at WDEQ station NGPI36 or the upstream WEST sample station. However, the WDEQ station NGPI36 and the WEST stations were comparable because the same stations were sampled and the same sampling and analysis methods were used.

5.3 QUALITY AND USE OF HISTORICAL AND CURRENT DATA

Water quality and macroinvertebrate data were obtained from numerous sources. When possible, electronic files and publications were obtained directly from the source agency to secure original or first-hand data sets. Nearly all of the USGS and WWRC data were downloaded directly from internet web sites. Electronic copies of WDEQ files were obtained directly from the agency.

In general, the USGS and WDEQ current and historical data were found to be the most useful and reliable. That is, these agencies are diligent in performing quality assurance practices on their data and also provide sufficient descriptive data to locate where sampling was conducted. Older historical data, and most of the data obtained from WWRC lacked sample descriptions for locating sample sites. Poor site and legal descriptions severely limit the quality and use of the WWRC data sets. In fact, the WWRC website contains a disclaimer that warns data users of the unknown quality assurance practices (if any) for these data.

Table 5-2. Site Descriptions and Location References for Historical and Current Sampling Stations Located Within the GCWA Project Area

Site ID	Site Description	Agency / Source	Latitude (deg-min-sec)*	Longitude (deg-min-sec)*	Appendix Map	Appendix Table
443559107122501	E F Big Goose Creek On Fs Rd 26, Nr Big Horn, WY	USGS	44-35-59	107-12-25	A-7	C-2
443638107070201	Tepee Creek Near Campground, Near Big Horn, WY	USGS	44-36-37	107-07-02	A-7	C-2
443654107110101	Rapid Cr On Forest Service Rd 26, Nr Big Horn, WY	USGS	44-36-54	107-11-01	A-7	C-2
443900107002201	L Goose C @ Bradford Brinton Mem, Nr Big Horn, WY	USGS	44-39-00	107-00-22	A-7	C-2
445258106591301	Goose Cr NR Mouth NR Kleenburn, WY	USGS	44-52-58	106-59-13	N/A	B-2
444014106593401	Little Goose Creek On CR103, Near Big Horn, WY	USGS	44-40-14	106-59-34	A-7	C-2
444101106591501	Little Goose Creek On CR28, Near Big Horn, WY	USGS	44-41-01	106-59-15	A-7	C-2
444246106572801	L Goose Creek At Bridge On Hwy 87, Near Banner, WY	USGS	44-42-46	106-57-28	A-7	C-2
444319107085201	Big Goose Creek Below Kane Draw Nr Sheridan, WY	USGS	44-43-19	107-08-52	A-7	C-2
444415106565001	L Goose C @ Hwy87 Brg Bl Woodland Pk Vil,Nr Sheridan, WY	USGS	44-44-15	106-56-50	A-7	C-2
444503107061601	Big Goose Creek At County Road 81 Nr Sheridan, WY	USGS	44-45-03	107-06-16	A-7	C-2
444550107042601	Big Goose Creek Bel Beaver Creek, Nr Sheridan, WY	USGS	44-45-50	107-04-26	A-7	C-2
444631107010901	Big Goose Creek Three Miles West Of Sheridan, WY	USGS	44-46-31	107-01-09	A-7	C-2
444634106565401	L Goose Creek Bel Brundage St Bridge, In Sheridan, WY	USGS	44-46-34	106-56-53	A-7	C-2
444637107014701	Big Goose Creek On Hwy 331 Nr Sheridan, WY	USGS	44-46-37	107-01-47	A-7	C-2
444803106574701	Big Goose Creek In Kendrick Park, In Sheridan, WY	USGS	44-48-03	106-57-47	A-7	C-2
444848106573701	Goose Creek At 11Th Street, In Sheridan, WY	USGS	44-48-48	106-57-37	A-7	C-2
444911106574601	Soldier Creek Near Mouth, In Sheridan, WY	USGS	44-49-11	106-57-45	A-7	C-2
444916107013401	Soldier Creek On Cr74, Near Sheridan, WY	USGS	44-49-16	107-01-34	A-7	C-2
06301500	West Fork Big Goose Creek Near Big Horn, WY	USGS	44-36-47	107-17-49	A-7	C-2
06302000	Big Goose Creek Near Sheridan, WY	USGS	44-42-08	107-10-51	A-7	B-8
06302200	Big Goose Creek Above Park Creek, Near Sheridan, WY	USGS	44-44-35	107-07-45	A-7	C-2,3
06303500	Little Goose Creek in Canyon, Nr Big Horn, WY	USGS	44-35-46	107-02-22	A-7	N/A
06303700	Little Goose Creek Ab Davis Ck, Nr Big Horn, WY	USGS	44-37-15	107-02-15	A-7	C-2
06304500	Little Goose Cr At Sheridan WY	USGS	44-48-10	106-57-10	A-7	B-9, C-2

Table 5-2. (Continued)

Site ID	Site Description	Agency / Source	Latitude (deg-min-sec)*	Longitude (deg-min-sec)*	Appendix Map	Appendix Table
06305500	Goose Creek Below Sheridan, WY	USGS	44-49-25	106-57-40	A-7	B-4 –B-7, C-2
06305700	Goose Creek Nr Acme, WY	USGS	44-53-11	106-59-18	A-7	B-3, C-2, D-2 – D-5
26501:0	Big Goose Creek at USGS Station No. 06302000	USFS	44-42-08	107-10-51	N/A	B-10
26503:0	Little Goose Creek at USGS Station No. 06303500	USFS	44-35-46	107-02-22	N/A	B-11
A1	Little Goose Creek upstream Brundage Lane	WDEQ	44-49-13	106-58-24	N/A	B-12
A2	Little Goose Creek b/w Loucks and Brundage Streets	WDEQ	44-49-13	106-58-24	N/A	B-13
A3	Little Goose Creek near mouth	WDEQ	44-49-13	106-58-24	N/A	B-14
A4	Big Goose Creek upstream bridge near Works and Elk Street	WDEQ	44-49-13	106-58-24	N/A	B-15
A5	Big Goose Creek near mouth	WDEQ	44-49-13	106-58-24	N/A	B-16
A6	Goose Creek near Marion and 5th Streets	WDEQ	44-49-13	106-58-24	N/A	B-17
A7	Goose Creek upstream Hwy 338 bridge crossing	WDEQ	44-49-13	106-58-24	N/A	B-18
SW1	Storm drain to Little Goose Creek-downstream Coffeen Ave	WDEQ	44-49-13	106-58-24	N/A	B-19
SW2	Storm drain to Little Goose Creek-near East 1st & North Gould	WDEQ	44-49-13	106-58-24	N/A	B-20
SW3	Storm drain to Goose Creek-from east 5th St	WDEQ	44-49-13	106-58-24	N/A	B-21
SW4	Storm drain to Goose Creek-from west 5th St	WDEQ	44-49-13	106-58-24	N/A	B-22
LGH1	Coffeen Avenue bridge	WDEQ	44-47-09	106-56-33	A-8	C-6
LGH2	Brundage Lane bridge	WDEQ	44-46-23	106-57-02	A-8	C-6
LGH3	Woodland Park bridge	WDEQ	44-44-14	106-56-47	A-8	C-6
LGH4	Highway 87 bridge	WDEQ	44-42-45	106-57-28	A-8	C-6
LGH5	Bird Farm Road bridge	WDEQ	44-41-00	106-59-14	A-8	C-6
LGH6	Bradford Brinton bridge	WDEQ	44-39-00	107-00-22	A-8	C-6
LGH7	County Road 77 bridge, Little Goose Ranch	WDEQ	44-37-14	107-02-17	A-8	C-6
BGH1	Kendrick Park in Sheridan	WDEQ	44-47-58	106-57-50	A-8	C-5
BGH2	Normative Services	WDEQ	44-46-37	107-00-50	A-8	C-5,7
BGH3	Bridge Above Beaver Cr.	WDEQ	44-45-35	107-04-30	A-8	C-5

Table 5-2. (Continued)

Site ID	Site Description	Agency / Source	Latitude (deg-min-sec)*	Longitude (deg-min-sec)*	Appendix Map	Appendix Table
BGH4	Bridge 1 mile Bel. Beckton	WDEQ	44-44-34	107-07-48	A-8	C-5,7
BGH5	Canyon, nr. Sheridan WTP int.	WDEQ	44-41-57	107-11-07	A-8	C-5,7
Goose Creek Lower	Goose Creek near mouth (NGP22)	WDEQ	44-54-43	106-58-50	A-8,9	C-4,L-43, M-5
Above KOA	Goose Creek-Above Big Horn Mtn KOA WWTP discharge (NGPI50)	WDEQ	44-50-03	106-57-49	A-8,9	C-4,L-46, M-4
Below KOA	Goose Creek-Below Big Horn Mtn KOA WWTP discharge (NGP21)	WDEQ	44-50-07	106-57-41	A-8,9	C-4,L-44, L-45,M-5
Above Sheridan WWTF	Goose Creek-Above Sheridan WWTP discharge (NGPI51)	WDEQ	44-49-15	106-57-43	A-8,9	C-4,L-48, M-4
Below Sheridan WWTF	Goose Creek-Below Sheridan WWTP discharge (NGPI19)	WDEQ	44-49-37	106-57-47	A-8,9	C-4,C-7, L-47,M-5
Woodland Park Village	Little Goose Creek-at Woodland Park Village bridge	WDEQ			A-8	C-6
Kruse Creek	Near Little Goose Creek confluence	WDEQ	44-42-42	106-57-27	A-8	C-6
Sackett Creek	Near Little Goose Creek confluence	WDEQ	44-43-07	106-57-14	A-8	C-6
Jackson Creek	Jackson Creek irrigation ditch in Big Horn	WDEQ	44-41-21	106-59-07	A-8	C-6
South of Big Horn	Little Goose Creek at CR 103 bridge	WDEQ	44-40-14	106-59-35	A-8	C-6
Below Beaver Creek	Big Goose Creek below Beaver Cr confluence	WDEQ	44-45-34	107-04-26	A-8	C-5
Beaver Creek	Near Big Goose Creek confluence	WDEQ	44-45-35	107-04-27	A-8	C-5
County Highway 81	Big Goose Creek-at CR 81 bridge	WDEQ	44-45-02	107-06-17	A-8	C-5
Park Creek	Near Big Goose Creek confluence	WDEQ	44-44-48	107-07-47	A-8	C-5
Rapid Creek	Near Big Goose Creek confluence	WDEQ	44-43-45	107-08-49	A-8	C-5
Above Sheridan	Little Goose Creek upstream Brundage Lane (NGPI20)	WDEQ	44-46-23	106-57-02	A-9	C-7, L-55,M-5
Storm Water	Little Goose Creek downstream Coffeen Ave storm drain (NGPI26)	WDEQ	44-47-09	106-56-34	A-9	C-7, L-53,M-5
Coffeen	Little Goose Creek upstream Coffeen Ave (NGPI36)	WDEQ	44-47-09	106-56-33	A-9	C-7, L-54,M-5

Table 5-2. (Continued)

Site ID	Site Description	Agency / Source	Latitude (deg-min-sec)*	Longitude (deg-min-sec)*	Appendix Map	Appendix Table
Highway 87	Little Goose Creek upstream Highway 87 and Kruse Creek (NGPI52)	WDEQ	44-42-42	106-57-33	A-9	L-56,57, C-7,M-6
Canyon	Little Goose Creek at Canyon Ranch (MRC38)	WDEQ	44-37-36	107-01-49	A-9	L-58,61, C-7,M-5
Above Sheridan	Big Goose Creek near Works St & Elk St (NGPI21)	WDEQ	44-47-43	106-57-56	A-9	C-7, L-49,M-4
Normative Services	Big Goose Creek at Normative Services (NGPI49)	WDEQ	44-46-25	107-01-11	A-9	L-50,M-4
Beckton	Big Goose Creek downstream Hwy 331 bridge S. of Beckton (NGPI50)	WDEQ	44-44-44	107-07-44	A-9	L-51,M-4
Canyon (T-T Ranch)	Big Goose Creek at USGS Station No. 06302000 (MRCI48)	WDEQ	44-41-57	107-11-07	A-9	L-52,M-4
Sheridan	Soldier Creek near mouth (NGP64)	WDEQ	44-49-12	106-57-43	A-9	C-7, L-62,M-6
County Road 330	Soldier Creek upstream CR 330 bridge-Soldier Creek Road (NGP63)	WDEQ			A-9	C-7, L-63,M-6
PK Ranch	Soldier Creek upstream Beckton Road bridge-CR 89 (MRC77)	WDEQ			A-9	C-7, L-64,M-6
Upper	Soldier Creek near Big Horn National Forest Boundary (MRC78)	WDEQ			A-9	C-7, L-65,M-6
WEST-1	Little Goose Creek downstream Coffeen Ave storm drain	WEST	44-47-09	106-56-34	N/A	C-7, L-59,M-5
WEST-2	Little Goose Creek upstream Coffeen Ave	WEST	44-47-09	106-56-33	N/A	C-7, L-60,M-5
WWRRI-1	Downstream Big Horn Mine, Upstream Acme	WWRRI			N/A	J-2
WWRRI-2	200 Meters Above Plachek Pit at Big Horn Mine	WWRRI			N/A	J-4
WWRRI-3	Upstream Big Horn Mine	WWRRI			N/A	J-3
213:0	Big Horn Coal Co (Acme Power Plant) Goose Creek at Mine Bridge	WDEQ	44-54-21	106-59-03	N/A	B-23
213:4	Big Horn Coal Co (Acme Power Plant) Goose Cr at Pt of Mine Discharge	WDEQ	44-54-48	106-58-26	N/A	B-24
83152017:0	Little Goose Cr 100 Yds BL Sugar Factory Outlet at Sheridan	WGFD	44-48-00	106-57-00	N/A	B-26
Station 1	Goose Creek (Sec 16, T57N, R84W)	WGFD			N/A	O-1
Station 2	Goose Creek (NE1/4 Sec 4, T56N, R84W)	WGFD			N/A	O-2

Table 5-2. (Continued)

Site ID	Site Description	Agency / Source	Latitude (deg-min-sec)*	Longitude (deg-min-sec)*	Appendix Map	Appendix Table
Station 3	Goose Creek (Sec 3, T56N, R84W)	WGFD			N/A	O-3
Rice Ranch	Goose Creek (W1/2 Sec3, T56N, R84W)	Patton			N/A	O-4
Sheridan	Goose Creek-above Sheridan WWTF (Sec 22, T56N, R83W)	Wesche et al.			N/A	O-5
Above Plachek Pit	Goose Creek-extended <1 kilometer above pit (Sec 22, T57N, R84W)	Wesche et al.			N/A	O-6
Plachek Pit	Goose Creek-in the pit proper (Sec 22, T57N, R84W)	Wesche et al.			N/A	O-7
Below Plachek Pit	Goose Creek-down to the Tongue River (Sec 15 & 22, T57N, R84W)	Wesche et al.			N/A	0-8
Sheridan	Big Goose Creek-N. Jefferson St. Bridge (NE1/4 Sec27, T56N,R84W)	WGFD			N/A	0-9
Ben Reynolds Ranch	Big Goose Creek-1 to 2 miles below Beaver Creek (NE1/4 Sec 1, T55N, R85W)	Patton			N/A	0-10
Station 4	Big Goose Creek-Bridge at Beaver Creek School (Sec 10, T55N, R85W)	WGFD			N/A	0-11,13
Station 4	Big Goose Creek-Bridge above Beaver Creek School (Sec 11, T55N, R85W)	WGFD			N/A	0-12
Station 5	Big Goose Creek-Bridge crossing at Becton (Sec 17, T55N, R85W)	WGFD			N/A	O-14,15,16
Mary Nelson's Place	Big Goose Creek-Upstream Beckton Bridge (SE1/4 Sec 8, T55N, R85W)	WGFD			N/A	O-17
T-T Ranch	Big Goose Creek-Lower Bridge (SW Sec 25, T55N, R85W)	WGFD			N/A	O-18,19
Station 6	Big Goose Creek-At T-T Ranch, corrals, split station (Sec 35, T55N, R86W)	WGFD			N/A	O-20
Mary Nelson's Place	Big Goose Creek-below Sheridan WTP discharge/chlorine (NW1/4 Sec 35, T55N, R86W)	WGFD			N/A	O-21
	Big Goose Creek-Near USFS Boundary? (NE1/4 Sec 3, T54N, R86W)	WGFD			N/A	O-22
Station 2	Little Goose Creek-Behind Big Horn Motel-in Sheridan? (No legal description available)	WGFD			N/A	O-23
Station 1	Little Goose Creek (Sec 2, T55N, R84W)	WGFD			N/A	O-24
Station 1	Little Goose Creek (SW1/4 Sec 14, T55N, R84W)	WGFD			N/A	O-25,26

Table 5-2. (Continued)

Site ID	Site Description	Agency / Source	Latitude (deg-min-sec)*	Longitude (deg-min-sec)*	Appendix Map	Appendix Table
Dick Summers Ranch	Little Goose Creek (SW1/4 Sec 14, T55N, R84W)	Patton			N/A	O-27
Station 2	Little Goose Creek-Upstream Woodland Park Bridge? (Sec 23, T55N, R84W)	WGFD			N/A	O-28
Nr. Maverick Forks	Little Goose Creek-Powderhorn Ranch (SE1/4, Sec 33, T55N, R84W)	WGFD			N/A	O-29,30
Station 3	Little Goose Creek-Gallatin Ranch Bridger, about 1/8th mile downstream Bradford-Brinton Bridge (Sec 17, T54N, R84W)	WGFD			N/A	O-31,32, 33,34,35, 36
Station 1	Little Goose Creek-Watts Smyth bridge in the experimental fly-fishing area, near the current Little Goose Ranch bridge (SE1/4 Sec 25, T54N, R85W)	WGFD			N/A	O-37,39, 40,41,42
Station 2	Little Goose Creek-Watts Smyth bridge (SE1/4 Sec25, R54N, T85W)	WGFD			N/A	O-38
Station 4	Little Goose Creek-Near USGS Gauge (?) in canyon, upstream Watts Smyth bridge (Sec 1, T53N, R85W)	WGFD			N/A	O-43,44, 45
Station 5	Little Goose Creek-at Harrison's just above metal gate (Sec 33, T54N, R85W)	WGFD			N/A	O-46,47
WRDS-03183:0	Little Goose Creek Near Sheridan, WY	EPA	44-49-15	106-57-00	N/A	B-25
WRDS-05500:0	Beaver Cr AB Confl with Goose Cr SW of Sheridan	WWRC	44-45-35	107-04-31	N/A	B-29
WRDS-05475:0	(Big) Goose Cr STA 1 SW of Sheridan	WWRC	44-42-40	107-10-00	N/A	B-30
WRDS-05478:0	(Big) Goose Creek at School STA 4 SW of Sheridan	WWRC	44-45-20	107-06-00	N/A	B-31
WRDS-05480:0	(Big) Goose Creek in City Park STA 6 Sheridan	WWRC	44-48-00	106-57-15	N/A	B-32
WRDS-05491:0	(Big) Goose Creek NR Beckton SW of Sheridan	WWRC	44-45-25	107-05-31	N/A	B-33
WRDS-05495:0	(Big) Goose Creek STA 3B SW of Sheridan	WWRC	44-45-35	107-05-00	N/A	B-34
WRDS-05479:0	(Big) Goose Creek STA 5 SW of Sheridan	WWRC	44-47-00	107-01-45	N/A	B-35
WRDS-06094:0	Big Goose Cr AB Cleveland Ave Storm Dr	WWRC	44-48-00	106-57-00	N/A	B-36
WRDS-06093:0	Big Goose Cr at Vale St and Cleveland Ave	WWRC	44-48-00	106-57-00	N/A	B-37
WRDS-05564:0	Goose Cr AB Irrigation Dam 1600ft from Sewage Outfall in Sheridan	WWRC	44-50-00	106-57-00	N/A	B-38
WRDS-05565:0	Goose Cr BL Irrigation Dam 1600ft from Sewage Outfall in Sheridan	WWRC	44-50-00	106-57-00	N/A	B-39
WRDS-05481:0	Goose Creek AB Confluence STA 7 Lewis St Br in Sheridan	WWRC	44-48-02	106-57-05	N/A	B-40
WRDS-05560:0	Goose Creek at Bridge to I-90 NR Sheridan	WWRC	44-49-31	106-57-22	N/A	B-41

Table 5-2. (Continued)

Site ID	Site Description	Agency / Source	Latitude (deg-min-sec)*	Longitude (deg-min-sec)*	Appendix Map	Appendix Table
WRDS-05490:0	Goose Creek at Port of Entry STA 9A North of Sheridan	WWRC	44-49-31	106-57-22	N/A	B-42
WRDS-05484:0	Goose Creek BL Old Bridge STA 10 North of Sheridan	WWRC	44-50-20	106-57-30	N/A	B-43
WRDS-05488:0	Goose Creek Control AB Sewage Outflow STA 7A Sheridan	WWRC	44-49-00	106-57-30	N/A	B-44
WRDS-05483:0	Goose Creek STA 9 at USGS Gauge 06305500 North of Sheridan	WWRC	44-49-10	106-57-30	N/A	B-45
WRDS-05501:0	Kruse Cr (LGC 2A) NE of Big Horn	WWRC	44-42-40	106-57-29	N/A	B-46
WRDS-05482:0	Little Goose Cr (GC 8) AB Confluence STA 4 Sheridan	WWRC	44-48-01	106-57-00	N/A	B-47
WRDS-06106:0	Little Goose Cr at Route 33 Bridge	WWRC	44-40-00	106-59-00	N/A	B-48
WRDS-06102:0	Little Goose Cr BL Sheltered Acres Storm Dr in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-49
WRDS-06103:0	Little Goose Cr BL Sheltered Acres Storm Dr in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-50
WRDS-06104:0	Little Goose Cr BL US 14-16 Bridge	WWRC	44-47-00	106-56-00	N/A	B-51
WRDS-06105:0	Little Goose Cr Drain at SE Side of US 14-16 Bridge	WWRC	44-47-00	106-56-00	N/A	B-52
WRDS-05485:0	Little Goose Cr STA 1 SE of Big Horn	WWRC	44-40-55	106-59-15	N/A	B-53
WRDS-05497:0	Little Goose Cr STA 1A at Bridge NE of Big Horn	WWRC	44-41-10	106-59-17	N/A	B-54
WRDS-05486:0	Little Goose Cr STA 2 NE of Big Horn	WWRC	44-42-00	106-58-50	N/A	B-55
WRDS-05494:0	Little Goose Cr STA 2C at Maverick Bridge South of Sheridan	WWRC	44-43-30	106-56-55	N/A	B-56
WRDS-05487:0	Little Goose Cr STA 3 South of Sheridan	WWRC	44-46-20	106-56-45	N/A	B-57
WRDS-06110:0	Little Goose Creek at USGS Gage	WWRC	44-36-00	107-02-00	N/A	B-58
WRDS-05493:0	McCormick Cr (LGC 2B) at 87 Bridge South of Sheridan	WWRC	44-42-50	106-57-28	N/A	B-59
WRDS-05476:0	Rapid Creek (GC 2) Southwest of Sheridan	WWRC	44-43-40	107-08-30	N/A	B-60
WRDS-05489:0	Sheridan Sewage Outfall STA 7B at Measuring Weir	WWRC	44-49-10	106-57-20	N/A	B-61
WRDS-05492:0	Soldier Creek AB Confluence with Goose Creek North of Sheridan	WWRC	44-49-00	106-57-40	N/A	B-62
WRDS-05496:0	Storm Dr at Burkitt Ave and Griffith St in Sheridan	WWRC	44-48-00	106-57-15	N/A	B-63
WRDS-06082:0	Storm Dr at Cleveland and Works Sheridan	WWRC	44-48-00	106-57-00	N/A	B-64
WRDS-06092:0	Storm Dr Behind Port of Entry in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-65
WRDS-06089:0	Storm Dr E Side Goose Creek at 7th St in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-66
WRDS-06080:0	Storm Dr E Side Little Goose at Park St Bridge Sheridan	WWRC	44-48-00	106-57-00	N/A	B-67
WRDS-06078:0	Storm Dr E Side Little Goose at Works St Bridge Sheridan	WWRC	44-48-00	106-57-00	N/A	B-68

Table 5-2. (Continued)

Site ID	Site Description	Agency / Source	Latitude (deg-min-sec)*	Longitude (deg-min-sec)*	Appendix Map	Appendix Table
WRDS-06076:0	Storm Dr E Side Little Goose Cr AB Herald St Bridge	WWRC	44-48-00	106-57-00	N/A	B-69
WRDS-06091:0	Storm Dr NE Side of 8th St Bridge in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-70
WRDS-06088:0	Storm Dr NW Side of 5th St Bridge in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-71
WRDS-06090:0	Storm Dr NW Side of 8th St Bridge in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-72
WRDS-06075:0	Storm Dr S Side Little Goose at Brooks St Bridge	WWRC	44-48-00	106-57-00	N/A	B-73
WRDS-06087:0	Storm Dr SE Side of 5th St Bridge in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-74
WRDS-06086:0	Storm Dr SW Side of 5th St Bridge in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-75
WRDS-06084:0	Storm Dr Under Loucks St Bridge NE Corner Sheridan	WWRC	44-48-00	106-57-00	N/A	B-76
WRDS-06085:0	Storm Dr Under Loucks St Bridge NW Corner Sheridan	WWRC	44-48-00	106-57-00	N/A	B-77
WRDS-06083:0	Storm Dr W End of Burkitt Street in Sheridan	WWRC	44-48-00	106-57-00	N/A	B-78
WRDS-06077:0	Storm Dr W Side Little Goose AB Herald St Bridge	WWRC	44-48-00	106-57-00	N/A	B-79
WRDS-06081:0	Storm Dr W Side Little Goose at Park St Bridge Sheridan	WWRC	44-48-00	106-57-00	N/A	B-80
WRDS-06079:0	Storm Dr W Side Little Goose at Works St Bridge Sheridan	WWRC	44-48-00	106-57-00	N/A	B-81
WRDS-03356:0	Big Goose Creek AB Old Strip Mine Pit South of Acme, WY	ANL	44-54-30	106-59-00	N/A	B-27
WRDS-03359:0	Big Goose Creek at HWY 1706 2 Miles South of Acme, WY	ANL	44-54-00	106-58-30	N/A	B-28

General Table Note (*): Many of the WRDS latitude and longitude descriptions were found to be incorrect; please use these data with caution.

Table Abbreviations:

N/A = Not Applicable
USGS = United States Geological Survey
WDEQ = Wyoming Department of Environmental Quality
USFS = United States Forest Service
WWRC = Wyoming Water Resources Center
WRDS = Water Resources Data System
WGFD = Wyoming Game and Fish Department
EPA = Environmental Protection Agency
ANL = Argonne National Laboratory
WWRRI = Wyoming Water Resources Research Institute
WEST = Western EcoSystems Inc.

6. MONITORING AND ASSESSMENT PLAN

6.1 MONITORING DESIGN

A primary goal of the Project was to determine the major types and reaches affected by non-point source impairments occurring in the Goose Creeks watershed. A monitoring design was developed by the GCDAG in consultation with WDEQ in order to meet this goal. The monitoring design was documented in the SAP and described the sampling stations, sampling parameters, frequency for sampling, and the methods for analysis and interpretation of data (SCCD, 2001a). The design was a component of the total monitoring program that functioned to provide the information required to meet Project goals and objectives. The monitoring program was designed to be cost effective, easy to implement, provide credible data, and result in realization of project goals through sound interpretation and analysis of data.

In 1999, the Wyoming Legislature enacted Credible Data legislation as per W.S. §35-11-103 of the Wyoming Environmental Quality Act. The statute defines Credible Data as scientifically valid chemical, physical, and biological monitoring data collected under an accepted SAP, including QA/QC procedures, and available historical data. Only credible data may be used to determine attainment of designated uses for a waterbody or assign classification of waterbody segments. Designated uses for Goose Creek and its associated tributaries within the Project area were identified in Section 4.2.

The monitoring design described in the SAP complies with the criteria and intent of the legislation. This was important because data collected during this assessment will likely be used to determine attainment of designated uses for Goose Creek and its tributaries and to propose stream classifications or change in stream classification when appropriate.

6.1.1 PRE-SURVEY

A pre-survey or study was conducted prior to development of the project monitoring design (Mendenhall et al. 1971; Green 1979; Mason et al. 1989). The pre-survey provided information to examine magnitude, spatial and temporal variability of target water quality parameters, and to determine where data gaps may exist. The historical data search served this purpose and revealed significant data gaps. Considerable data existed for upper Big Goose Creek, upper Little Goose Creek, lower Little Goose Creek, and Goose Creek. However, little data was available for the middle reaches of Big Goose Creek, Little Goose Creek, and the tributaries. With the exception of recent WDEQ and USGS sampling, little bacteria data existed for the watershed and was considered by GCDAG as a monitoring priority due to potential public health and safety concerns.

6.1.2 TYPES OF MONITORING DESIGNS EMPLOYED

The monitoring design for the Project incorporated four types of monitoring into a multi-disciplinary chemical, physical, biological, and habitat monitoring program. Each monitoring type provides certain types of information. The four types of monitoring include:

1. Baseline monitoring

2. Long term trend monitoring

3. Above and below monitoring with discharge

4. Below only monitoring

Baseline monitoring involved initial data collection at a specified frequency and fixed location. This monitoring type occurred on upper Goose Creek, lower and middle Big Goose Creek, middle Little Goose Creek, and the tributaries because these reaches had little or no previous water quality data. Baseline data described the current water quality and stream conditions.

Baseline monitoring over a period of years evolves into **long term trend monitoring**. Trend monitoring continues over many years and is used to identify temporal (seasonal or annual) water quality variability within the watershed and assist in determination of water quality change. This type of monitoring occurred within the project area at established USGS stations on Goose Creek (06305700 and 06305500), upper Big Goose Creek (06302000), and upper (06303700) and lower (06304500) Little Goose Creek. Significant water quality data exist for these stations, however, the frequency and parameters sampled were not always consistent.

Above and below monitoring with discharge measurement was used to identify general areas of pollutant sources (MacDonald et al., 1991) and when used in conjunction with discharge measurements was fairly specific for detection of water quality change related to change in land use and water use (Spooner et al., 1985). In general, stations were located above and below each tributary to monitor their effects on the water quality of the main streams. Accurate discharge measurements were critical to the above and below monitoring design since many chemical and physical water quality parameters may be directly affected by change in discharge. Good discharge data were necessary to partition discharge dependent water quality parameters according to discharge measured during the Project.

Below only monitoring consisted of monitoring at a single fixed site located at the lower end of the tributaries. This is not the preferred monitoring method since comparisons cannot be made to an upstream control location. Although long term monitoring will be needed to detect water quality change in the absence of a control location, the single lower stations provide adequate data to determine compliance with most numeric

Wyoming water quality standards. Further, the single fixed site provides data to determine the effect that water quality in the tributary may have on water quality in the receiving stream.

6.1.3 MODIFICATIONS TO MONITORING DESIGN

During the course of the project, two modifications to the SAP (SCCD, 2001a) were deemed necessary by the GCDAG. Revision Number 1 to the SAP was approved by the WDEQ QA/QC Officer on April 24, 2002. This revision updated changes in site descriptions, water quality standards, and other minor textual corrections. However, the main purpose of this revision was to eliminate Biochemical Oxygen Demand (BOD) from the 2002 sampling program and to include *E. coli*, pesticide, herbicide, and additional Total Residual Chlorine (TRC) monitoring in the 2002 sampling program. Approximately 96% of all BOD samples collected in 2001 were analyzed as non-detectable. For this reason and the high cost of analyses, it was decided to remove BOD from the sampling program and pursue other monitoring parameters that would provide more cost effective data. Pesticide and herbicide monitoring were included because of their widespread use within the watershed and results from this type of monitoring are generally of great interest to the local public. *E. coli* monitoring was added because WDEQ had proposed to change the bacteria standard from the current fecal coliform indicator to an *E. coli* indicator during 2003. The change in standard would be effective during 2003 or 2004. Additional TRC monitoring was included to determine the accuracy of TRC samples analyzed by a HACH Pocket Colorimeter during 2001.

Revision Number 2 to the SAP was approved by the WDEQ QA/QC Officer on September 6, 2002. The purpose of this amendment was to modify portions of the macroinvertebrate sample analysis to expedite return of analytical data from the contract laboratory. Data from 2001 macroinvertebrate samples were not completed by the contract laboratory until July 2002. The GCDAG decided to allow SCCD to sort the 2002 samples and analyze midge taxa before submittal to the laboratory to speed sample analysis and the return of macroinvertebrate data. This revision was determined necessary in order to complete this Final Report in a reasonable time period. A special study to determine the presence of fecal coliform bacteria in stream bed sediment was conducted in 2002. The study was designed to provide information for the dynamics of fecal coliform bacteria concentrations in Little Goose Creek, Big Goose Creek and Goose Creek.

6.2 SAMPLE SITE DESCRIPTIONS

In cooperation with WDEQ, the GCDAG selected and established 46 water quality monitoring stations within the watershed to include:

- 6 Goose Creek stations;
  - 5 stations on Goose Creek from its origination to the Highway 339 crossing
  - 1 station at the mouth of Soldier Creek

- 18 Big Goose Creek stations;
  - # 15 stations on Big Goose Creek from the mouth of Big Goose canyon to Kendrick Park in Sheridan
  - # 1 station each on lower Beaver Creek, Park Creek, and Rapid Creek

- 22 Little Goose Creek stations.
  - # 17 stations on Little Goose Creek from near the mouth of the canyon to near its confluence with Big Goose Creek
  - # 1 station each on lower McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek
  - # 1 station for storm drain discharge located downstream of the Coffeen Avenue crossing of Little Goose Creek in Sheridan

In addition to the water quality monitoring stations, 19 Beneficial Use Reconnaissance Project (BURP) stations were selected as follows:

- 5 Goose Creek stations;
- 7 Big Goose Creek stations; and
- 7 Little Goose Creek stations.

Many of the water quality and BURP monitoring stations used for this project were at the same site. Maps A-3 through A-6 in Appendix A illustrate the locations for these sites. These sites are described in more detail in Tables 6-1 through 6-4.

Table 6-1. Goose Creek Water Quality Monitoring Site Descriptions

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)	Additional Information
GC1	Located on Goose Creek approximately 75 yards downstream of HWY 339 bridge crossing at USGS Station No. 06305700. Most downstream site in watershed (approximately 2 miles south of Acme).	44°52.992' / 106°59.263'	3,660	Mainly cattle grazing and irrigated haylands upstream to Sheridan. A few residences along Goose Creek. Railroad and HWY 338 parallel east side of Goose Creek.	Continuous temperature data logger used at this site during 2001 & 2002 seasons.
GC2	Located on Goose Creek approximately 200 yards downstream of Sheridan WWTP.	44°49.340' / 106°57.932'	3,701	A concrete plant is located south of creek with settling ponds north of creek. Sheridan WWTP is upstream.	USGS Station No. 06305500 located upstream at Sheridan WWTP. Grinnell Livestock Company Ditch located approximately 300 yards downstream.
GC3	Located on Goose Creek approximately 75 yards upstream from Fort Road bridge crossing.	44°49.239' / 106°57.712'	3,703	Mainly residential with recreational trails along creek. This reach of Goose Creek has been channelized for flood control.	Soldier Creek confluence is about 125 yards upstream.
GC4	Located near the mouth of Soldier Creek approximately 10 yards downstream from Dana Avenue bridge.	44°49.198' / 106°57.719'	3,705	Downer Addition is the main land use in lower watershed.	Continuous temperature data logger used at this site during 2001 & 2002 seasons.
GC5	Located on Goose Creek approximately 10 yards upstream of footbridge in Thorne-Rider city park.	44°48.922' / 106°57.616'	3,708	Mainly recreational (park and trails) with residential neighborhoods nearby. This reach of Goose Creek has been channelized for flood control.	Deadman Gulch enters Goose Creek upstream near 8th Street after passing through Holly and Hume Ponds.
GC6	Located on Goose Creek approximately 200 yards upstream 5th Street bridge.	44°48.360' / 106°57.567'	3,715	Residential along both banks, Marion Street parallels west bank. Business areas located upstream. This reach of Goose Creek has been channelized for flood control.	Big and Little Goose Creek confluence is less than ¼ mile upstream.

Table 6-2. Big Goose Creek Water Quality Monitoring Site Descriptions

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)	Additional Information
BG1	Located on Big Goose Creek at footbridge in Kendrick Park in Sheridan.	44°47.960' / 106°57.841'	3,735	Mainly residential with park located on north bank. This reach is highly recreational.	Little Goose Creek confluence is approximately 1/3 mile downstream.
BG2	Located on Big Goose Creek approximately 100 yards downstream from the footbridge at the intersection of Works and Elk Street.	44°47.751' / 106°58.164'	3,745	Predominantly urban / residential.	Continuous temperature data logger used at this site during 2001 & 2002 seasons. Upstream from the site, Chapek Draw enters from the south and Hamma Draw enters from the north.
BG3	Located on Big Goose Creek at the west end of Leopard Street.	44°47.176' / 106°59.228'	3,779	Site is located on the west side of Sheridan. This is a transition area from urban residential to small acreage properties with more open space.	Gillispie Draw enters approximately ½ mile upstream. Gregg Draw, which can be used as a tailwater drain for the Colorado-Colony Ditch, is located about 2 miles upstream.
BG4	Located on Big Goose Creek about 30 yards upstream from Brayton Lane bridge at Normative Services.	44°46.615' / 107°00.840'	3,825	Area consists of small acreage properties with some cattle grazing and other domestic stock present.	A large beaver dam was present during the assessment approximately ¼ mile upstream.
BG5	Located on Big Goose Creek about 25 yards upstream from the HWY 331 bridge crossing 4 miles west of Sheridan.	44°46.628' / 107°01.768'	3,855	Primarily hayland, irrigated hayland, and cattle grazing with interspersed rural residences.	An irrigation dam (fabric) is typically installed immediately upstream from the site.
BG6	Located on Big Goose Creek at the west end of the Paulson Youth Camp.	44°46.384' / 107°02.755'	3,890	Recreational (youth camp), cattle grazing, and haylands.	Continuous temperature data logger used at this site during 2001 & 2002 seasons. Forbes Draw enters upstream.
BG7	Located on Big Goose Creek ½ mile west of the Paulson Youth Camp. Access is through private landowner.	44°46.143' / 107°03.275'	3,905	Rural residential, cattle grazing, and irrigated haylands. A sod farm is located upstream.	Upstream from site, Wolf Draw enters from the south and Owl Creek enters from the north.
BG8	Located on Big Goose Creek approximately 75 yards downstream from the Beaver Creek confluence.	44°45.559' / 107°04.434'	3,940	Rural residential, wildlife habitat, cattle grazing, and haylands.	The Daisy Ditch intake is about 30 yards downstream from the site.

Table 6-2. (Continued)

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)	Additional Information
BG9	Located on Beaver Creek about 25 yards upstream from the Big Goose Creek confluence.	44°45.579' / 44°45.579'	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.	Continuous temperature data logger used at this site during 2001 season.
BG10	Located on Big Goose Creek approximately 40 yards upstream from the County Road 87 bridge crossing.	44°45.778' / 107°04.501	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.	Baker Creek, which may be used to return Ditch No. 9 water back to Big Goose Creek, enters from the south upstream from the site.
BG11	Located on Big Goose Creek about 50 yards upstream from the County Road 81 bridge crossing.	44°45.036' / 107°06.285'	4,005	Properties become larger upstream from this site (fewer residences). Cattle grazing, irrigated haylands, and wildlife habitat are common.	
BG12	Located on Big Goose Creek approximately 75 yards downstream from the Park Creek confluence.	44°44.869' / 107°07.736'	4,045	Cattle grazing, irrigated haylands, and wildlife habitat.	Above Park Creek, Dry Gulch enters from the south. Beaver dams are common downstream from the site.
BG13	Located on Park Creek approximately 20 yards downstream from the HWY 331 crossing.	44°44.800' / 107°07.736'	4,050	Cattle grazing, irrigated haylands, and wildlife habitat.	Park Creek flows through a wetlands upstream of HWY 331.
BG14	Located on Big Goose Creek at first riffle upstream from HWY 331 bridge crossing south of Beckton.	44°44.573' / 107°07.798'	4,075	Cattle grazing, irrigated haylands, and wildlife habitat. Large corrals located north of creek upstream from site.	USGS Station No. 06302200 is also located at this bridge crossing.
BG15	Located on Big Goose Creek about 200 yards downstream from Rapid Creek confluence.	44°43.804' / 107°08.692'	4,155	Cattle grazing, irrigated haylands, and wildlife habitat.	Ditch No. 9 runs parallel to Big Goose Creek through this reach.
BG16	Located on Rapid Creek approximately 150 yards upstream from the Big Goose Creek confluence.	44°43.752' / 107°08.667'	4,160	Cattle grazing, irrigated haylands, and wildlife habitat.	During 2001, this site was located below the reach used by Ditch No. 9 for flow conveyance. The site was moved upstream from the Ditch No. 9 confluence prior to the 2002 season. The Big Goose and Beaver Ditch uses Rapid Creek for flow conveyance further upstream.

Table 6-2. (Continued)

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)	Additional Information
BG17	Located on Big Goose Creek approximately 40 yards upstream from the Ditch No. 9 intake.	44°43.367' / 107°08.814'	4,210	Cattle grazing, irrigated haylands, and wildlife habitat.	Proceeding upstream, Kane Draw enters from the south and then Cave Creek enters from the north.
BG18	Located near the mouth of Big Goose Canyon at USGS Station No. 06302000. The Alliance Ditch intake is approximately 50 yards downstream.	44°42.137' / 107°10.894'	4,505	Primarily wildlife habitat. Cattle grazing was infrequent during assessment. The BHNF boundary is about 1 mile upstream from the site.	Continuous temperature data logger used at this site during 2001 & 2002 seasons. Upstream from the site, the Sheridan Water Treatment Plant and the PK Ditch remove water from the creek.

Table 6-3. Little Goose Creek Water Quality Monitoring Site Descriptions

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)	Additional Information
LG1	Located on Little Goose Creek approximately 30 yards upstream from the Big Goose Creek confluence.	44°48.189' / 106°57.474'	3,721	Urban – mostly a business area with some residences.	Little Goose Creek flows through a concrete channel used for flood control immediately upstream from this site. Several storm drains enter this channel.
LG2	Located on Little Goose Creek approximately 30 yards upstream from the concrete channel described in the previous description.	44°48.086' / 106°57.148'	3,725	Urban – mostly business with some light industrial and residential areas. Railroad tracks are adjacent to the east bank.	This reach of the creek has been channelized for flood control purposes. Continuous temperature data logger used at this site during 2001 & 2002 seasons.
LG3	Station monitors effluent from the Storm Drain east of the Coffeen Avenue bridge crossing over Little Goose Creek.	44°47.154' / 106°56.559'	3,755	Urban – business area	
LG4	Located on Little Goose Creek about 20 yards upstream from the Coffeen Avenue bridge crossing.	44°47.144' / 106°56.582'	3,755	Local area is mainly businesses, residential areas located upstream. A concrete path follows the north side of the creek.	Storm drains are present immediately upstream from the site.
LG5	Located on Little Goose Creek approximately 100 yards upstream from the Brundage Lane bridge crossing.	44°46.391' / 106°57.029'	3,775	Located just upstream from Sheridan, uses are mainly wildlife habitat, irrigated haylands, and rural residential.	Dry Creek enters upstream from the site.
LG6	Located on Little Goose Creek approximately 20 yards downstream from the County Road 66 bridge crossing.	44°44.873' / 106°57.350'	3,825	Small acreage properties with livestock grazing and irrigated haylands.	Jeffries Draw enters from the west upstream from the site.
LG7	Located on Little Goose Creek approximately 75 yards upstream from the HWY 87 bridge crossing near Woodland Park.	44°44.241' / 106°56.782'	3,850	Small acreage properties with livestock grazing and irrigated haylands. A trailer park is located upstream.	Swaim Draw, the return for the Gerdel Ditch, enters upstream. The Burn Cleuch Ditch removes water above Swaim Draw. Coyote Creek enters further upstream.
LG8	Located on Little Goose Creek approximately ¼ mile downstream from McCormick Creek near the Cox Valley Road.	44°43.185' / 106°57.068'	3,895	Small acreage properties with livestock grazing, wildlife habitat, and irrigated haylands.	Continuous temperature data logger used at this site during 2001 & 2002 seasons.

Table 6-3. (Continued)

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)	Additional Information
LG9	Located on McCormick Creek approximately 20 yards upstream from the Little Goose Creek confluence.	44°43.110' / 106°57.229	3,905	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.	
LG10	Located on Little Goose Creek approximately 20 yards upstream from the HWY 87 bridge crossing near the HWY 335 intersection.	44°42.749' / 106°57.229	3,915	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.	Kruse Creek enters approximately 200 yards upstream.
LG11	Located on Kruse Creek about 100 yards upstream from the Little Goose Creek confluence.	44°42.615' / 106°57.444'	3,915	Small acreage properties with cattle grazing and irrigated haylands.	A small reservoir is located just upstream from the site.
LG12	Located on Little Goose Creek approximately 30 yards upstream from the Kruse Creek confluence.	44°42.700' / 106°57.548'	3,920	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.	Small ponds are adjacent to this reach of the creek.
LG13	Located on Little Goose Creek approximately 20 yards upstream from the County Road 60 bridge crossing at Knode Ranch subdivision.	44°42.149' / 106°58.104'	3,940	Large subdivisions with small acreage lots, wildlife habitat, and haylands.	
LG14	Located on Little Goose Creek 20 yards upstream from the Clubhouse Road bridge crossing at the Powderhorn golf community.	44°41.856' / 106°58.433'	3,970	Local area is golf course with many incorporated residences.	During the assessment, the golf course was expanded from 18 to 27 holes. Denio Draw enters upstream
LG15	Located on Little Goose Creek 40 yards upstream from the Gerdle Ditch intake.	44°41.483' / 106°59.055'	4,000	Golf course/subdivision with small acreage properties west of Little Goose Creek.	Reese Gulch enters about 1/8 mile upstream.
LG16	Located on Little Goose Creek approximately 150 – 200 yards downstream from Jackson Creek.	44°41.424' / 106°59.157'	4,018	Golf course/subdivision east of creek and small acreage properties west of the creek.	
LG17	Located on Jackson Creek near the Little Goose Creek confluence.	44°41.357' / 106°59.121	4,020	Small acreage properties with cattle grazing and irrigated haylands.	Continuous temperature data logger used at this site during 2002 season.

Table 6-3. (Continued)

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)	Additional Information
LG18	Located on Little Goose Creek about 25 yards downstream from the Bird Farm Road bridge and Sackett Creek confluence.	44°41.003' / 106°59.225'	4,035	Small acreage properties with the town of Big Horn upstream.	Hanna Creek enters Little Goose Creek south of Big Horn.
LG19	Located on Sackett Creek 10 yards upstream from the Little Goose Creek confluence.	44°43.110' / 106°57.228'	4,040	Small acreage properties with cattle grazing and irrigated haylands. Big Horn residences are located within the lowermost reaches of Sackett Creek.	
LG20	Located on Little Goose Creek 10 yards upstream from the County Road 103 bridge crossing ½ mile south of Big Horn.	44°40.230' / 106°59.582'	4,100	Dense vegetation along creek provides good wildlife habitat, small acreage properties are common.	Upstream the East Side Ditch removes water and Kemp Creek enters further upstream.
LG21	Located on Little Goose Creek above County Road 103 bridge crossing near entrance to Bradford-Brinton Memorial	44°38.994' / 107°00.362'	4,220	Cattle grazing, irrigated haylands, and wildlife habitat.	Trabing Creek enter about 200 yards downstream from the site. Hurlburt, Hilman, and Davis Creeks enter upstream. The Colorado-Colony Ditch removes water upstream.
LG22	Located on Little Goose Creek above the County Road 77 bridge crossing at the entrance to the Little Goose Ranch. Same location as USGS Station No. 06303700.	44°37.239' / 107°02.290'	4,533	Ranch buildings, cattle grazing, and wildlife habitat. The BHNF boundary is approximately 3 miles upstream.	Continuous temperature data logger used at this site during 2001 & 2002 seasons. The Last Chance, Peralta, and Red Hill ditches remove water upstream.

Table 6-4. Goose Creek Watershed Assessment BURP Monitoring Site Descriptions

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)
GC1	Base of riffle sampled located on Goose Creek approximately 300 yards upstream from the HWY 339 bridge crossing.	44°52.858' 106°59.252'	3,660	Mainly cattle grazing and irrigated haylands upstream to Sheridan. A few residences along Goose Creek. Railroad and HWY 338 parallel east side of Goose Creek.
GC1A	Base of riffle sampled located on Goose Creek downstream from Big Horn Mountain KOA WWTP discharge.	44°50.127' 106°57.684'	3,685	Cattle grazing/wildlife habitat on east side of reach. Campground on west side of reach.
GC1B	Base of riffle sampled located on Goose Creek upstream from Big Horn Mountain KOA WWTP discharge. The sample location is approximately 40 downstream from Interstate 90.	44°50.046' 106°57.811'	3,686	Wildlife habitat, highways, campground, and residences upstream.
GC2	Riffle is located about 200 yards downstream from Sheridan WWTP discharge.	44°49.34' 106°05.'46'	3,701	A concrete plant is located south of creek with settling ponds north of creek. Sheridan WWTP is upstream.
GC3	Located on Goose Creek at the first riffle upstream of the Fort Road bridge.	44°49.16' 106°57.42'	3,703	Mainly residential with recreational trails along creek. This reach of Goose Creek has been channelized for flood control.
BG2	Located on Big Goose Creek at first riffle upstream from the footbridge at Works and Elk Street.	44°47.46' 106°58.08'	3,745	Predominantly urban / residential.
BG4	Located at first riffle upstream from the Brayton Lane bridge at Normative Services.	44°46.24' 107°01.09'	3,825	Area consists of small acreage properties with some cattle grazing and other domestic stock present.
BG8	Located at first riffle downstream from Daisy Ditch intake, also is first riffle downstream from Beaver Creek.	44°45.635' 107°04.438'	3,940	Rural residential, wildlife habitat, cattle grazing, and haylands.
BG10	Located at riffle near first bend upstream from County Road 87 bridge crossing.	44°45.621' 107°04.501'	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.
BG14	Located at second riffle upstream (about 150 yards) from Highway 331 bridge south of Beckton.	44°44.510' 107°07.863'	4,075	Cattle grazing, irrigated haylands, and wildlife habitat. Large corrals located north of creek upstream from site.
BG15	Riffle sampled is approximately 200 yards downstream from Rapid Creek confluence.	44°43.804' 107°08.698'	4,155	Cattle grazing, irrigated haylands, and wildlife habitat.

Table 6-4. (Continued)

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)
BG18	Riffle is located at USGS Station No. 06302000, approximately 150 yards downstream footbridge at T-T Ranch.	44°41.58' 107°11.07'	4,505	Primarily wildlife habitat. Cattle grazing was infrequent during assessment. The BHNF boundary is about 1 mile upstream from the site.
LG2A	Riffle is located near first bend downstream (100-150 yards) from Coffeen Avenue bridge crossing.	44°47.205' 106°56.480'	3,750	Local area is mainly businesses, residential areas located upstream. A concrete path follows the north side of the creek.
LG5	Located at riffle below first bend upstream Brundage Lane bridge.	44°47.11' 106°56.31'	3,775	Located just upstream from Sheridan, uses are mainly wildlife habitat, irrigated haylands, and rural residential.
LG7	Riffle sampled in 2001 was at base of steel pilings used to support the county road approximately 75 yards upstream HWY 87 bridge crossing. This riffle did not exist in 2002 due to a beaver dam. 2002 sample riffle was located about 100 yards upstream.	44°44.265' 106°56.755'	3,850	Small acreage properties with cattle grazing and irrigated haylands. A trailer park is located upstream.
LG10	Located at first riffle below the Kruse Creek confluence.	44°42.697' 106°57.520'	3,915	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.
LG18A	Located at first riffle above the Bird Farm road bridge, also just upstream from the Sackett Creek confluence.	44°41.008' 106°59.240'	4,040	Small acreage properties with the town of Big Horn upstream.
LG21	Located at the first riffle upstream from the County Road 103 bridge crossing near entrance to Bradford-Brinton Memorial.	44°38.993' 107°00.373'	4,220	Cattle grazing, irrigated haylands, and wildlife habitat.
LG22	Located approximately 100 yards upstream from County Road 77 bridge crossing at Little Goose Ranch.	44°37.191' 107°02.290'	4,533	Ranch buildings, cattle grazing, and wildlife habitat. The BHNF boundary is approximately 3 miles upstream.

6.3 SAMPLING PARAMETERS

This assessment was intended to be a reconnaissance level study to identify any impaired stream segments in Goose Creek, Big Goose Creek, and Little Goose Creek. Reconnaissance level studies are typically used to determine the extent and magnitude of the water quality problem. The GCDAG, in consultation with WDEQ, held meetings to discuss parameter and site selection. Historical data were also referenced to determine worthwhile parameters and sites. Further rationale for sampling each parameter is described below.

6.3.1 FIELD WATER CHEMISTRY AND PHYSICAL PARAMETERS

6.3.1.1 WATER TEMPERATURE

Water temperature affects growth, distribution, and survival of aquatic organisms including trout. These organisms are cold-blooded and thus assume the temperature of the water in which they reside. Dissolved oxygen (DO), also critical to trout and other aquatic life, is inversely related to stream temperatures. Water temperature in the Project area is affected by seasonal changes in air temperature, solar radiation, and other factors. Physical factors may affect stream temperature through loss of vegetative cover caused by disruption of the riparian zone and variation in stream flow due to diversion and irrigation returns.

Trout are most sensitive to high summer water temperatures. Trout are mobile and may migrate to cooler upstream reaches. However, low stream flow and diversion structures may prevent trout movement and result in death when lethal temperatures of 25.6°C (78°F) are attained (Garside and Tait, 1958).

Wyoming surface water quality standards for Class 2 waters prohibit temperature increases that change natural water temperatures to levels deemed harmful to existing coldwater fish life. WDEQ considers this level to be 68 degrees F (20 degrees C) (WDEQ, 2001a). In addition, these standards also prohibit activities that cause temperature changes in excess of 2 degrees F (1.1 degrees C) from ambient water temperatures in a cold water fishery (WDEQ, 2001a).

Instantaneous grab samples for water temperature normally collected during routine water quality monitoring are insufficient to detect maximum daily temperatures in streams (SCCD, 2000b). For this reason, continuous water temperature recorders were utilized to more effectively monitor instream temperatures at select site locations. However, grab samples were also collected at each site during each sampling event for comparisons and correlations to other water quality parameters.

6.3.1.2 pH

The pH of water is a standard measurement conducted for water quality monitoring. Values for pH range from 0 to 14 standard units (SU). The pH of pure water at 24 degrees C (75.2 degrees F) is 7.0 SU, which is neutral. Water greater than 7.0 SU is considered basic and water with a pH below 7.0 SU is considered acidic. The pH for most mountain streams in northeast Wyoming ranges from near neutral to slightly basic while plains streams are usually basic.

Daily fluctuations in stream pH are common and may be quite pronounced when considerable instream plant growth is present. The pH usually rises during daylight hours in response to plant photosynthesis, which reduces the buffering capacity of water. Reduction in pH normally occurs during the night when plant photosynthesis is reduced.

EPA and WDEQ have set a pH range from 6.5 SU to 9.0 SU to protect aquatic life (EPA, 1986; WDEQ, 2001a).

6.3.1.3 CONDUCTIVITY

The primary purpose for measurement of conductivity is to estimate the relative concentration of Total Dissolved Solids (TDS). TDS is a measure of the amount of total substances that are dissolved in water and, although not entirely correct, has also been referred to as salinity. Conductivity is not directly proportional to the TDS concentration; however, the higher the concentration of dissolved substances in water, the higher the conductivity measurement. Thus, conductivity is a reliable, inexpensive estimator of TDS. Conductivity is measured in the field whereas determination of TDS concentration requires a more expensive laboratory analysis.

TDS may pollute streams due to irrigation delivery system seepage (Riggle and Kysar, 1985) and poor quality irrigation return flows (MacDonald et al., 1991). High conductivity may affect aquatic organisms. King (1990) reported that aquatic organisms in several northeast Wyoming ponds were affected when conductivities were greater than 6,900 umhos/cm. EPA (1988) found that high conductivity and chloride concentrations resulted in lower diversity of stream macroinvertebrate taxa. Lower diversity of stream macroinvertebrates used as a food source for stream fish may negatively affect fish populations.

There are no Wyoming surface water standards for conductivity or TDS since these parameters generally pose no direct, significant threat to surface water supplies, beneficial uses, fisheries, and aquatic organisms. However, quality standards are established for Wyoming groundwater such that TDS concentrations for domestic use, agriculture, or livestock use shall not exceed 500 mg/l, 2000 mg/l, or 5000 mg/l, respectively (WDEQ, 1993).

6.3.1.4 DISSOLVED OXYGEN

DO is the amount of free oxygen available to fish and aquatic organisms. A minimum of 4 milligrams per liter (mg/l) is required for maintenance and survival of most aquatic organisms (WDEQ, 2001a). One mg/l is equivalent to one part per million (ppm). Trout and other coldwater fish require a minimum of 5 mg/l DO.

Water temperature and DO are inversely related. Therefore, as the water temperature rises, the DO concentration generally decreases. The extent to which a supply of oxygen can be maintained in a stream depends in part on the hydraulic properties that influence rates at which atmospheric oxygen can be supplied in the water column. The DO concentration may be depleted by processes that consume organic matter, and values above equilibrium can be produced in systems containing actively photosynthesizing biota (Hem, 1992). However, DO depletion rarely occurs in shallow, well mixed, aerated streams (Hynes, 1970).

Wyoming surface water quality standards for DO in Class 2 are designed to protect both the early life stages for coldwater fish (eggs, larvae and juveniles) and other life stages (adults). A 1 day minimum DO concentration of 5.0 mg/l is set to protect early life stages and a minimum 1 day minimum DO concentration of 4.0 mg/l is set to protect adult coldwater fish (WDEQ, 2001a).

6.3.1.5 TOTAL RESIDUAL CHLORINE

Chlorine is one of the most toxic substances known to affect aquatic organisms. Chlorine is commonly used in industrial applications, household cleaning agents, disinfection of municipal water supplies, and wastewater treatment plant effluents to kill nuisance microorganisms and harmful disease causing bacteria (Brungs, 1973). Chlorine may enter waterways through malfunctioning septic systems and point source discharges from facilities using chlorine in water treatment processes.

Although chlorine is necessary for water and wastewater treatment, low levels of residual chlorine in water bodies may kill non-target aquatic organisms including benthic macroinvertebrates and fish. Laws (1981) reported infrequent, but significant fish kills caused by the discharge of chlorine periodically used to prevent fouling in the condenser tubes at electric generating power plants. EPA (1986) reported low level acute lethal chlorine toxicities of 28 micrograms per liter (*u*g/L) for the freshwater zooplankter, *Daphnia magna*, and a lethal concentration of 710 *u*g/L for the threespine stickleback fish species. EPA (1986) indicated that aquatic organisms and aquatic life use should not be affected unacceptably if the 4-day average concentration of TRC does not exceed 11 *u*g/L more than once every 3 years on the average and if the 1-hours average concentration does not exceed 19 *u*g/L more than once every 3 years on the average.

The acute and chronic Wyoming water quality standard for TRC to protect aquatic life use is 19 *u*g/L and 11 *u*g/L, respectively (WDEQ, 2001a).

6.3.1.6 DISCHARGE

Discharge is the measure of the amount of water flowing in a water body and is usually expressed as cubic feet per second (cfs). Discharge is an important physical parameter monitored during water quality sampling because it may affect the quantities of pollutants present. For example, in most Wyoming streams Total Suspended Solids (TSS), turbidity, nitrate, and phosphorus will normally increase with increasing stream discharge while conductivity, chlorides, sulfates, and other ions will normally decrease with increasing stream discharge. Discharge may be used to estimate the load, or total amount, of a pollutant by combining measured stream flow with the concentration of a pollutant. Estimates of pollutant loads may assist in evaluating responses to varying stream flows and may provide information to identify sources of pollutants.

6.3.1.7 HABITAT ASSESSMENT

Evaluation of stream habitat is a necessary component of the total water quality monitoring program. Disruption of upland, riparian, and instream habitat can adversely affect stream water quality and biological communities. Good habitat quality is a key to good fish populations and healthy aquatic biological communities. Soil compaction, loss of ground cover, and eroding stream banks can result in increased discharge, erosion, sedimentation, and water temperature in the stream. Trout spawning and rearing habitat may be lost and macroinvertebrate populations that serve as food for trout may be reduced. Habitat assessments may be quantitative (habitat parameters measured) or qualitative (subjective with no measurements).

There are no numeric standards for habitat quality in Wyoming water quality standards. However, Section 15 (Settleable Solids) and Section 16 (Floating and Suspended Solids) in the Wyoming water quality standards refer to narrative (non-numeric) standards for Settleable Solids, Floating and Suspended Solids, which shall not be present in quantities that could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect other beneficial uses (WDEQ, 2001a).

In addition to using the habitat assessment to address narrative Wyoming water quality standards, the habitat assessment may be used to determine if changes in benthic macroinvertebrate populations are due to changes in water quality or to changes in habitat quality.

6.3.2 LABORATORY ANALYZED WATER CHEMISTRY PARAMETERS

6.3.2.1 TURBIDITY

Turbidity is a common parameter measured in water quality monitoring studies since analysis of samples is inexpensive and results may be used as an indicator of suspended sediment concentration. Turbidity is based on a comparison of the intensity of light scattered by a water sample with the intensity of light scattered by a standard reference solution under the same conditions (American Public Health Association (APHA), 1975).

A strong correlation may exist between turbidity and suspended sediment. The higher the turbidity value is in a sample, the higher the suspended sediment concentration. High turbidity values may be caused by substances other than sediment. Presence of natural water color due to high mineral content (i.e. sulfates, chlorides) or to significant amounts of algae entrained in water may affect turbidity values.

The Wyoming water quality standard for turbidity in Class 2 water bodies states that the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities that would result in a turbidity increase of more that 10 nephelometric turbidity units (NTU's) (WDEQ, 2001a).

6.3.2.2 TOTAL SUSPENDED SOLIDS

TSS is the measure of suspended solid material in the water column. The majority of TSS present in streams within the Project area is expected to be comprised of sediment. This is a valuable indicator parameter because it may be used to track and identify sources contributing sediment to a water body. TSS is highly variable and is correlated to stream discharge. Because of this variability, large numbers of samples may be required to adequately estimate annual TSS concentration.

There is no Wyoming water quality standard for TSS. However, narrative standards in Section 15 and Section 16 of the Wyoming water quality standards (WDEQ, 2001a) address effects due to sediment deposition. Section 15 states that in all Wyoming surface waters, substances attributable to or influenced by the activities of man that will settle to form sludge, bank, or bottom deposits shall not be present in quantities that could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife (WDEQ, 2001a). Section 16 states that in all Wyoming surface waters, floating and suspended solids attributable to or influenced by the activities of man shall not be present in quantities that could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife (WDEQ, 2001a).

6.3.2.3 ALKALINITY

Alkalinity is the sum total of components in the water that tend to elevate the pH of the water above a value of about 4.5 SU. It is a measure of the buffering capacity of the water, and since pH has a direct effect on organisms as well as an indirect effect on the toxicity of certain other pollutants in the water, the buffering capacity is important to water quality (EPA, 1986). Its measurement is also used in the evaluation and control of water and waste water treatment processes.

Dissolved substances such as carbonates, bicarbonates, phosphates, hydroxides (EPA, 1986), borates, and silicates (APHA, 1975) can increase stream alkalinity. Stream water high in alkalinity can maintain ambient pH when exposed to acidic water better than water low in alkalinity. Alkalinity is important for primary production (bacteria and algae) in streams, which directly affects benthic macroinvertebrate populations that serve as food for fish. Generally, as alkalinity increases, stream productivity and density (total number of organisms) increases.

There is no water quality standard for alkalinity in Wyoming surface waters. Naturally occurring maximum alkalinity levels up to approximately 400 mg/l as calcium carbonate

($CaCo_3$) are not considered a problem to human health. Without adequate alkalinity levels, a water body may experience dramatic shifts in pH that can disrupt fish and other aquatic life. EPA (1986) suggests a minimum of 20 mg/l alkalinity for adequate productivity in streams.

6.3.2.4 TOTAL SULFATE

Sulfate is a potential significant pollutant in Wyoming streams. It is naturally present in water with concentrations ranging from a few to several thousand mg/l (APHA, 1975). Higher sulfate content is expected in groundwater close to the deposits in sedimentary rocks. These deposits may include sodium chloride and other chloride salts. Drinking water high in sulfate (greater than 600 mg/l) may have laxative effects on individuals. Water high in sulfate consumed by livestock may cause the "blind staggers" and eventual death. Increased sulfate concentrations in streams are a good indicator of anthropogenic (due to man) effects because irrigation return, industrial, oil field produced water, and other point source discharge effluents may artificially elevate ambient levels.

An increase in sulfate appears to negatively affect aquatic life and benthic macroinvertebrates. Winget and Mangum (1979) studying streams in the Great Basin found that as sulfate levels increased, macroinvertebrate community diversity decreased. They indicated that a sulfate concentration below 150 mg/l was optimal for macroinvertebrates.

Wyoming has not established surface water quality standards for sulfate. Sulfate concentration for Wyoming groundwater has been set at 250 mg/l, 200 mg/l, and 3000 mg/l for domestic, agricultural, and livestock use, respectively (WDEQ, 1993). The secondary drinking water standard is set at 250 mg/l (EPA, 2000).

6.3.2.5 TOTAL CHLORIDE

Chloride naturally occurs in streams and is a principal component of salt (NaCl). Wyoming streams generally contain low chloride concentrations (generally <25 mg/l). Streams draining through sedimentary deposits high in salts may result in high chloride levels. Stream chloride levels may increase due to oilfield produced water, industrial and municipal effluent, and irrigation returns.

Aquatic life is sensitive to chlorides at higher concentrations. O'Neil et al. (1989) studying effects of coalbed methane produced water, found that chloride concentrations at or below 565 mg/l produced no significant effects to the benthic macroinvertebrate community structure in study streams. Chloride values above 565 mg/l showed defined impairment to the community. Birge et al. (1985) found that benthic macroinvertebrate community structure was negatively affected by increasing chloride concentration. They recommended that the average chloride concentration should not exceed 600 mg/l over thirty consecutive days and a maximum instantaneous (one time sample) should not exceed 1,200 mg/l.

Plants are more sensitive than humans to high chloride content. Thus, Wyoming groundwater standards set chloride content at 250 mg/l for domestic use, 100 mg/l for agricultural/irrigation water, and 2000 mg/l for livestock use. The Wyoming surface water quality standard for chloride is 860 mg/l for protection of aquatic life (WDEQ, 2001a).

6.3.2.6 TOTAL NITRATE NITROGEN

Nitrate nitrogen in streams may originate from several possible sources including the atmosphere, plant debris, animal waste and sewage, nitrogen based fertilizers, and some industrial wastes. Nitrate is considered to be one of the primary nutrients (along with phosphorus) associated with non-point source pollution. Nitrate is the end product of the decomposition of organic material such as sewage and excrement, and can be responsible for nutrient enrichment and/or oxygen depletion. Bacteria acts on organic material changing it to ammonia (NH_3), then nitrite (NO_2), and finally nitrate (NO_3).

Nitrate generally has no direct effect on aquatic organisms. Indirect effects are manifest by stimulation of bacteria, periphyton, algae, and instream macrophyte (submerged and rooted plants) growth which, in turn, may stimulate macroinvertebrate and fish production. The benthic macroinvertebrate community structure may shift due to increased abundance of periphyton and algae used as food or refuge by different taxa. Thus, evaluation of the macroinvertebrate community change can indicate nitrate pollution.

Wyoming has adopted the EPA drinking water human health standard of 10 mg/l for Class 2 surface waters (WDEQ, 2001a). EPA has not established surface water standards for nitrates since concentrations required for toxicity to cold or warm water fish rarely occur in natural waters (EPA, 1986). EPA established a standard of 10 mg/l for drinking water supplies to protect against toxic infant methemoglobinemia (blue baby syndrome) characterized by a bluish color of the skin (EPA, 1986). High concentrations of nitrate in livestock drinking water have resulted in abnormally high mortality rates in baby pigs and calves and abortion in brood animals. USGS (1999) reported that national background concentrations of nitrate from streams in undeveloped areas (similar concept to WDEQ Reference areas) were about 0.6 mg/L. However, they cautioned that the overall national background levels were higher than those concentrations measured from relatively undeveloped areas.

6.3.2.7 TOTAL PHOSPHORUS

Phosphorus, along with nitrate, is one of the two most common nutrients associated with NPS pollution. Phosphorus is an essential element for plant growth. However, generally low levels of phosphorus (>0.2 mg/l) can stimulate primary production (bacteria, periphyton, algae) and plant growth when in the presence of sunlight. Strict control of phosphorus is required in watersheds draining to lakes and reservoirs because aquatic organisms and plants rapidly assimilate phosphorus resulting in potential nuisance algae and plant populations, which create unfit conditions for human recreation. Bacterial breakdown of dense growth of algae and plants consumes DO often resulting in oxygen depletion in lakes and reservoirs stressing or killing fish and aquatic organisms.

Naturally occurring phosphorus enters streams primarily by soil erosion and sediment transport. Additional phosphorus may enter streams through municipal and industrial point discharges, runoff containing animal wastes and phosphate fertilizes. Phosphorus creates fewer problems in streams than in lakes and reservoirs since phosphorus is accumulated in bottom sediments. It is difficult to eliminate from standing water bodies because they serve as sediment traps and generally cannot be flushed of bottom sediments.

Wyoming has not established surface water quality standards for phosphorus because problems associated with this pollutant are generally site-specific due to localized sources of phosphorus affecting individual water bodies. EPA (1977) recommended that the total phosphorus concentration should not exceed 0.05 mg/l in a stream that enters a lake or reservoir to prevent development of nuisance algal and plant populations. Mackenthun (1973) suggested a target phosphorus level of less than 0.10 mg/l for streams that did not directly enter lakes or reservoirs. Recent information provided by USGS (1999) from nationwide NAWQA monitoring and assessment reported that national background concentrations for total phosphorus from streams in undeveloped (reference) areas was about 0.10 mg/L. USGS indicated that waters with concentrations of total phosphorus greater than the national background concentration were considered to have been affected by human activities. They found that enrichment of streams with nutrients generally occurred in small watersheds and or regions dominated by agricultural or urban land use.

6.3.2.8 AMMONIA

Ammonia is a byproduct of the decomposition of organic material and can be formed by the hydrolysis of urea. It is toxic to aquatic organisms in low concentrations. U.S. EPA (1986) cited chronic (long term) mortality in trout when ammonia concentration ranged from 0.083 to 1.090 mg/l and from 0.140 to 4.60 mg/l for non-trout species.

Ammonia is generally unstable in water and in most streams quickly converts to nitrite and then to nitrate. Thus, it provides evidence of localized pollutant sources when identified in streams. The Wyoming water quality standard for ammonia is variable because of the interaction between pH and temperature. Seemingly harmless changes in pH and temperature can greatly affect the toxicity of ammonia to aquatic organisms and fish. The toxicity of ammonia to aquatic organisms is increased by increasing water pH. Decreasing water temperature generally increases the toxicity of ammonia to fish. An upper limit of 0.26 mg/l for ammonia based on a single sample exposure should protect trout and coldwater aquatic life from mortality (WDEQ, 2001a). The Wyoming groundwater standard for ammonia for domestic use is 0.50 mg/l (WDEQ, 1993).

6.3.2.9 TOTAL HARDNESS

Hardness is related to the concentration of metals (metallic ions) and is conventionally expressed as the concentration of calcium carbonate ($CaCo_3$) in mg/l. Hardness may be used as an indicator to determine suitability of water for industrial use (Industry Beneficial Use). The maximum acceptable hardness concentration for industrial use varies according the type of industry (Table 6-5).

Table 6-5. Maximum Hardness Levels Accepted by Industry (after EPA, 1986).

Industry	Maximum Concentration (mg/L) as $CaCO_3$
Electric Utilities	5,000
Textile	120
Pulp and Paper	475
Chemical	1,000
Petroleum	9000
Primary Metals	1,000

A commonly used classification for hardness is presented in Table 2-2 (*in* EPA, 1986; after Sawyer, 1960).

Table 6-6. Classification of Water by Hardness Content (mg/l as $CaCo_3$).

Concentration	Description
0 – 75	Soft
75 – 150	Moderately Hard
150 – 300	Hard
300 +	Very Hard

Water that has come into contact with natural limestone formations is the primary source for hardness in streams. Municipal and industrial (especially subsurface mines) point source effluents, storm drain discharge, and to a lesser extent, runoff from agricultural areas, may elevate hardness concentrations.

Wyoming and U.S. EPA have not established water quality standards for hardness. Because hardness in water can be removed with treatment by such processes as softening or ion exchange systems, a standard for industrial use or for public water supply is not practical. Moreover, the effects of hardness on fish and aquatic life appear to be related to the specific ions causing the hardness (i.e. calcium, magnesium, manganese) rather than the hardness itself (EPA, 1986).

6.3.2.10 PESTICIDES AND HERBICIDES

Pesticides and herbicides may enter surface water bodies through surface runoff, ground water discharge, or direct application through accidental spillage or haphazard aerial and ground application. Once in water, many of these man-made compounds may persist and pose human health and safety risks. Pesticides and herbicides may work their way into the aquatic food chain by benthic and terrestrial organism uptake, consumption of the organisms by fish, and accumulation in fish tissue consumed by wildlife and humans. Contamination of drinking water supplies is a major concern because many of these compounds may be carcinogenic at low concentrations.

Thirteen pesticides and herbicides were selected for water quality monitoring during the 2002 sample season. The Sheridan County Weed and Pest and the Sheridan County Extension Agent were consulted to determine what chemicals are used locally, the approximate application times, and the general areas receiving chemical applications. From these discussions, the pesticides and herbicides found in Table 6-7 were suspected to be among those most likely present in local surface waters. Several of these chemicals have also been found in local groundwater tables as shown in an on-going USGS groundwater monitoring project (USGS, 2001). The USGS has sampled for numerous pesticides and herbicides in fish tissue and bed sediment at USGS station 06305700 (SCCD GC1 station) in 1998 as part of the Yellowstone NAWQA (Appendix D).

Table 6-7. Pesticides and Herbicides Monitored During 2002

Pesticide / Herbicide Name	Common Trade Name(s)	Chemical Type
Atrazine	Aatrex, Bicep, Lasso, others	Herbicide
Diazanon	Bug-B-Gone, Spectracide, AG 500, others	Pesticide
Malathion	Cythion, For-Mal, Malakill, others	Pesticide
Parathion	Used in many products	Pesticide
Methyl-Parathion	Used in many products	Pesticide
Prometon	Pramitol	Herbicide
Simazine	Princep, Caliber 90, Simadex, others	Herbicide
Tebuthiuron	Spike	Herbicide
Carbaryl	Sevin, Vioxan, Germain's, others	Pesticide
Carbofuran	Furodan	Pesticide
2,4-D	Weed-B-Gone, Demise, Agrotect, others	Herbicide
Picloram	Tordon	Herbicide
Dicamba	Banvel, Brush Buster, Weedmaster, others	Herbicide

WDEQ and EPA have established drinking water standards for numerous pesticides and herbicides. The list of standards for individual pesticides and herbicides is extensive and is not presented in this Final Report. However, the reader may refer to Wyoming surface water quality standards (WDEQ, 2001a) for standards applicable to many of these compounds.

6.3.3 LABORATORY ANALYZED BIOLOGICAL PARAMETERS

6.3.3.1 FECAL COLIFORM BACTERIA

Fecal coliform bacteria are present in the digestive tracts of warm-blooded animals including humans, other mammals, and birds. Sampling for fecal coliform bacteria may be considered as one of the most important tests conducted in water quality monitoring programs because of public health and safety concerns. Though not harmful itself, the presence of fecal coliform bacteria in water indicates the water is contaminated with fecal material and suggests the possible presence of pathogenic organisms harmful to humans. Cholera, typhoid fever, bacterial dysentery, infectious hepatitis, and cryptosporidiosis are some of the well known diseases that are carried by humans and animals and may spread through contact with contaminated water. Eye, ear, nose, and throat infections may also result from contact with contaminated water. Because of this, domestic sewage from wastewater treatment systems and runoff from land may contaminate water with human pathogens.

The Wyoming fecal coliform bacteria standard reads as follows (WDEQ, 2001a):

During the entire year, fecal coliform concentrations shall not exceed a geometric mean of 200 organisms per 100 mL (based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30 day period), nor shall the geometric mean of 3 separate samples collected within a 24 hour period exceed 400 organisms per 100 mL in any Wyoming surface water.

6.3.3.2 *ESCHERICHIA COLI*

Escherichia coli (*E. coli*) is a species of fecal coliform bacterium commonly identified as an indicator of fecal contamination. This species comprises many different bacterial strains, of which the vast majority are not pathogenic to humans (Hinton, 1985). However, particular strains of *E. coli* (i.e. *E. coli* 0157:H7) and other very toxic strains may be responsible for haemorraghic colitis (severe diahhrea) and haemolytic uraemic syndrome (kidney failure) in humans, which may be fatal if left untreated.

E. coli is widely considered to be the best or most reliable indicator of pathogens originating from fecal matter. For this reason, WDEQ is currently proposing rule changes that would make *E. coli* the bacterial indicator species for Wyoming surface water quality standards. The proposed *E. coli* standards will likely be based on seasonal use of surface waters and may differ between hydrologic watersheds. However, the proposed changes will likely set limits for Full Body Contact waters at 126 organisms per 100 mL (WDEQ, 2002a).

6.3.3.3 BIOCHEMICAL OXYGEN DEMAND

BOD is the measure of the amount of oxygen required to breakdown organic matter through the action of microorganisms. Large amounts of organic matter may consume large amounts of oxygen during this process depriving aquatic organisms and fish of oxygen. Fish kills have resulted from spillage of large quantities of waste manure from confined animal feeding operations into streams. Sources of organic material in streams affecting BOD may include municipal wastewater discharges, runoff from animal feeding operations, storm drain discharge, septic tank leach field systems, and agricultural runoff.

Wyoming and U.S. EPA have not established surface water quality standards for BOD. However, required monitoring for BOD is common in municipal wastewater treatment system discharge to determine effectiveness of the specific system and to evaluate potential impact to receiving water bodies.

6.3.3.4 BENTHIC MACROINVERTEBRATES

Aquatic macroinvertebrates reside in and on the bottom substrate of streams and provide another valuable tool for assessment of water quality. They are small but visible to the naked eye and large enough to be retained in a U.S. Standard Number 30 sieve. Water chemistry sampling provides information for the quality of water at the time of sample collection. In contrast, macroinvertebrates serve as continuous monitors of stream water quality since they live in the water during the majority of their life cycle and are exposed to variable concentrations of pollutants over extended periods of time. This is an important concept because water quality sampling may miss important changes in water quality due to normal seasonal and spatial variability, changes in land use, water management, or accidental pollutant spills.

Wyoming Water Quality Standards established for chemical and physical water quality parameters (WDEQ, 2001a) are established to protect aquatic life and human health. Instead of using sampling results from individual chemical and physical water quality parameters, evaluation of benthic macroinvertebrate populations may serve as a direct measure for the attainment of the Aquatic Life beneficial use in addition to validating the effectiveness of individual numeric water quality chemical and physical standards. Benthic macroinvertebrates also serve to integrate water quality and habitat quality interaction, and evaluate potential synergistic effects from multiple chemical and physical water pollutants not measured during routine water quality monitoring.

Wyoming has developed biological criteria for streams statewide, but they have not been adopted as numeric, enforceable standards (Stribling et al., 2000; Jessup and Stribling, 2002). As such, they may be used as narrative standards to determine beneficial use for protection and propagation of fish and wildlife. The Biological Criteria in Section 32 of the Wyoming Water Quality Standards provide a narrative standard for protection of indigenous or intentionally introduced aquatic communities (i.e. brown, brook, and rainbow trout species). In addition, Section 4 in the Wyoming Water Quality Standards relates the presence of food sources (e.g. benthic macroinvertebrates) for game and non-game fish as a criteria for Surface Water Classes and (beneficial) uses (WDEQ, 2001a).

6.3.4 ADDITIONAL STUDIES

6.3.4.1 FECAL COLIFORM IN BED SEDIMENT SAMPLING

Several studies have documented that a definite relationship exists between elevated bacteria concentrations and bottom sediments, as compared with those in the overlying water column (Stephenson and Rychert, 1982). Sampling of bed sediments for this Project were conducted to assist with data interpretation and to provide additional information for future watershed planning efforts.

Monitoring of bacteria (fecal coliform) concentrations in bed sediment was conducted during April and September 2002. Turbidity samples were collected concurrently with fecal coliform samples to determine if any relationships existed between bacteria concentrations and bed sediment. April was selected for monitoring to determine whether bacteria in bed sediments survive the winter months in cold stream temperatures. September was selected to monitor concentrations while water temperatures were still relatively warm, in addition, most of the streams relatively higher sediment loads likely have been deposited by this time. It was assumed that bacteria-laden sediment is generally flushed from local streams during peak flows in May and June and then allowed to deposit during lower late summer stream flows. Field methods employed for this sampling is discussed in Section 6.5.1.

6.3.4.2 TOTAL RESIDUAL CHLORINE ANALYSIS BY ALTERNATIVE METHODS

Preliminary analysis of 2001 TRC samples revealed data that were suspected to be unreliable due to the existing stream water properties. Discussions with the manufacturer revealed several possibilities that may create false positive TRC readings using the HACH Pocket Colorimeter. Therefore, during 2002, samples were collected in duplicate for analysis by the HACH field method and by a titration method used at the Sheridan WWTP. This sampling was conducted to verify the accuracy of the HACH Pocket Colorimeter data. Please refer to Section 8.7 for more information about the analyses of these data.

6.3.5 SUPPORTING INFORMATION

6.3.5.1 PRECIPITATION AND AIR TEMPERATURE

Precipitation and air temperature are essential components for a watershed-scale monitoring project. Both may be used to predict the timing and magnitude for water yield within the watershed. The timing and magnitude of water yield will affect chemical, physical, biological, and habitat characteristics for water bodies. Precipitation and air temperature must be factored into water quality data analyses because observed water quality changes among years may be related to normal annual fluctuation rather than anthropogenic (man-caused) effects.

6.4 SAMPLING FREQUENCY

Monitoring was based on a random (unbiased) systematic sampling design. This program was designed to collect data from varying flow and seasonal regimes by utilizing an extended sampling season. Water quality samples were collected from April through October during 2001 and 2002. Monitoring was not intended to be oriented toward select flow or precipitation events; sampling dates were provided by random number generation using MicroSoft Excel®. All sample stations on Goose Creek and its associated tributaries (stations GC1 – GC6) were sampled on the same day proceeding upstream from the most downstream location. The same procedure was utilized on Big Goose Creek and its associated tributaries (stations BG1 – BG18) and Little Goose Creek and its associated tributaries (stations LG1 – LG22).

Laboratory analyzed water quality parameters including nitrate nitrogen, phosphorus, ammonia, BOD, chloride, sulfate, TRC, hardness, TSS, and alkalinity were sampled monthly from April through October. Field analyzed water quality parameters including electrical conductivity, DO, temperature, pH, and flow were collected during each scheduled sampling event to coincide with fecal coliform sampling. Laboratory analyzed turbidity samples were also collected during each scheduled sampling event. Fecal coliform bacteria samples were collected during April, May, August, and October. Sampling for fecal coliform consisted of taking five samples during separate 24 hour periods within a thirty (30) day period as required by Wyoming water quality standards (WDEQ, 2001a).

Continuous temperature data loggers were used to record instream water temperatures every 15 minutes from April through October. Seven sites were equipped with data loggers in 2001 and 10 sites were selected in 2002. Continuous temperature data were downloaded from the data loggers on a monthly basis to ensure the data were being properly recorded.

Benthic macroinvertebrate samples and reach level habitat assessments (BURP monitoring) were performed at 19 sites on an annual basis. This work was completed during September 2001 and September 2002. Precipitation and air temperature data were collected from the Billings, Montana National Weather Service website for the Sheridan County Airport station. Multiple photograph panoramas were collected at each water quality sampling site during spring (April), summer (June/July), and fall (October) at each site. Photographs were also collected during each BURP monitoring event.

E. coli, fecal coliform in bed sediment, pesticide/herbicide, and TRC titration sampling were conducted on a limited basis during 2002 only.

Tables 6-8 and 6-9 provide the GCWA sampling schedules for 2001 and 2002, respectively. These schedules apply to all sampling sites unless noted otherwise.

Table 6-8. 2001 Scheduled Sampling Frequency for Sample Stations Used in the Goose Creeks Watershed Assessment

Parameter	Number of sample events scheduled per month						
	April	May	June	July	August	September	October
Temperature	5	5	1	1	5	1	5
pH	5	5	1	1	5	1	5
Conductivity	5	5	1	1	5	1	5
Dissolved Oxygen	5	5	1	1	5	1	5
Discharge	5	5	1	1	5	1	5
Turbidity	5	5	1	1	5	1	5
Fecal Coliform	5	5	0	0	5	0	5
Total Residual Chlorine	1	1	1	1	1	1	1
Biochemical Oxygen Demand	1	1	1	1	1	1	1
Total Alkalinity	1	1	1	1	1	1	1
Total Chloride	1	1	1	1	1	1	1
Total Sulfate	1	1	1	1	1	1	1
Total Hardness	1	1	1	1	1	1	1
Total Ammonia	1	1	1	1	1	1	1
Total Nitrate Nitrogen	1	1	1	1	1	1	1
Total Phosphorus	1	1	1	1	1	1	1
Total Suspended Solids	1	1	1	1	1	1	1
Temperature (data loggers)[1]	Continuous – measured every 15 minutes						
Benthic Macroinvertebrates	0	0	0	0	0	1	0
Habitat Assessments	0	0	0	0	0	1	0
Photographs – Panoramic	1	0	1	0	0	0	1
Photographs – BURP	0	0	0	0	0	1	0

Notes:

1. Continuous temperature data loggers were used at sites GC1, BG2, BG6, BG18, LG2, LG8, and LG22 during 2001.

Table 6-9. 2002 Scheduled Sampling Frequency for Sampling Stations Used in the Goose Creeks Watershed Assessment

Parameter	Number of samples events scheduled per month						
	April	May	June	July	August	September	October
Temperature	5	5	1	1	5	1	5
pH	5	5	1	1	5	1	5
Conductivity	5	5	1	1	5	1	5
Dissolved Oxygen	5	5	1	1	5	1	5
Discharge	5	5	1	1	5	1	5
Turbidity	5	5	1	1	5	1	5
Fecal Coliform	5	5	0	0	5	0	5
Total Residual Chlorine	1	1	1	1	1	1	1
Total Alkalinity	1	1	1	1	1	1	1
Total Chloride	1	1	1	1	1	1	1
Total Sulfate	1	1	1	1	1	1	1
Total Hardness	1	1	1	1	1	1	1
Total Ammonia	1	1	1	1	1	1	1
Total Nitrate Nitrogen	1	1	1	1	1	1	1
Total Phosphorus	1	1	1	1	1	1	1
Total Suspended Solids	1	1	1	1	1	1	1
Temperature (data loggers)[1]	Continuous – measured every 15 minutes						
Benthic Macroinvertebrates	0	0	0	0	0	1	0
Habitat Assessments	0	0	0	0	0	1	0
Photographs – Panoramic	1	0	0	1	0	0	1
Photographs – BURP	0	0	0	0	0	1	0
E. coli[2]	1	1	0	0	5	0	1
Fecal Coliform – Bed Sediment[3]	1	0	0	0	0	1	0
Pesticides / Herbicides[4]	0	0	1	0	0	0	0
Total Residual Chlorine – Lab[5]	0	0	1	1	0	0	0

Notes:

1. Continuous temperature data loggers were used at sites GC1, GC4, BG2, BG6, BG9, BG18, LG2, LG8, LG17, and LG22 during 2002.
2. *E. coli* was scheduled only for sites GC1, GC2, GC4, GC6, BG1, BG4, BG9, BG11, BG13, BG16, BG18, LG1, LG6, LG9, LG11, LG14, LG17, LG19, and LG22.
3. Fecal Coliform in Bed Sediment was scheduled only for sites GC2, BG18, and LG8.
4. Pesticides and Herbicides were scheduled only for sites GC3, BG3, and LG5.
5. Lab titrations of Total Residual Chlorine were scheduled for sites GC1, GC2, GC4, GC5, BG1, BG4, BG9, BG14, BG18, LG1, LG3, LG6, LG13, LG18, and LG22.

6.5 SAMPLING AND ANALYSIS METHODS

Field methods followed approved sampling protocols as stated in WDEQ Standard Operating Procedures (WDEQ, 1999). Sample stations were located in well mixed portions of the stream channels and staff gauges were established to record stream discharge. Sampling was generally performed near the center of the channel and progressed from downstream stations to upstream stations.

Prior to sampling, field personnel ensured that all equipment were available and in proper working condition. Equipment checklists were completed to verify all necessary equipment was taken to the field. Field meters were calibrated prior to leaving for sampling and calibration logs were kept for each calibration. The DO meter was also calibrated in the field with every 300 foot elevation change. Calibrations were performed as described in Section 7.4. Maintenance logs were used to document any necessary repairs (battery changes, probe replacement, etc.). Coolers, sample bottles, trip blanks, and preservatives (if necessary) were gathered from the contract laboratory, Inter-Mountain Laboratories (IML), prior to sampling. Ice was purchased for sample preservation before collecting samples.

6.5.1 WATER QUALITY

Field water chemistry parameters were measured in-situ, or at the stream, with portable monitoring instruments (field meters). Temperature and pH were measured with a Hanna Instruments meter Model Number HI 9025. Conductivity was measured with a Hanna Instruments conductivity meter Model Number HI 8733. DO measurements were made with a YSI 95 meter; this meter also measured temperature.

Before sampling, a five gallon plastic bucket was triple rinsed with ambient stream water. Facing upstream, the bucket was then filled with stream water (see Figure 6-2) and then probes were immersed into the bucket (see Figure 6-3). The YSI 95 manufacturer recommended that the probe be stirred to provide accurate readings. Once the meter readings stabilized, the analytical results were immediately recorded on appropriate field data sheets.

For TRC, the HACH Pocket Colorimeter was zeroed using a sample bottle of stream water obtained from the sample bucket. A second sample bottle was filled with water and the contents from a DPD Total Chlorine Powder Pillow were added. This sample was then vigorously shaken for 20 seconds and after 3 to 6 minutes the sample was inserted into the colorimeter and a reading was obtained and recorded.

Instantaneous grab samples for parameters requiring laboratory analysis were collected directly from the stream in labeled plastic containers. Fecal coliform and *E. coli* samples were collected in pre-sterilized bottles containing sodium thiosulfate to neutralize potential residual chlorine. Nutrient samples were preserved with sulfuric acid and hardness samples were preserved with nitric acid. Pesticide and herbicide samples were collected in one (1) liter glass containers.

Samples were collected at 0.6 the depth of the water column when discharge or adequate depth allowed (Ponce, 1980). Care was taken to prevent agitation of stream substrate during low discharge to prevent accidental introduction of sediment into the sample container. With the exception of pesticide / herbicide samples and bed sediment samples, at least ten percent of samples were collected in duplicate for QA/QC purposes. High analytical cost prevented collection of duplicate pesticide and herbicide samples and duplication of bed sediment samples was not practical by the sampling method used (Section 6.5.1.1).

Samples requiring preservation were immediately preserved, placed on ice in a cooler, and hand delivered to the laboratory for analysis. Appropriate chain of custody (COC) forms and procedures were completed to ensure proper sample tracking, analysis, and disposition (EPA, 1988; WDEQ, 2001). Referenced sample analysis methods are listed in Table 6-10.

Table 6-10. Standard Field and Laboratory Methods for Chemical, Physical, Biological, and Habitat Sampling Conducted at Goose Creek Watershed Assessment Sample Stations, 2001 through 2002

Parameter	Recording Unit	Method / Reference[1]	Location of Analysis	Preservative	Holding Time
Water Temperature	°C	Grab / EPA 1983 170.1	On-Site / Field	N/A	Analyze in Field
Water Temperature	°C	Data Logger	On-Site / Field	N/A	Analyze in Field
pH	Standard Units	Grab / EPA 1983 150.1	On-Site / Field	N/A	Analyze in Field
Conductivity	µmhos/cm	Grab / EPA 1983 120.1	On-Site / Field	N/A	Analyze in Field
Dissolved Oxygen	mg/L	Grab / EPA 1983 360.1	On-Site / Field	N/A	Analyze in Field
Total Residual Chlorine	mg/L	Grab / EPA 1983 330.5	On-Site / Field	N/A	Analyze in Field
Turbidity		Grab / EPA 1983 180.1	IML[2]	Ice	48 hours
Biochemical Oxygen Demand	mg/L	Grab / EPA 1983 405.1	IML	Ice	48 hours
Fecal Coliform		Grab / SM 9222D[3]	IML	Ice, Sodium Thiosulfate	6 hours
E. coli		mColiBlue 24	IML	Ice, Sodium Thiosulfate	6 hours
Total Suspended Solids	mg/L	Grab / SM 2540D	IML	Ice	7 days
Total Alkalinity	mg/L	Grab / SM 2320B	IML	Ice	14 days
Total Nitrate Nitrogen	mg/L	Grab / EPA 1983 353.2	IML	Ice, Sulfuric Acid	28 days
Total Ammonia	mg/L	Grab / EPA 1983 350.1	IML	Ice, Sulfuric Acid	28 days
Total Phosphorus	mg/L	Grab / EPA 1994 200.7	IML	Ice, Sulfuric Acid	28 days
Total Chloride	mg/L	Grab / EPA 1983 300.0	IML	Ice	28 days
Total Sulfate	mg/L	Grab / EPA 1983 300.0	IML	Ice	28 days
Total Hardness	mg/L	Grab / EPA 1983 130.2, SM 2340B	IML	Ice, Nitric Acid	6 months
Atrazine, Simazine, Tebuthiuron, Prometon, Diazanon, Malathion, Parathion, Methyl-Parathion	µg/L	Grab / EPA Method 525	IML	Ice	7 days
Dicamba, Picloram, 2,4-D	µg/L	Grab / EPA Method 8151	IML	Ice	7 days
Carbaryl, Carbofuran	µg/L	Grab / EPA Method 531	IML	Ice	7 days

Table 6-10. (Continued)

Parameter	Recording Unit	Method / Reference[1]	Location of Analysis	Preservative	Holding Time
Discharge	cfs	Mid-Section Method	On-Site / Field	N/A	N/A
Benthic Macroinvertebrates	Metrics	King 1993	ABA[4]	Formalin	N/A
Habitat Assessments	N/A	King 1993	On-Site / Field	N/A	N/A
Ambient Air Temperature	°C	National Weather Service Internal Methods	NWS – Billings, MT Office	N/A	N/A
Precipitation	Inches	National Weather Service Internal Methods	NWS – Billings, MT Office	N/A	N/A

Notes:

1. Method references for laboratory analysis were provided by contract laboratories and are defined in their standard operating procedures.
2. IML refers to Inter-Mountain Laboratories in Sheridan, Wyoming.
3. SM refers to Eaton et. al., 1995. Standard Methods for the Examination of Water and Wastewater. Washington, D.C.
4. ABA refers to Aquatic Biology Associates in Corvallis, Oregon.

6.5.1.1 FECAL COLIFORM IN BED SEDIMENT

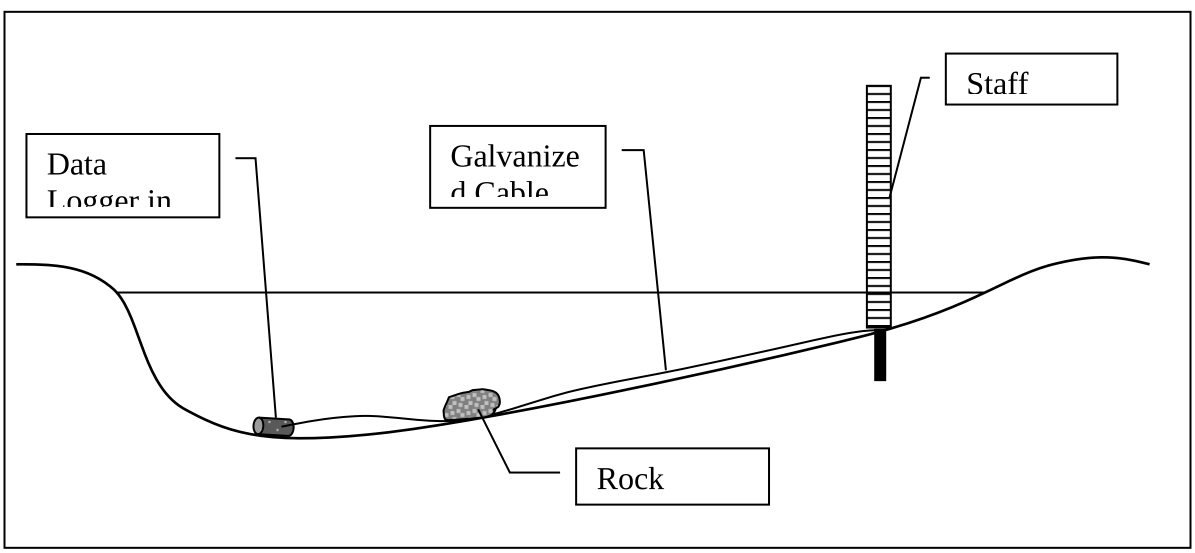
This method for obtaining fecal coliform concentrations within stream bed sediment is based upon the sampling method used by Stephenson and Rhychert (1982). Two sets of ambient water samples for turbidity and fecal coliform analysis were collected before disturbing the bed sediment. Approximately 4 square yards of bed sediment were then disturbed with a lawn rake by a person assisting the sampler. The sampler would stand approximately 10 yards downstream from the person raking the sediment in the flow path of the sediment plume (see Figure 6-4). The sampler would then take turbidity and fecal coliform samples 15, 30, 45, and 60 seconds after disturbing the sediment. After all samples were collected, velocity was measured at the sample location.

6.5.1.2 CONTINUOUS WATER TEMPERATURE MONITORING

Instream temperatures were measured on a continuous basis at seven sites in 2001 and at 10 sites in 2002. Tables 6-8 and 6-9 identify sites that were equipped with continuous data loggers. Onset® Tidbit temperature loggers (model #TBI32-05+37) were programmed to measure temperature at 15 minute intervals. Approximately once per month, data were electronically transferred in the field to a Shuttle. Once all logger data were collected, the Shuttle was used to transfer data to a computer.

To house the data loggers, each logger was placed inside a six inch piece of HDPE pipe with galvanized mesh at each end to allow water passage (see Figure 6-5). The pipe was placed in a relatively deep portion of the channel, secured with a weight (if necessary), and cabled to the station's staff gauge (see Figure 6-6). Figure 6-1 depicts typical data logger deployment equipment.

Figure 6-1. Stream Cross-Section of a Typical Continuous Temperature Data Logger Arrangement



6.5.2 DISCHARGE

Discharge was measured at all but three sample sites during every sampling event with the use of calibrated staff gauges. Discharge at BG14 and LG22 was measured using USGS wire-weighted gauges and discharge at LG3 was estimated by the bucket-time method; discharge monitoring at these three sites is discussed later in this section.

During this assessment, a typical staff gauge installation included securing the gauge to a steel post or bridge abutment (see Figure 6-7) that allowed measurement of several different stream stages. Survey benchmarks were used to determine if the staff gauge had moved during the sample season and/or during the winter of 2001-2002. If available, a permanent, stable local landmark was used as for a benchmark, otherwise, a section of re-bar was driven into the ground for use as a permanent benchmark. By surveying the benchmark (see Figure 6-8) and the top of the staff gauge, elevation changes in the staff gauge could be detected. Staff gauge movement would occur when ice froze around the staff gauge followed by higher stream flows that would lift the ice and pull the staff gauge out of the streambed. Staff gauges that experienced movement were reinstalled and recalibrated.

Calibration of staff gauges was performed by measuring discharge with the Mid-Section Method (WDEQ, 1999) at three to five varying stream stages/discharge rates. The Mid-Section Method entails stretching a tape perpendicular to the stream channel and measuring velocity and flow depth at intervals along the tape. Straight channels with uniform flow and minimal flow obstruction (boulders, logs, etc) were selected in locations near the staff gauge for measuring discharge. Velocity was measured at 0.6 times the flow depth (as determined by a top-setting rod) using a Marsh-McBirney 2000 portable current meter. If flow depths exceeded three feet, velocity measurements were taken at 0.2 and 0.8 times the flow depth and then averaged for that section. Instantaneous discharge was later calculated with spreadsheets using the continuity equation where:

$$\textit{Discharge } (ft^3/sec) = \textit{Velocity } (ft/sec) \times \textit{Cross-Sectional Area } (ft^2)$$

Results for the three to five calibration measurements were plotted using the stage (staff gauge reading) as the independent variable and measured discharge as the dependent variable (log scale). A regression was performed on the data to produce a stage-discharge equation that could be used to determine discharge rates for each staff gauge reading observed while collecting water quality samples.

Stream stages measured with USGS wire-weighted gauges at sites BG14 and LG22 utilized the same method for estimating discharge as was used when using staff gauges (see Figure 6-9). Discharge was estimated with the Mid-Section Method while noting the wire-weighted gauge reading at varying flow regimes. Stage-discharge equations were then produced as described above.

At site LG3, discharge was measured by noting the time in which flow from the Coffeen Avenue storm drain would fill a calibrated five-gallon bucket. After three measurements had been taken, an average discharge rate was calculated.

6.5.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate sample collection and analysis methods were the same as those used by WDEQ described in King (1993) and WDEQ (1999). Samples were collected in mid- to late September. Eight benthic macroinvertebrate samples were collected from a representative maximum 100 foot riffle/run and composited into a single sample. Sampling began at the downstream portion of the riffle and proceeded upstream to prevent substrate disturbance and incidental sampling of drift. A one square foot modified Surber sampler (extended 3 foot net length) fitted with 500 micron (um) netting was used. Computer generated random numbers were used to select individual square foot quadrants. At least ten percent of all locations were sampled in duplicate. Duplicate sampling consisted of two samplers each equipped with a Surber sampler collecting simultaneously next to one other.

The Surber sampler was firmly seated on the stream bottom facing upstream into the stream flow. Before disturbing substrate surrounded by the Surber sampler, substrate particle size composition and embeddedness measurements were taken. After completion of substrate and embeddedness measurements, larger cobble and gravel within the Surber sampler were scraped by hand and soft brush, visually examined to ensure removal of all organisms, then discarded outside the sampler. Remaining substrate within the sampler was thoroughly agitated to a depth of 2 to 3 inches (5 to 8 centimeters). Net contents were placed in a tub and rinsed into a U.S. Standard Number 35 (500um) sieve. Sieve contents were placed into labeled plastic jars containing an isopropyl alcohol - formalin mixture for preservation. A macroinvertebrate sample COC form was completed and placed with samples in a cooler to accompany samples from the field to the laboratory.

Stream current velocity was measured in feet per second (fps) at each Surber sample quadrant after macroinvertebrate collection by placing a portable current meter at 0.6 times the water depth. The meter was placed where the front of the Surber sampler was located. The purpose for velocity measurement was to determine if differences in sediment deposition and embeddedness among stations may be due to differences in current velocity.

Samples were sent to Aquatic Biology Associates (ABA) in Corvallis, OR for processing and analysis. This is the same laboratory used by WDEQ and thus, the same analytical methods are used. Lead taxonomist was Mr. Robert Wisseman, ABA Senior Scientist.

In the laboratory, at least 500 organisms (usually 500 to 550) were removed from randomly selected squares in a gridded tray described by Caton (1991). When organism density was high (greater than 300 organisms per square), the next square or subsample was subdivided into quarters by placing an X-shaped frame over the petri dish or sorting container. A random number from 1 to 4 was selected and all organisms were removed from the corresponding quarter. The entire sample was analyzed if less than 500 organisms were present. After subsampling was completed and 500 to 550 organisms removed, the sorter re-distributed the remaining sample within the gridded tray and spent about 5 minutes looking for Large and Rare organisms (Vinson and Hawkins, 1996). Organisms removed during the large and rare search were placed in a separate vial and assigned an occurrence of one (1) for the correction factor, density and metric calculations. Organisms were hand picked using illuminated 2X and 3X magnifiers or stereozoom binocular microscope and no flotation methods were employed.

The majority of organisms were identified to genus or species with the exception of taxonomically indistinct worms and certain difficult Dipteran taxa. Zooplankton, including Cladocera, Copepoda and Rotifera, terrestrials, fish, amphibians, reptiles, Ostracoda, bryozoans, protozoans and gastrotrichs were noted, but were not included in taxa lists and metric calculations. A consistent Standard Level of Identification was used during the Project to provide comparable data among years (Table 6-13). The same Level of Identification should be used in future benthic macroinvertebrate monitoring for comparability. Density estimates were expressed as number per square meter (No./m^2). Figure 6-10 shows an example of a mayfly (*Tricorythodes*), Figure 6-11 shows an example of a caddisfly (Glossosomatidae), Figure 6-12 shows an example of a crayfish (Decapoda), Figure 6-13 shows an example of a blackfly (Simuliidae) and Figure 6-14 shows an example of a midge fly larva (*Chironomus*).

Electronic and hard copy analytical results were sent to SCCD from ABA. Included in the data package was a Taxa List and a list of seventy-two (74) macroinvertebrate metrics for each station. See Appendix M for the list of macroinvertebrate metrics.

6.5.3.1 BENTHIC MACROINVERTEBRATE DATA ANALYSIS, DETERMINATION OF BIOLOGICAL CONDITION, AND AQUATIC LIFE USE

A series of metrics were calculated for each benthic macroinvertebrate sample. A metric is a descriptor of one facet of the benthic population that responds to water quality and habitat change in a predictable manner (Barbour et al., 1999). Table 6-14 lists select macroinvertebrate metrics and their response to water quality and habitat quality stressors. Appendix Tables M-1 through M-4 lists seventy-four (74) total metrics calculated for each sample.

Benthic macroinvertebrate data evaluation methods described in the SAP included use of the Wyoming Biological Condition Index (WBCI) developed by Barbour et al. (1994) for Bighorn Mountain foothill streams and use of the Wyoming Stream Integrity Index (WSII) developed by Stribling et al. (2000) for Wyoming streams statewide. Recent work by Jessup and Stribling (2002) updated the WSII and presented new biological criteria for Bighorn Mountain foothill streams in the Middle Rockies ecoregion and new biological criteria for streams in the Northwestern Great Plains ecoregion of Wyoming. The new biological criteria were used to evaluate biological condition for this Project.

The biological criteria presented by Jessup and Stribling (2002) were based on analysis of monitoring data collected by WDEQ from 1993 through 1999 from multiple reference and non-reference quality streams statewide. The updated biological criteria for the WSII are presented in Table 6-15. Biological communities in the Middle Rockies ecoregion foothill streams naturally differ from biological communities in the plains streams of the Northwestern Great Plains ecoregion. Because benthic communities naturally differ between ecoregions, expectations for benthic communities required a different set of biological criteria for each ecoregion. Biological criteria for the Middle Rockies ecoregion were used to evaluate biological condition at foothill stations BG18 and LG22. Biological condition criteria for the Northwestern Great Plains were used to evaluate biological condition at the remaining sample stations. Stations BG18 and LG22 although in the Middle Rockies ecoregion, were also assessed using Northwestern Great Plains biological criteria to allow evaluation of comparable changes in benthic macroinvertebrate communities along the longitudinal stream gradient for both Big Goose Creek and Little Goose Creek.

The biological criteria presented by Jessup and Stribling compare metric values for the sample station to optimal metric values from combined reference (least impacted) stations (Table 6-16). Metrics from the sample are compared to the optimal metric value and expressed as a percent. The percentages are summed for each sample metric to provide a biological condition rating. The biological condition rating was used to rate the biological community as Very Good, Good, Fair, Poor, or Very Poor (Table 6-15). Biological condition ratings of Very Good or Good indicated full support for aquatic life use and ratings of fair, poor, or very poor indicated non-support for aquatic life use. Non-support indicates the aquatic community is stressed and water quality or habitat improvement is needed to restore the stream to full support for aquatic life use.

Benthic macroinvertebrate communities were also compared by station among years (temporal comparison) and between stations (spatial comparison). Biological condition ratings and certain metric values were compared to certain water quality and habitat variables (including discharge) by linear regression to determine significant associations.

6.5.4 HABITAT ASSESSMENT

Habitat assessments were conducted at the same stream reach where benthic macroinvertebrates were collected after biological sampling was completed. The habitat assessment was conducted following methods found in Platts et al. (1983), Plafkin et al. (1989) and Hayslip (1993) compiled and modified by King (1993) for use in Wyoming.

The habitat assessment included three components:

1. Semiquantitative substrate particle size composition and embeddedness evaluation;

2. Qualitative habitat assessment for the stream reach; and

3. Photopoints.

6.5.4.1 SUBSTRATE COMPOSITION

Evaluation of substrate was required because substrate particle size was an important factor controlling the composition and density of benthic macroinvertebrate populations. Stream reaches dominated by diverse cobble and gravel substrate will have a diverse benthic macroinvertebrate population (in the absence of water pollution). Stream reaches dominated by sand and silt substrate will exhibit different benthic community composition when compared to reaches dominated by cobble and gravel. Population density and diversity is usually reduced because favorable habitat for colonization of organisms is reduced. Water quality monitoring programs must include evaluation of substrate to determine whether observed change in benthic macroinvertebrate population was due to water pollutants or merely to change in stream substrate. Evaluation of differences in substrate particle size among stations may reveal disruptions in the watershed often evidenced by increased sand and sediment deposition.

Immediately after the Surber sampler was seated and before substrate was disturbed, the percent area occupied by cobble, gravel, fine gravel, sand and silt was estimated (DeBrey and Lockwood, 1990; Platts et al., 1983). A piece of plexiglass was used to reduce surface glare to aid in observation of substrate (Figure 6-15). The following particle size classification was based on Plafkin et al. (1989) and Burton (1991). Particle size composition was evaluated for each of the eight Surber sample quadrates.

Table 6-11. Stream Substrate Particle Size Classification

Substrate Type	Substrate Size
Boulder	Greater than 10 inches
Cobble	2.5 inches to 10 inches
Coarse Gravel	1 inch to 2.5 inches
Fine Gravel	0.3 inch to 1 inch
Silt	0.3 inch and below (texture soft, fine)
Sand	0.3 inch and below (texture gritty, coarse
Hard Pack Clay	0.3 inch and below (solid, slick)

When silt was greater than approximately 1/4 inch (about 6 millimeters) in depth, it was classified as silt. When silt was less than approximately 1/4 inch, the substrate underneath the silt was classified.

6.5.4.2 EMBEDDEDNESS (SILT COVER)

Embeddedness is a measure of the degree to which cobble and gravel were covered or surrounded by fine silt. Silt that settles on, or penetrates into the streambed is detrimental to fish and benthic macroinvertebrate populations compared to silt entrained in the water column (Campbell and Doeg, 1989). Silt deposited on substrate can result in lowered inter-gravel oxygen concentration reducing survival of trout eggs and negatively affect stream productivity and density of aquatic organisms, which are the main food source of cold water stream fish

(Hynes, 1970; Hawkins et al., 1983; Waters, 1995). Low levels of silt generally reduce the density of organisms while high levels of silt reduce both density and diversity of organisms (Chutter, 1969; Lenat et al., 1981). Heavy silt deposition combined with nutrient enrichment (from nitrate and phosphorus) may produce drastic effects by reducing diversity through elimination of macroinvertebrate species (Lemly, 1982).

Embeddedness was classified at the same time as substrate particle size classification for each of the 8 Surber sample quadrates.

The following embeddedness rating system used was described by Platts et al. (1983).

Table 6-12. Embeddedness Rating Classification

Embeddedness Rating	Description
5	Less than 5 percent of surface covered by silt
4	Between 5 to 25 percent of surface covered by silt
3	Between 25 to 50 percent of surface covered by silt
2	Between 50 to 75 percent of surface covered by silt
1	Greater than 75 percent of surface covered by silt

Embeddedness data from each quadrate were combined into the Weighted Embeddedness Value (WEV) that described the degree that cobble and gravel were covered or surrounded by silt. Because each quadrate was randomly selected, the WEV provided an unbiased estimate of silt coverage at the studied riffle/run. The WEV may range from 20 (complete silt cover) to 100 (no silt cover). Figure 6-16 illustrated stream substrate with a WEV value of 99 and Figure 6-17 shows stream substrate with a WEV value of 20.

6.5.4.3 QUALITATIVE HABITAT ASSESSMENT

The habitat assessment is a qualitative assessment comprised of thirteen (13) parameters. Because of the subjective nature of the assessment, results must be interpreted with caution. SCCD attempted to reduce uncertainty by estimating precision for assessments through intra-crew assessments at ten percent of total stations assessed. The intra-crew assessment consisted of two or more individuals each performing the assessment independent of one another without communication. Despite uncertainty for accuracy for the subjective assessment, with proper training, general instream and riparian habitat condition may be adequately described to identify significant habitat deficiencies needing improvement.

The majority of habitat assessment parameters were “discharge dependent”. This means many habitat parameters rated higher during periods of higher discharge and some rated lower during periods of low discharge. This was an important consideration because discharge may vary several fold between spring high flow and the fall and winter low base flow. SCCD attempted to conduct habitat assessments within two weeks of the preceding annual date of assessment to reduce bias introduced by variable seasonal stream discharge.

The qualitative habitat assessment method used by SCCD was described in King (1993) and was based on compilation of methods presented in Plafkin et al. (1989), EPA (1991) and Hayslip (1993). The length of stream reach assessed was determined by multiplying the bankfull width times 20, or a minimum of 360 feet (Burton, 1991). SCCD determination of stream reach length assessed was the same as that used by WDEQ.

Habitat parameters were weighted according to their influence on aquatic organisms. **Primary parameters** received the greatest weight and described microhabitat characteristics that have a direct influence on macroinvertebrates. **Secondary parameters** described macrohabitat characteristics through stream channel morphology that indirectly influenced macroinvertebrates and fish. **Tertiary parameters** were weighted less than primary and secondary parameters. These parameters described surrounding land use characteristics that affected streambank and riparian zone stability. The higher the individual or cumulative score, the better the habitat. The maximum habitat assessment score was 200 points.

Primary Parameters (each 20-0 points)

1. **Bottom substrate / Percent fines (silt, sand)**: estimated the percent of combined sand and silt **only** within the riffle/run sampled. See Section 6.5.4.1 for Substrate Composition methods.

2. **In stream cover (for fish)**: estimated the amount of in stream features serving as habitat and cover for fish for the entire reach.

3. **Embeddedness (silt cover)**: estimated the degree to which cobble and gravel were covered or surrounded by silt **only** within the riffle/run sampled. See Section 6.5.4.2 for embeddedness evaluation methods.

4. **Velocity / Depth**: estimated the relative contribution for four different velocity and depth regimes within the entire reach.

- Fast and deep
- Slow and deep
- Fast and shallow
- Slow and shallow

A stream reach with equal mixtures of each is desirable and would score high. A stream reach dominated by one velocity/depth regime (which may naturally occur in some stream types) would score low.

5. **Channel Flow Status**: estimated how much of the stream channel and in stream structures were covered by water within the entire reach. Complete inundation of the channel and in stream structures would rate highest.

Secondary Parameters (each 15-0 points)

6. **Channel shape** (at bankfull stage): evaluates the approximate shape of the stream channel at the bankfull stage for the entire reach. Four shapes may be selected and a stream channel may normally be comprised of an admixture of two shapes.

- **Trapezoidal** (undercut banks) will rate highest.
- **Rectangular** will rate high.
- **Triangular** will rate lower.
- **Inverse trapezoidal** (obvious deposition and bars in channel) will rate lowest.

7. **Channel alteration** (channelization): the amount of man-caused channelization (straightening) and channel disruption (dredging) was estimated for the entire reach. The length of time in years since channelization was an important element for assessing this parameter.

8. **Pool / Riffle Ratio**: the approximate ratio for the distance between pools and riffles was estimated. A consistent pool and riffle sequence within the entire reach was desired. A variety of pool and riffle habitat would rate high. Lack of a pool and riffle sequence and dominance by all pool or all riffle would rate low.

9. **Width to Depth Ratio:** the approximate average "wetted" channel width divided by average water depth within the entire reach provided an estimate for the amount of channel that may support fish and aquatic life. A low width to depth ratio less than 7 was optimal and a high width to depth ratio greater than 25 would rate low.

Tertiary Parameters (each 10-0 points)

10. **Bank Vegetation Protection**: estimated the amount of stream bank (at the bankfull stage) within the entire reach that was covered by vegetation, large cobble, boulder and larger woody debris serving to provide bank stability. The rating would increase as bank area covered by protective bank features increased.

11. **Bank Stability**: estimated the amount of bank erosion (at the bankfull stage) within the entire reach evidenced by raw, sloughing or unstable banks. A low proportion of unstable bank areas would rate high. A stream reach dominated by unstable banks would rate low.

12. **Disruptive Pressures**: estimated the degree that vegetation was cropped or removed from the streambank immediately adjacent to stream along the entire reach. Presence of all vegetation expected for the ecoregion, stream channel type

and seasonal development would rate high. Significant removal of vegetation would rate lower.

13. **Zone of Influence**: estimated the width of the riparian zone within the entire reach. Consideration was given to the degree of human impact within the riparian zone. A wide riparian zone with negligible human impact provides an adequate buffer zone to filter water pollutants and would rate high. A narrow riparian zone impacted by man related activity would rate low.

Stribling et al. (2000) reported that reference (least impaired) streams in the Middle Rockies ecoregion and Northwestern Great Plains ecoregion of Wyoming would have total habitat assessment scores greater than 100. However, this does not imply all streams with total habitat assessment scores greater than 100 are reference quality.

6.5.4.4 PHOTOPOINTS

Photopoints were established at the base of the stream reach. Upstream, downstream and panorama photographs were taken of the stream reach to aid in station relocation, provide a visual record, and assist in interpretation of habitat assessment data.

Table 6-13. Minimum Standard Level of Identification used for Analysis of Benthic Macroinvertebrate Samples Collected During the Goose Creeks Watershed Assessment

Ephemeroptera (mayflies)	
Genus for:	Acanthametropodidae, Ameletidae, Ametropodidae, Callibaetis, Heptageniidae, Isonychiidae, Pseudironidae, Polymitarcyidae, Baetiscidae, Caenidae, Tricorythidae, Ephemeridae, Leptophlebiidae, Oligoneuriidae, Siphlonuridae, Metretopodidae, Ephemerellidae (see below for genera *Drunella* **and** *Timpanoga*).
Species for:	Mature nymphs of the Genus *Baetis*; immatures to genus Mature nymphs of the genera *Drunella* and *Timpanoga*; immatures to genus
Plecoptera (stoneflies)	
Genus for:	Perlodidae, Pteronarcyidae, Peltoperlidae, Perlodidae, Nemouridae
Species or Species Groups for:	Perlidae, mature specimens for the genera *Zapada*, *Kathroperla*, *Sweltsa* and *Doddsia*; immatures to genus
Family for:	early instar Capniidae, Leuctridae, Chloroperlidae, Taeniopterygidae
Trichoptera (caddisflies)	
Genus for:	All genera except for genera in the Family Rhyacophilidae
Species or Species Groups for:	Rhyacophilidae
Coleoptera (beetles)	
Genus for:	Elmidae (combine larvae and adults into one taxon)
Genus or Family for:	All other families (combine larvae and adults into one taxon)
Chironomidae (midge flies)	
Genus for:	All genera except certain *Cricotopus*, *Orthocladius*
Species or species groups for:	*Cricotopus nostococladius, C. trifascia, C. bicinctus, C. isocladius, C. festivellus, C. tremulus; Orthocladius* Complex
NOTE!	Combine all pupae into one taxon identified as Chironomidae pupae
Assorted Diptera (flies)	
Family for:	Ceratopogonidae, Culicidae, Dolichopodidae, Ephydridae, Scathophagidae, Sciomyzidae, Stratiomyiidae, Tabanidae
NOTE!	Combine all pupae into one family taxon
Oligochaeta (worms)	
Genus or Species for:	Mature specimens
Family for:	Immature specimens; NOTE: immature Tubificidae will be subdivided into two groups: 1. With capilliform setae, and 2. Without capilliform setae

Table 6-13. (Continued)

Turbellaria (flatworms or planarians)	
Class for:	Immatures
Genus for:	Matures
Species for:	Dugesia tigrina
Hirudinea (leeches)	
Order for:	Immature specimens
Genus or Species for:	Mature specimens such as Helobdella stagnalis which may be common and abundant
Mollusca (clams and snails)	
Family for:	Hydrobiidae, Lymnieidae, Physidae, Planorbidae, Ancylidae, Sphaeriidae, Unionidae
Various Orders and Families	
Genus for:	Anostraca, Eubranchiopoda, Lepidoptera, Megaloptera, Mysidacea, Neuroptera, Notostracea, Odonata; and for the following Dipteran Families: Anthericidae, Blephariceridae, Chaoboridae, Deuterophlebiidae, Dixidae, Empididae, Pelecorhynchidae, Phoridae, Psychodidae, Ptychopteridae, Simuliidae, Syrphidae, Tanyderidae, Thaumaleidae, Tipulidae
Various Orders	
Phyla or Class for:	Acari, Nematoda, Nemertea, Porifera, Tardigrada, Coelenterata
Order for:	Collembola, Conchostraca, Polychaeta
Genus for:	Isopoda, Amphipoda (Hyallela azteca to species)
Family for:	Decapoda, Hemiptera, Nematomorpha, Orthoptera, Hydroida (Coelenterata), Hirudinea

Table 6-14. Definition of Select Macroinvertebrate Metrics and Expected Response to Perturbation Including Water Quality and Habitat Change (from King, 1993 and Barbour et al., 1999)

Metric	Definition	Expected Response
Total Number Taxa	Measures the overall variety of the macroinvertebrate assemblage	Decrease
Total Number EPT Taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies, and Trichoptera (caddisflies)	Decrease
Total Number Ephemeroptera Taxa	Total Number of mayfly taxa	Decrease
% Ephemeroptera	Percent of mayfly nymphs	Decrease
Total Number Plecoptera Taxa	Total Number of stonefly taxa	Decrease
% Plecoptera	Percent of stonefly nymphs	Decrease
Total Number Insect Taxa	Total Number taxa in the Class Insecta	Decrease
Total Number Non - Insect Taxa	Total Number taxa not in the Class Insecta	Increase
% Non - Insects	Percent of Non - Insects	Increase
% Chironomidae	Percent of midge larvae	Increase
% Oligochaeta	Percent of worms	Increase
% 5 Dominant	Total Percent of the 5 most dominant taxa	Increase
% 10 Dominant	Total Percent of the 10 most dominant taxa	Increase
Number Predator Taxa	Number of taxa that feed upon other organisms or themselves in some instances	Variable, but appears to decrease in most regions of Wyoming
Total Number Scraper Taxa	Total Number of taxa that scrape periphyton for food	Decrease
% Scrapers	Percent organisms that scrape periphyton for food	Decrease
% Collector - Filterers	Percent organisms that filter Fine Particulate Organic Material from either the water column or sediment	Increase in most Wyoming ecoregions
% Collector - Gatherers	Percent organisms that either collect or gather food particles	Increase
Modified HBI	Uses tolerance values to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic pollution.	Increase
BCI CTQa	Tolerance classification based on nonpoint source impact of sedimentation and velocity alteration	Increase
Shannon H (Log base 2)	Incorporates both richness and evenness in a measure of general diversity and composition	Decrease
% Multivoltine	Percent of organisms having short (several per year) life cycle	Increase
% Univoltine	Percent of organisms relatively long-lived (life cycles of 1 or more years)	Decrease

Table 6-15. Assessment rating criteria for benthic macroinvertebrate communities based on the Wyoming Stream Integrity Index (WSII; from Jessup and Stribling, 2000) in the Middle Rockies ecoregion and Northwestern Great Plains ecoregion of Wyoming.

Rating of Biological Condition (Aquatic Life Use Support)	WSII (% of Reference)	
	Middle Rockies	Northwestern Great Plains
Very Good (Full Support)	>80.3	>77.5
Good (Full Support)	60.6 - 80.3	55.0 - 77.5
Fair (Non - Support)	40.4 - 60.5	36.7 - 54.9
Poor (Non - Support)	20.2 - 40.3	18.3 - 36.6
Very Poor (Non - Support)	<20.2	<18.3

Table 6-16. Wyoming Stream Integrity Index (WSII) biological condition scoring criteria for benthic macroinvertebrate communities developed for Middle Rockies and Northwestern Great Plains ecoregion streams (from Jessup and Stribling, 2002)

Macroinvertebrate Metric	Middle Rockies (5^{th} or 95^{th} %ile)	Northwestern Great Plains (5^{th} or 95^{th} %ile)
Total Taxa	NA[A]	45
Ephemeroptera taxa	11	9
Plecoptera taxa	8	5
Trichoptera taxa	11	10
% Ephemeroptera (w/o Baetidae)	54	NA
% Plecoptera	NA	13
% Trichoptera (w/o Hydropsychidae)	46.6	31.3
% Non-insects	NA	0.5
% 5 dominant taxa	45.7	NA
% scrapers	54.5	31.8
BCI CTQa	44.1	62.6
HBI	1.40	NA
Semi-Voltine Taxa	NA	7

NA[A] = Metric not applicable to ecoregional scoring criteria.

Figure 6-2. Collecting a sample for field pH, conductivity, dissolved oxygen, and temperature analysis. Sample location is a stream riffle at Big Goose Creek site BG6.

Figure 6-3. **Field analysis of pH, conductivity, dissolved oxygen, and temperature. Fecal coliform and turbidity samples are shown near center of picture.**

Figure 6-4. **Collecting fecal coliform and turbidity samples while disturbing bed sediment with a rake.**

Figure 6-5. **Continuous temperature data loggers (left) were secured in plastic pipe designed to allow passage of stream water. The plastic pipe was anchored to a staff gauge with cable.**

Figure 6-6. **Securing a continuous temperature logger casing to a staff guage with stainless steel cable. Station shown is Big Goose Creek site BG18.**

Figure 6-7. **An example of a staff gauge installation. Little Goose Creek site LG1 staff gauge (shown above) was secured to the concrete lined channel near the Big Goose Creek confluence.**

Figure 6-8. **Left photograph. Surveying a bridge abutment used for a permanent benchmark to determine if staff gauge movement had occurred. Location shown is the Soldier Creek site GC4 downstream from the Dana Avenue bridge. During 2002, construction in this area provided the Downer Addition (upstream) with public water and sewer utilities (as described in Section 3.2.1).**

Figure 6-9. **Right photograph. Photograph of the USGS wire-weighted gauge used at Big Goose Creek site BG14. Site BG14 was located south of Beckton at USGS Station No. 06302200.**

Figure 6-10. **The mayfly *Tricorythodes*. *Tricorythodes minutus* was the dominant mayfly in the Goose Creeks watershed increasing in occurrence and abundance at stations with moderate to high silt deposition and embeddedness.**

Figure 6-11. **Caddisfly in the family Glossosomatidae. Glossosoma is a cold water taxon found only in streams with excellent water, low silt deposition and low embeddedness. It was present only at Little Goose Creek station LG22.**

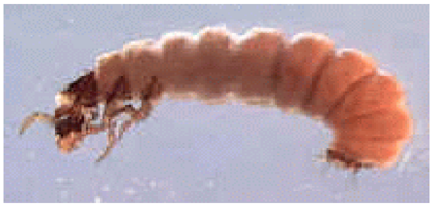


Figure 6-12. **Crayfish in the Order Decapoda. *Orconectes*, a predator, was present at Little Goose Creek station LG21. It is normally present in lower gradient streams in the plains.**

Figure 6-13. **The blackfly larva, *Simulim*, is a collector-filterer present where fine paticulate organic matter is available for food. *Simulim* was present at 71% of sample stations in the Goose Creeks watershed.**

Figure 6-14. **Head capsule of *Chironomus*, a genus of pollution tolerant midge fly and indicator of poor water quality. Present only at Goose Creek stations GC2 and GC3.**

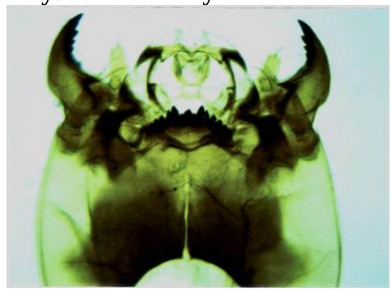


Figure 6-15. **Plexiglass used by SCCD to provide enhanced resolution for stream substrate particle size determination and embeddedness measurement.**

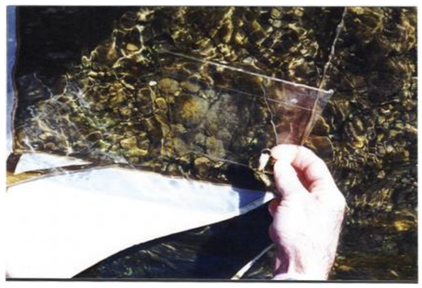
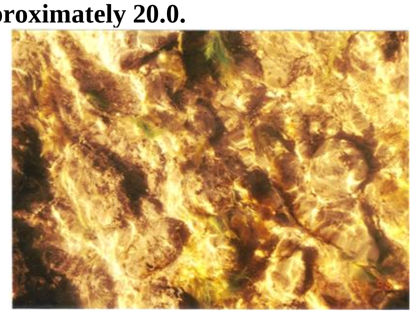


Figure 6-16. **Example of steam substrate comprised primarily by cobble and gravel with low embeddedness (low degree of silt covering or surrounding cobble and gravel). Weighted embeddedness value at this sample quadrate is approximately 99.0.**

Figure 6-17. **Example of steam substrate with high embeddedness (high degree of silt covering or surrounding cobble and gravel). Weighted embeddedness value at this sample quadrate is approximately 20.0.**



7. QUALITY ASSURANCE AND QUALITY CONTROL

7.1 FUNCTION OF QUALITY ASSURANCE AND QUALITY CONTROL

Quality Assurance (QA) may be defined as an integrated system of management procedures designed to evaluate the quality of data and to verify that the quality control system is operating within acceptable limits (Friedman and Erdmann, 1982; EPA, 1995). Quality control (QC) may be defined as the system of technical procedures designed to ensure the integrity of data by adhering to proper field sample collection methods, operation and maintenance of equipment and instruments. Together, QA/QC functions to ensure that all data generated are consistent, valid and of known quality (EPA 1980; 1993). QA/QC should not be viewed as an obscure notion to be tolerated by monitoring and assessment personnel, but as a critical, deeply ingrained concept followed through each step of the monitoring process. Data quality must be assured before the results can be accepted with any scientific study.

The QAPP is the SCCD document used to guide QA/QC procedures for water quality assessments and was used to develop QA/QC practices that would be implemented throughout the GCWA. The QAPP has been reviewed and approved by the WDEQ QA/QC Coordinator. Project specific objectives and requirements were set forth in the project’s SAP, which was reviewed and approved by WDEQ on March 28, 2001. These two documents provide the necessary framework for collecting and reporting usable, credible data, which can be referenced in future monitoring and watershed planning efforts.

7.2 TRAINING

Personnel involved in collection and analysis of samples should receive adequate training for proper implementation of Project field and laboratory methods. SCCD personnel have received the proper training through a combination of college studies, previous employment experiences, and on the job training. The SCCD District Manager holds a Watershed Management degree from the University of Wyoming and the Project Supervisor has an Environmental Engineering degree from Montana Tech of the University of Montana. Both employees have water quality assessment skills obtained through prior employment experiences. The District Manager has taken a Water Quality Assessment course provided by WACD. Kurt King, former WDEQ QA/QC Officer, has provided thorough, annual training for both employees in conducting benthic macroinvertebrate sampling and reach level habitat assessments. On a few occasions, other SCCD and/or NRCS employees assisted the Project Supervisor when conducting the macroinvertebrate sampling and habitat assessments. These personnel were trained by the Project Supervisor prior to sampling and were under direct supervision by the Project Supervisor during sampling.

7.3 COLLECTION, PRESERVATION, ANALYSIS, AND CUSTODY OF SAMPLES FOLLOWING APPROVED METHODS

7.3.1 COLLECTION, PRESERVATION, AND ANALYSIS

Accepted referenced methods for the collection, preservation, and analysis of samples were described in Section 6.0 and listed in Table 6-10 of this report.

7.3.2 SAMPLE CUSTODY

Sample custody described the sampling and analysis record starting with sample collection and ending with laboratory analysis and sample disposition. The purpose of sample custody was to ensure that samples were not tampered with by outside entities and the integrity of samples was maintained.

During sampling, project field measurements were recorded onto field data sheets. Water samples requiring laboratory analysis were immediately placed on ice in a cooler, preserved (if required) and hand delivered to IML. A COC form was prepared, signed, and dated by the sampler before samples entered laboratory custody. An IML employee would then sign and date the COC form after receiving custody of the samples.

Benthic macroinvertebrate samples were preserved in the field (as described in Section 6.5.3), placed in a cooler, and transported to the NRCS/SCCD office in Sheridan. A project specific macroinvertebrate COC form was completed. After all macroinvertebrate samples were collected, samples and COC forms were sealed inside a cooler and shipped by United Parcel Service to ABA. ABA then opened the cooler, performed a visual check for the number and general condition of samples, and signed the COC form. The completed original COC form was returned to SCCD by ABA after completion of analyses.

7.4 CALIBRATION AND PROPER OPERATION OF FIELD AND LABORATORY EQUIPMENT ACCORDING TO MANUFACTURER'S INSTRUCTIONS

The project SAP outlined requirements for calibration and maintenance of field equipment. SCCD performed no laboratory analyses of samples. On every sampling day, before leaving the office, the pH meter, conductivity meter, and DO meter were calibrated according to the manufacturer's instructions. The Hanna 9025 pH meter was calibrated using a two-point calibration method with pH 7.01 and pH 10.01 buffer solutions. Buffer solutions were purchased from Hanna Instruments and used before their shelf life expired. The Hanna 8733 conductivity meter was calibrated using a 1000 or 1413 µmhos/cm calibration standard. All calibration solutions were discarded after each use. A YSI 95 DO meter was used throughout the project and did not require a calibration solution. The DO meter was calibrated with the probe placed in the calibration chamber before each sampling event and with each 300 foot change in elevation during sampling. Calibration of each meter was documented on the appropriate calibration log.

To sustain proper performance, periodic maintenance was performed on the pH meter, conductivity meter, DO meter, Marsh-McBirney flow meter, HACH Pocket Colorimeter, Garmin Global Positioning System (GPS), and Pentax camera as necessary. Equipment maintenance followed requirements set forth in the project SAP and manufacturer's instructions. Maintenance included periodic battery replacement, pH probe and pH thermistor replacement, DO cable replacement, and monthly replacement of the DO meter membrane cap. All maintenance activities were documented on the maintenance log.

The Marsh-McBirney flow meter and the HACH Pocket Colorimeter were factory calibrated and did not require field calibration. Onset Tidbit data loggers, used for continuous temperature monitoring, were factory calibrated and completely encapsulated. These loggers were considered disposable; when the enclosed battery is depleted, it cannot be replaced. Factory calibration of the loggers was checked at the end of each field season by utilizing a "crushed-ice test" to ensure the loggers were performing adequately. Descriptions and results of these tests are available in Appendix R.

Equipment used for benthic macroinvertebrate sample collection and reach level habitat assessment did not require calibration. However, nets for surber samplers and other equipment were thoroughly checked for damage prior to entering the field.

7.5 COLLECTION OF REPRESENTATIVE SAMPLES

Collection of representative samples was ensured by sampling at well-mixed stream riffles or runs on randomly selected sampling dates. Of concern was the siting of some sampling stations downstream of road crossings due to lack of access and/or landowner consent. Placement of sampling sites downstream of road crossings normally does not affect collection of representative water quality samples. However, macroinvertebrate populations may be affected by the scouring action often observed downstream of bridges. Habitat assessment may be affected due to channelization often observed downstream of bridges and road crossings.

7.6 DETERMINATION OF DATA QUALITY OBJECTIVES, PRECISION, ACCURACY, COMPLETENESS, AND COMPARABILITY

7.6.1 DATA QUALITY OBJECTIVES

Data Quality Objectives (DQO's) are qualitative and quantitative specifications used for water quality monitoring programs. DQO's function to limit data uncertainty to an acceptable level. DQO's were established for each monitoring parameter for precision, accuracy, and completeness at levels sufficient to allow SCCD to realize project goals and objectives. Table 7-1 lists DQO's for this assessment.

Table 7-1. Data Quality Objectives for Chemical, Physical, Biological, and Habitat Sampling Conducted During the 2001-2002 Goose Creeks Watershed Assessment

Parameter	Precision (%)	Accuracy (%)	Completeness (%)
Temperature	10	10	95
pH	5	5	95
Conductivity	10	10	95
Dissolved Oxygen	20	20	95
Total Residual Chlorine	10	10	95
Turbidity	10	10	95
TSS	10	10	95
Total Alkalinity	10	10	95
Total Sulfate	20	20	95
Total Chloride	10	10	95
Total Nitrates	20	20	95
Total Phosphorus	20	20	95
Total Ammonia	20	20	95
Total Hardness	10	10	95
Fecal Coliform	50	NA	95
E. coli	50	NA	95
BOD	20	20	95
Macroinvertebrates	NA	NA	95
Total Abundance	50	NA	95
Total Taxa	15	NA	95
Habitat Assessment	NA	NA	95
Intra-crew	15	NA	10
Discharge	NA	NA	95
Stage-Discharge Relationships	NA	NA	95
Atrazine	30	30	95
Simazine	30	30	95
Tebuthiuron	30	30	95
Prometon	30	30	95
Diazanon	30	30	95
Malathion	30	30	95
Parathion	30	30	95
Methyl-Parathion	30	30	95
Dicamba	50	12-157	95
Picloram	50	14-181	95
2,4-D	50	45-117	95
Carbaryl	20	30	95
Carbofuran	20	30	95

7.6.2 PRECISION

Precision was defined as the degree of agreement of a measured value as the result of repeated application under the same condition. Because the determination of precision was affected by changes in relative concentration for certain chemical parameters, the Relative Percent Difference (RPD) statistic was used. RPD is determined as follows:

$$RPD = [(A - B)/(A + B)] X 200$$

For example, the field measurement for conductivity Duplicate 1 was 855 umhos/cm and the conductivity Duplicate 2 measurement was 875 umhos/cm. The RPD = [(855 - 875)/(855 + 875)] X 200 = 2.3%. The DQO for precision for conductivity was 10% (from Table 7-1) thus, the agreement between duplicate measurements was within the precision DQO established for conductivity.

Precision was determined for chemical, physical, biological, and habitat measurements by conducting duplicate samples at 10 percent of sampling sites. Duplicate intra-crew habitat assessments were conducted simultaneously by each observer conducting the assessment without communication.

7.6.3 ACCURACY

Accuracy was defined as the degree of agreement of a measured value with the true or actual value. Accuracy for water quality parameters measured in the field was assured by calibration of equipment to known standards. Accuracy for water quality parameters measured by the contract laboratory was determined by % Recovery. Accuracy for water samples requiring laboratory analysis was determined by the contract analytical laboratory, IML. No QA problems were reported by IML concerning accuracy or for other QA/QC components during this Project.

Accuracy for macroinvertebrate sampling and habitat assessment could not be determined since the true or actual value for macroinvertebrate populations or habitat parameters was unknown. In this instance, precision served as the primary QA check for benthic macroinvertebrate sampling and habitat assessment.

7.6.4 COMPLETENESS

Completeness refers to the percentage of measurements that are determined to be valid and acceptable compared to the number of samples scheduled for collection. This DQO was achieved by avoiding loss of samples due to accidents, inadequate preservation, holding time exceedences, and proper access to sample sites for collection of samples as scheduled. Completeness was calculated by the following formula:

Completeness = Amount of Valid Data Reported / Amount of Data Expected X 100

For example, 595 valid turbidity measurements were reported during a hypothetical water quality monitoring project out of a total of 605 turbidity samples scheduled for collection. Completeness was determined by the following calculation: 595/605 = .983 X 100 = 98.3%. Because the Project DQO for completeness for turbidity was 95%, the DQO was met for completeness.

7.6.5 COMPARABILITY

Comparability refers to the degree to which data collected during this Project were comparable to data collected during other past or present studies. This was an important factor because future water quality monitoring will occur in the Goose Creek watershed and current project data must be comparable to future data in order to detect water quality change with confidence. Several steps were taken to assure data comparability including:

- Collection of samples at previously used monitoring stations;
- Collection of samples during the same time of year;
- Collection of samples using the same field sampling methods and sampling gear;
- Analysis of samples using the same laboratory analytical methods and equipment;
- Use of the same reporting units and significant figures;
- Use of the same data handling and reduction methods (i.e. data rounding and censoring); and
- Use of similar QA/QC processes.

Frequently, a lack of comparability among data sets is due to lack of documentation for historical data sets, change in sensitivity of laboratory analytical equipment, and differing monitoring goals and objectives among sampling groups.

Chemical, physical, biological, and habitat data collected during this assessment were highly comparable because of close coordination prior to initiation of sampling. Each step identified above was implemented to assure comparability.

7.7 DATA VALIDATION

Data generated by the contract laboratories was subject to the internal contract laboratory QA/QC process before it was released. Data were assumed valid because the laboratory adhered to its internal QA/QC plan. Field data generated by SCCD were considered valid and usable only after defined QA/QC procedure and process were applied, evaluated, and determined acceptable. Data determined to be invalid were rejected and not used in preparation of this Final Report. A discussion of the type and quantity of rejected data was presented in Section 8.1.2.

7.8 DOCUMENTATION AND RECORDS

All water quality field data were recorded onto data sheets prepared for the appropriate waterbody and monitoring station. Macroinvertebrate and habitat assessment data were recorded onto data sheets that are very similar in format to those used by WDEQ. Equipment checklists, COC forms, and calibration and maintenance logs were documented on the appropriate forms and are maintained in three-ring binders. Photographs and photograph descriptions are maintained in binders organized by waterbody and by year. Photograph negatives have been logged and are kept in a fire-proof box.

Water quality and supporting QA/QC data were received electronically and in hard copy format from IML. These data are maintained in binders organized by waterbody, sample station, and by year. Macroinvertebrate sample results were received from ABA electronically along with hard copies. All electronic laboratory data are maintained in SCCD database(s) on the USDA Service Center server.

7.9 DATABASE AND DATA REDUCTION

7.9.1 DATABASE CONSTRUCTION

The project database consists of a series of electronic computer files. Each database file was constructed with reportable data (accepted after QC checks) by entering into MicroSoft Excel® spreadsheets. Electronic files for water quality, discharge, continuous water temperature, macroinvertebrate, and habitat data were prepared. A second individual checked all computer data entries for mistakes. If a mistake was suspected, the original field or laboratory data sheet was re-examined and the data entry corrected. Suspect data not resolved were either not entered into the database or were deleted from the database once detected.

Two master databases were prepared to house all assessment water quality data:

1. Reportable data (not censored) database; and
2. Censored database

The uncensored database contained data reported from field measurements and data reported by the analytical laboratory including all values less than Minimum Detection Limits (MDL's). All reported data presented in Appendices in this Final Report represent uncensored data.

The censored database contained data that were censored to allow various statistical procedures to be performed. Values for the major sampling parameters (e.g. fecal coliform, total chloride, total nitrates, etc.) reported as less than the MDL, were "censored to the left" following guidance found in Gilbert (1987).

When a relatively small number of data were censored, the rule was to replace the less than (<) value with a value ½ of the MDL. For example, the censored value for a total chloride reportable value of <1.0 mg/L would be ½ the MDL or 0.5 mg/L. When more than 20 percent of the reportable values for a given parameter were less than (<) values, random numbers generated by computer assisted in the assignment of censored values.

For example, 24 total chloride values out of a total of 46 reportable values were less than (<) the MDL of 1.0 mg/L. A random number ranging from 0.1 mg/L to 0.9 mg/L was selected by computer for each of the 24 total chloride samples. The random number value replaced the original reported value in the censored database. Statistical summaries appearing in this document are derived from the censored database.

7.9.2 DATA REDUCTION

After data validation and database construction, data were statistically summarized for the following calculations (see Section 8.0 and Appendix Q):

- Number of samples;
- Maximum;
- Minimum;
- Median;
- Mean;
- Geometric mean;
- Coefficient of variation;
- Regression analysis; and
- Time series trend analysis.

These statistics and analyses provided insight for temporal and spatial water quality changes within the watershed. MicroSoft Excel® was used to generate the statistical tables and graphics for this report.

7.10 DATA REPORTING

Data collected by SCCD for the GCWA are presented in tabular, narrative, and graphical formats throughout this report. This Final Report will be submitted by the GCDAG to the EPA, WDEQ, City of Sheridan, SCC, and other interested parties as necessary. Copies of this report will be available through the SCCD office, the City of Sheridan, and the SCC. Compact disks containing the MicroSoft Excel®, MicroSoft Word®, and ArcMap 8.2® files used to construct this document will also be available through these local offices.

7.11 DATA RECONCILIATION

Data collected by SCCD were evaluated before being accepted and entered into the database. Obvious outliers were flagged after consideration of "expected" values based upon evaluation of historical and current data. Field data sheets were re-checked and if no calibration or field note anomalies or excursions were identified, the data were accepted as presented. Otherwise, data were rejected and not included in the database.

8. RESULTS AND DISCUSSION

8.1 SUMMARY OF QA/QC EVALUATIONS

The QA/QC summary was presented first in the Results and Discussion Section because data must first be accepted as valid and of known quality before it is evaluated and final conclusions and recommendations made. Five audits of Project data and sampling methods were conducted during the course of the assessment and include:

1. An internal QA/QC audit was conducted by SCCD following the 2001 field season. Findings of the audit were documented in a January 17, 2002 memo from Mr. Jason Nehl addressed to the Project files. This memo is located in the SCCD project files.

2. A February 3, 2002 *Quality Assurance Audit for the Goose Creek Drainages 319 Water Quality Assessment, Year 2001 Sampling* was prepared by Mr. Kurt King. Mr. King was QA Officer for the WDEQ NPS Program from 1993-1997. This audit is located in the SCCD Project files.

3. On August 6, 2002, Mr. Mike Foster (WDEQ QA/QC Officer) conducted a field audit with Mr. Jason Nehl and Mr. Kurt King. The audit included a review of instrument calibration methods, sample collection and preservation, and Project files. Findings of the audit are summarized in an August 9, 2002 letter from Mr. Foster to the SCCD. This letter is presented in Appendix R.

4. A second internal QA/QC audit was conducted by SCCD following the 2002 field season. Findings of the audit were documented in a December 11, 2002 memo from Mr. Jason Nehl addressed to the Project files. This memo is located in the SCCD Project files.

5. An April 26, 2003 *Final Quality Assurance Audit for the Goose Creek Drainages Water Quality Assessment* was prepared by Mr. Kurt King. This review is a comprehensive audit of all 2001 and 2002 data and Project records. A copy of this report is provided in Appendix R.

Following the 2001 and 2002 field seasons, a "Crushed Ice Test" was performed on each of the continuous temperature recorders used during the previous season. The Crushed Ice Test is a QA check designed by its manufacturer, Onset Computer Corporation, to determine whether the recorders are functioning within proper limits (see Figure 8-100). Following the manufacturers instructions, SCCD performed these tests annually and summarized the findings in December 12, 2001 memo and in a November 26, 2002 memo. In summary, the 2001 and 2002 continuous water temperature data were found to be valid and of known quality. These SCCD memos are also provided in Appendix R.

8.1.1 RESULTS OF QA/QC AUDITS

This section provides a summary of results found in the evaluations described in Section 8.1. The following summaries are from Mr. King's April 26, 2003 *Final Quality Assurance Audit for the Goose Creek Drainages Water Quality Assessment* found in Appendix R.

Chemical, Physical, and Biological Water Quality Results

1. Completeness for the total number of chemical, physical, and biological water quality samples was 98.3%, which met the DQO of 95%. All individual parameters, except discharge, met the DQO of 95% for completeness. Discharge completeness was calculated at 94.8% and did not meet the required DQO due to dry stream channels during scheduled sampling events, staff gauges impounded by beaver dams, and staff gauges affected by seasonal irrigation dams within the stream channels.

2. Precision was calculated using the RPD between a sample and its duplicate. All parameters, except TRC, met the required DQO for precision. The SAP established a DQO of 10% for TRC. Average RPD for TRC was calculated to be 19.8%. The high RPD for TRC was likely due to natural substances within the water samples that interfered with the field meter (HACH Pocket Colorimeter), which utilized color-producing reagents. These interferences are described in Section 8.7.

   Precision of duplicate samples performed by IML (internal laboratory duplicates) showed high precision for all parameters. Each parameter met the DQO for precision based on these laboratory duplicates.

3. Accuracy for laboratory analyzed parameters was determined by percent recovery on laboratory spike samples. All laboratory analyzed parameters met the required DQO for accuracy. The accuracy of field measured parameters could not be measured. However, the accuracy of the field meters was assumed adequate because of daily instrument calibration to known standards.

4. Duplicates were collected for field and laboratory analyzed parameters. In total, 10.2% of all water quality samples were duplicated, which met the DQO of 10%.

5. Trip blanks were used during each sampling event as required in the SAP. A total of 19 out of 475 trip blank samples exhibited detection. Nine of these samples were for alkalinity. Detectable alkalinity in trip blanks is not uncommon as laboratory prepared samples may absorb small amounts of atmospheric carbon dioxide. The infrequent detection and low levels of turbidity, total ammonia, and total nitrate nitrogen did not suggest contamination problems during sample collection, preservation, or laboratory analysis.

6. Holding times for all laboratory analyzed samples were adhered to by IML and SCCD. Samples were hand delivered by SCCD to IML immediately after collection of samples.

   A discrepancy was found in Mr. King's *Final Quality Assurance Audit for the Goose Creek Drainages Water Quality Assessment* (see Appendix R). At the time Mr. King was provided the information to conduct this audit, the holding times for 17 out of 4,384 samples from 2002 were found to have expired at the time of analysis. It was later determined, via a phone conversation with IML Water Lab Manager, Wade Nieuwsma, that a newly hired technician had been recording the time at which sample processing was completed as the analysis time rather than recording the time at which sample processing began. IML later recorded the correct time from bench sheets onto the final data sheets and submitted these corrected sheets to SCCD.

7. Sampling methods, including equipment calibration, sample collection, and sample preservation, adhered to the requirements set forth in the SAP.

8. Documentation and records, including data sheets, calibration and maintenance logs, COC forms, equipment checklists, and sample labeling, were maintained as required in the SAP.

Macroinvertebrate Sampling and Habitat Assessment Results

1. Completeness of macroinvertebrate sampling and habitat assessments was 100%. This met the DQO set forth in the SAP of 95%.

2. Precision for duplicate intra-crew habitat assessments was determined by calculating the RPD between the two duplicate "blind" habitat assessments conducted in the field. The average RPD for the eight duplicate intra-crew habitat assessments was 3.1%, which met the DQO of 15%.

   Precision for macroinvertebrate samples was determined by calculating the RPD for Total Density and Total Taxa from duplicate samples. The DQO for Total Density was 50% and the DQO for Total Taxa was 15% as set forth in the SAP. The average RPD for Total Density on the four duplicate samples was 52.4%, which exceeded the DQO. High variability between duplicate macroinvertebrate samples for Total Density is common due to the patchy distribution of benthic organisms in stream substrate. The average RPD for Total Taxa was 10.2%, which met the DQO set forth in the SAP.

3. Accuracy estimates for habitat assessments could not be made because the true value for each parameter within the stream reach assessed was unknown. Accuracy estimates for macroinvertebrate communities and metrics could not be made because the true value for each community or each metric was unknown.

4. Duplicates were collected during habitat assessments and macroinvertebrate sampling. In total, 21% of all habitat assessments were duplicated, which met the DQO of 10%. In addition, 10.5% of all macroinvertebrate samples were duplicated, which met the DQO of 10%.

5. Sampling methods, including habitat assessment methods, macroinvertebrate sample collection, and macroinvertebrate sample preservation, adhered to the requirements set forth in the SAP.

6. Documentation and records, including field data sheets, COC forms, equipment checklists, and sample labeling, were maintained as required in the SAP.

Conclusion of QA/QC Evaluations

In summary, Mr. King wrote: "This audit concluded that chemical, physical, biological, benthic macroinvertebrate, habitat and BURP data collected during 2001 and 2002, with the exception of TRC data, were valid, of known quality and sufficient to meet Project goals and objectives identified in the SAP. Continuous water temperature recorders were properly operated and maintained. Continuous water temperature data were complete and acceptable. The data were considered representative for water quality, benthic macroinvertebrate communities and habitat present in water bodies assessed. The data were considered comparable not only between years 2001 and 2002, but also to historical data and data that may be generated from future water quality monitoring projects as long as the same sample collection and analysis methods are used. Consequently, data were considered valid for purposes of compliance with the intent of the State of Wyoming Credible Data statute W.S. § 35-11-302(b)(i) and W.S. § 35-11-302(b)(ii) identified in the Wyoming Environmental Quality Act."

8.1.2 SUMMARY OF DATA VALIDATION EFFORTS

Discharge at Little Goose Creek site LG2 on May 22, 2002 was estimated with the calibrated staff gauge to be approximately 2,082 cfs. However, due to drought-induced low flows during 2002, flow measurements taken during 2002 to calibrate the staff gauge were conducted over a much lower range of flows (from 4 to 23 cfs). Low flows at this site could be confidently estimated during 2002, however, significantly higher flows could not be estimated with accuracy. On the same day, calibrated staff gauges at sites LG1 and LG4 (above and below LG2) estimated discharge to be 125.75 cfs and 166.85 cfs, respectively. Consequently, the LG2 discharge value of 2,082 cfs was replaced with the average of sites LG1 and LG4 discharge values (146.30 cfs). The value of 146.30 cfs was used as the reported discharge value for site LG2 on May 22, 2002 in Appendix Table E-27.

A beaver dam was constructed across Little Goose Creek, which affected true stream stages observed on the site LG8 staff gauge. The beaver dam was built immediately downstream from the gauge sometime between the September 11, 2002 and October 3, 2002 sampling events. The result was that a deeper than normal pool formed in the vicinity of the LG8 staff gauge. These higher stages observed on the staff gauge falsely indicated more discharge in Little Goose Creek than was actually experienced. Therefore, for the remaining sampling events from October 3, 2002 to the end of the 2002 season, discharge at site LG8 was estimated as an average of sites LG6 (downstream) and LG10 (upstream) discharge. The final six 2002 discharge measurements at site LG8 were estimated by this average and are presented in Appendix Table E-33.

During a monthly retrieval of continuous temperature data on June 27, 2002, the Soldier Creek (site GC4) data logger was found to be partially buried in stream sediment. After downloading the data for viewing in Microsoft Excel®, continuous temperature data from June 3, 2002 through June 27, 2002 were found to have been affected because little or no daily changes in water temperature had occurred. Therefore, these data were removed and are not included in Appendix Figure F-3.

TRC field measurements taken during 2001 and 2002 were determined to be inaccurate. The field meter could not accurately repeat analyzed values on the same sample or between duplicate samples. Since the field instrument is a photometer that utilizes color producing reagents, several natural surface water characteristics including turbidity and high alkalinity may create false positives. Because an unknown number of TRC false positives exist in the data set, the GCDAG decided not to include the TRC data in this Final Report. This data cannot be used with sufficient confidence to determine beneficial use support or compliance with Wyoming water quality standards. In 2002, an effort to produce higher quality TRC data was undertaken and is discussed in Section 8.7.

8.2 GENERAL DISCUSSION OF WATER QUALITY

Sections 8.2.1 through 8.2.3 provide a summary of the water quality, riparian habitat, and benthic macroinvertebrate data observations made during the GCWA. A more detailed discussion of these results is provided in Sections 8.3 through 8.24. Discussions in the following sections may often refer to a monitoring station by site name (i.e. GC1, BG4, USGS Station Number 06305700, etc.) and usually do not explain its location. For ease of reference, GCWA site locations are described in Tables 6-1 through 6-4 and are shown on Appendix Maps A-3 through A-6. For discussions of current and historical data and the monitoring stations used by various agencies, please refer to Table 5-2 for location descriptions and to Appendix Maps A-7 through A-9. These maps locate monitoring stations used by USGS and WDEQ only. However, Table 5-2 describes the approximate location for every current and/or historical monitoring station discussed within this report.

8.2.1 GOOSE CREEK

Water temperatures in Goose Creek were often found to exceed the 20°C limit set forth in the Wyoming Water Quality Standards for cold water streams. Instantaneous measurements with field meters occasionally recorded temperatures in excess of 20°C, however, the time at which samples were taken often did not correspond with the actual daily high water temperatures. Continuous water temperature data indicated that daily high temperatures generally occurred between mid- to late-afternoon; the majority of Goose Creek monitoring was completed before noon. Table 8-1 summarizes the number of instantaneous water temperature measurements on Goose Creek exceeding 20°C. Continuous water temperature data were collected at site GC1 during 2001 and 2002 with the use of a data logger. The continuous water temperature data show that Goose Creek exceeded 20°C during 103 days in 2001 and 93 days in 2002 (Table 8-8). The extent to which below normal stream flows, irrigation and domestic use diversions, and warmer than normal summer air temperatures affected stream temperatures cannot be estimated. Water temperatures exceeded 20°C as early as May and as late as September during 2001 and 2002. Based on this information, water temperature exceedences of 20°C are also suspected to occur during the warmer summer months of June, July, and August in years with "normal" environmental conditions. This would suggest that Goose Creek does not meet its intended use as a cold-water fishery.

Fecal coliform data collected during the GCWA found sites GC2, GC3, GC5, and GC6 to exceed the Wyoming water quality standard of 200 CFU/100 mL on at least one occasion (see Table 8-1). The lowermost site, GC1, did not have a geometric mean based from five samples that exceeded 200 CFU/100 mL during this assessment. The August 2002 *E. coli* geometric mean at site GC2 was greater than the proposed 126 CFU/100 mL standard (WDEQ, 2002a). Current and historical WDEQ and USGS monitoring generally revealed higher fecal coliform concentrations than those found during the 2001-2002 GCWA. WDEQ 1998 monitoring found fecal coliform impairments on Goose Creek at stations located below the Sheridan WWTP (near GCWA site GC2), above the Big Horn Mountain KOA, and below the Big Horn Mountain KOA. Monthly fecal coliform samples collected by WDEQ during the 1993-1994 Salt Monitoring Project revealed fecal coliform concentrations greater than 400 CFU/100 mL in individual samples taken from the Highway 338 (also known as the Decker Road) bridge crossing up to the Big Goose Creek and Little Goose Creek confluence. Historically, EPA studies determined that statistically significant swimming-associated gastrointestinal illness may occur when concentrations of fecal coliform are greater than 400 CFU/100 mL for a single sample (USGS, 2003 after EPA, 1976).

Approximately 36% of samples collected from 1983 to 1987 by the USGS at Station Number 06305700 (GCWA site GC1) found fecal coliform concentrations in excess of 400 CFU/100 mL. USGS monitoring Station Number 06305500 (GCWA site GC2) has shown a large reduction (98%) in fecal coliform concentrations after the renovation of the Sheridan WWTP in 1983 and again in 1984. However, the average concentrations of fecal coliform in USGS samples taken since that time continue to be greater than 400 CFU/100 mL.

During 2001, discharge at USGS Station Number 06305700 averaged 48.6 cfs, which was 30.7% of the annual average discharge for the period of record (1984-2002). At the time this Final Report was written, 2002 discharge data were only available for January through September. Average discharge for these months was 52.5 cfs, which is 29.1% of normal. Instantaneous discharge measurements collected from upper and lower Goose

Creek during GCWA sampling did not indicate substantial discharge losses owing to the seasonal dewatering of Goose Creek.

A single DO measurement of 4.97 mg/L was recorded at Goose Creek site GC1 on August 6, 2001. However, stream discharge was estimated at 5.1 cfs during the sampling event, which was the lowest recorded discharge during the two-year project. Normal discharge for August 6 at USGS Station Number 06305700 (same site as GC1) is 62.5 cfs. All other DO measurements on Goose Creek were above 5.0 mg/L and met Wyoming water quality standards.

During the assessment, no pH samples were collected below 6.5 or greater than 9.0 standard units (Table 8-1). All conductivity measurements were less than 3,000 µmhos/cm, which met irrigation suitability recommendations by the NRCS (2000). Turbidity and TSS data did not indicate sediment problems within Goose Creek. Alkalinity values were generally greater than 200 mg/L indicating that Goose Creek is a well buffered system and not prone to sudden changes in pH. Hardness values were often greater than 300 mg/L, which suggest that Goose Creek water is usually very hard (EPA, 1986 after Sawyer, 1960). Chloride and sulfate analytical results showed that beneficial uses relating to these parameters were met in Goose Creek. No exceedences of the ammonia water quality standard were found. Average total nitrate nitrogen was less than the national background levels of 0.60 mg/L (USGS, 1999). Upper Goose Creek (sites GC3, GC5, and GC6) averaged total phosphorus levels less than the 0.10 mg/L national background level for undeveloped areas (USGS, 1999). However, EPA (1977) recommends a limit of 0.05 mg/L for streams entering reservoirs, which was often exceeded in Goose Creek (Table 8-1). No pesticides or herbicides were detected in Goose Creek at site GC3 during the June 2002 sampling event.

8.2.1.1 GOOSE CREEK TRIBUTARIES – SOLDIER CREEK

In general, Soldier Creek had poorer water quality than Goose Creek. Average conductivity, turbidity, TSS, total alkalinity, total sulfate, total hardness, total chloride, total nitrate nitrogen, and total phosphorus were higher in Soldier Creek than in upstream (GC5) and downstream (GC3) Goose Creek sites. Average pH and DO were lower in Soldier Creek than at sites GC3 and GC5. However, these parameters did not exceed Wyoming water quality standards. As with Goose Creek, the EPA recommended limit of 0.05 mg/L phosphorus was often exceeded in Soldier Creek.

Instantaneous water temperature measurements on Soldier Creek (site GC4) did not exceed the Wyoming water quality standard of 20°C during 2001 or 2002. However, these measurements did not usually coincide with daily maximum temperatures as discussed in Section 8.2.1. Continuous water temperature data were collected on Soldier Creek during 2002. Temperature data from June 3, 2002 through June 27, 2002 were not viable because the temperature logger was partially buried in bed sediment. Nonetheless, the temperature logger recorded 34 days when water temperatures on Soldier Creek were greater than 20°C.

Fecal coliform geometric means were greater than 200 CFU/100 mL in 4 separate months during the GCWA. The fecal coliform standard was exceeded during May and August, 2001 and 2002. The August 2002 *E. coli* geometric mean was also greater than the proposed 126 CFU/100 mL standard (WDEQ, 2002a).

8.2.1.2 GOOSE CREEK BENTHIC MACROINVERTEBRATES SUMMARY

A total of twelve benthic macroinvertebrate samples were collected from five Goose Creek stations (GC1, GC1A, GC1B, GC2 and GC3) during 2001 and 2002. Included in the total number of samples were two duplicate samples. The duplicate samples were used for QA/QC purposes, construction of taxa lists and for general discussion of macroinvertebrate results. Duplicate samples were not used for the determination of biological condition.

Biological condition was determined for each Goose Creek station by year. Biological condition was also determined using the mean biological condition score for samples collected in 2001 and 2002. Taxa lists for Goose Creek benthic macroinvertebrate samples are presented in Appendix Tables L-1 through L-12. The list of metrics for each sample is presented in Appendix Tables M-2 and M-3. Comparable historical and current benthic macroinvertebrate samples collected by WDEQ at Goose Creek were also evaluated for biological condition. A historical WDEQ taxa list for a single Goose Creek benthic macroinvertebrate sample is presented in Appendix Table J-5. The list of metrics for the sample is presented in Appendix Table K-1. Samples collected by WDEQ within five years from the start of this Project were termed "current" samples. Taxa lists for current WDEQ Goose Creek benthic macroinvertebrate samples were presented in Appendix Tables L-43 through L-48. The lists of metrics for each sample are presented in Appendix Tables M-4 and M-5.

A total of sixteen historical and current benthic macroinvertebrate samples were evaluated for biological condition. Determination of biological condition for each station is presented in Table 8-16 and illustrated in Figure 8-76. Biological condition was either fair or poor at each Goose Creek station. Biological condition scores derived from the WSII (Jessup and Stribling, 2002) ranged from a low of 24.4 at station GC2 in 2001 to a high of 50.1 at station GC1 in 2002.

The highest average WSII score among Goose Creek stations was at the lowermost station GC1 (average = 46.9) located about 300 yards upstream of the Highway 339 bridge and the lowest average score was at station GC1B (average = 26.1) located upstream of the Bighorn Mountain KOA near the northern Sheridan city limit. The change in biological condition among Goose Creek stations is illustrated in Figure 8-76. The general trend was a decrease in biological condition from the uppermost station (GC3) upstream of the Fort Road bridge in Sheridan to downstream stations (GC1B and GC1A) with an increase in biological condition at the lowermost station (GC1). The trend for decrease in biological condition from upper to downstream stations with subsequent increase to maximum biological condition at the most downstream station in Goose Creek was just the opposite as that observed for biological condition at Soldier

Creek stations (Figure 8-77), Big Goose Creek stations (Figure 8-78) and Little Goose Creek stations (Figure 8-79), where biological condition generally decreased from upstream stations to downstream stations.

There was some variability in biological condition between 2001 and 2002. Biological condition increased at two stations (GC1A and GC1B) during 2002 while three stations (GC1, GC2 and GC3) exhibited decreased biological condition from 2001 to 2002. Station GC1B and GC2 had the two lowest mean WSII scores among all stations sampled in the Project area (Figure 8-80). Stations GC1A and GC3 had the 4^{th} and 5^{th} lowest mean WSII scores out of 23 total stations (including WDEQ Soldier Creek stations) sampled in the Project area. Station GC3 exhibited the best biological condition among Goose Creek stations, but only represented the 9^{th} highest ranked station for biological condition among all stations. This observation indicated that biological condition in Goose Creek was lower than Big Goose Creek, Little Goose Creek and the majority of Soldier Creek.

WDEQ benthic macroinvertebrate samples collected at Goose Creek stations in 1994 and 1998 found similar results for biological condition when compared to benthic macroinvertebrate samples collected at similar stations during the Project. WDEQ sampled in 1994 and 1998 at Goose Creek station NGPI19. The station was located near the north Sheridan city limit just upstream of the bridge near the Wyoming Highway Department Port of Entry. The samples collected in 1998 were believed to be located at a station further upstream and closer to the Sheridan WWTP outfall than the 1994 samples. Both WDEQ samples were collected in 1998 at Goose Creek stations GC2 and GC1B for the current Project. The biological condition score for the 1994 samples was 35.8 and the biological condition score for the 1998 sample was 42.6 (Table 8-16). Biological condition was poor in 1994 and fair in 1998. The biological condition ratings both indicated non-support for aquatic life use.

Duplicate benthic macroinvertebrate samples were reported for WDEQ sampling at Goose Creek station NGP21 in 1998 located below the Big Horn Mountain KOA discharge outfall. This was the same station as GC1A for the current Project. WDEQ Goose Creek station NGPI50 sampled in 1998 was sited upstream from the Big Horn Mountain KOA discharge outfall. This was the same station as GC1B for the current Project. The biological condition score for station NGP21 was 40.5 and the biological condition score for station NGPI51 was 38.4 (Table 8-16). Biological condition was fair at both stations indicating non-support for aquatic life use.

WDEQ Goose Creek station NGPI51 sampled in 1998 was sited upstream of the Fort Road bridge and upstream of the Sheridan WWTP discharge outfall. This station was the same as Goose Creek station GC3 during the Project. The biological condition score for station NGPI51 was 38.4 indicating fair biological condition and non-support for aquatic life use.

The lowermost WDEQ Goose Creek sample station in 1998 was NGP22. The station was located on Big Horn Coal property and was about ¼ mile downstream of Goose

Creek station GC1 for the Project. The biological condition score for station NGP22 was 49.3 indicating fair biological condition. This station exhibited the highest biological condition score of any Goose Creek station sampled, but non-support for aquatic life use was still indicated. The higher biological condition score at WDEQ station NGP22 appeared to be related to its location downstream of the Placheck Pit. The Placheck Pit was a former surface coal mine pit constructed in the main Goose Creek channel at the Big Horn Mine and serves as a trap for sediment contained in Goose Creek. The benthic macroinvertebrate community at the WDEQ station located downstream of the Placheck Pit appeared to benefit from better water quality and probably cooler water flowing from the Pit.

More discussion for benthic macroinvertebrate community composition at Goose Creek stations is presented in Section 8.21.

The results from benthic macroinvertebrate sampling provided a direct measure of aquatic life use support through monitoring of instream biological communities. However, WDEQ requires a "weight of evidence" approach using chemical, physical, and biological data in addition to consideration of soils, geology, hydrology, climate, geomorphology, or stream succession (Table 8-17 *from* Table 3, Page 18 *in* WDEQ, 2002b) before a conclusive determination for attainment of aquatic life use can be made. The reader should be cautioned that consideration of soils, geology, hydrology, climate, geomorphology, or stream succession in the "weight of evidence" approach is difficult because direct relationships between these various physical elements and stream biological communities can only be inferred because of the absence of direct cause and effect relationships. However, this Project attempted to evaluate aquatic life use support by integrating benthic macroinvertebrate data with soil and geologic information presented in Section 3.3, hydrologic information presented in Section 8.8, climatic information presented in Section 8.24, habitat information presented in Section 8.22, fisheries information presented in Section 8.23 and chemical / physical water quality information presented in Section 8.2 through Section 8.20.

Based on mean WSII scores derived from current and historical benthic macroinvertebrate sampling, the entire reach of Goose Creek from its headwaters in Sheridan at the confluence of Big Goose Creek and Little Goose Creek, to its confluence with the Tongue River, had either fair or poor biological condition. It should be noted however, that aquatic life use support in the Placheck Pit, a former surface coal mine pit constructed in the main Goose Creek channel, was unknown due to lack of sampling. Two rainbow trout, a cold water game fish species, were collected in gillnet samples from the Placheck Pit by WWRRI in 1977. The rainbow trout were probably stocked or transients from upstream Goose Creek or downstream Tongue River and were apparently able to survive in the cooler water temperature refuge afforded by the pit. Brown trout were collected in 62% of samples from Goose Creek (see Fisheries Section 8.23) and the 2 rainbow trout collected only from the Placheck Pit suggested the Pit may support cold water aquatic life use. It should also be noted that Brown trout, when collected in Goose Creek, were never abundant and ranged from only 1 fish to 3 fish per sample. This observation indicated brown trout populations were marginal at Goose Creek sample stations.

Although biological condition based on benthic macroinvertebrate populations improved downstream of Sheridan between Goose Creek station GC1A and GC1, the lower biological condition scores indicated non-support of the narrative WDEQ water quality standard for aquatic life use for all of Goose Creek, with perhaps the exception of the Placheck Pit (see Appendix Map A-12). Integration of the additional information presented in Final Report Sections 3.3, 8.2 through 8.20, 8.22, 8.23 and 8.24 supported this conclusion. Planning and possible remedial measures to restore aquatic life use support in Goose Creek are presented in Section 9.

The summary of historical macroinvertebrate sampling conducted by WDEQ in Soldier Creek is included in the Goose Creek summary section because Soldier Creek is a tributary to Goose Creek. No macroinvertebrate samples were collected from Soldier Creek during the current Project.

A total of four benthic macroinvertebrate samples were collected by WDEQ in 1999 from four Soldier Creek stations. Soldier Creek station NGP64 was located just upstream of the confluence with Goose Creek in Sheridan near water quality sample station GC4 for this Project. Station NGP63 was located at the County Road 330 bridge west of Sheridan. Soldier Creek station MRC77 was located on the PK Ranch. Although the station identification code indicated this sample site was located in the Middle Rockies ecoregion, the station was located in the Northwestern Great Plains ecoregion. Soldier Creek station MRC78 was located in the Bighorn Mountain foothills and was identified as the “upper” station.

Biological condition was determined for each Soldier Creek station by year. Taxa lists for Soldier Creek benthic macroinvertebrate samples are presented in Appendix Tables L-62 through L-65. The list of metrics for each sample is presented in Appendix Table M-6.

A total of four benthic macroinvertebrate samples were evaluated for biological condition. Determination of biological condition for each station is presented in Table 8-16 and illustrated in Figure 8-77. Biological condition scores derived from the WSII (Jessup and Stribling, 2002) for stations located in the Northwestern Great Plains ecoregion (all stations downstream of Soldier Creek upper station MRC78) ranged from a low of 32.5 at station NGP64 located in Sheridan near the confluence with Goose Creek to a high of 70.3 at station NGP-- located on the PK Ranch. Biological condition at Bighorn Mountain foothill station MRC78 using WSII values for the Middle Rockies ecoregion was 71.7. Biological condition at station MRC78 was also determined using WSII values for the Northwestern Great Plains ecoregion to allow comparison to the other Soldier Creek stations. The biological condition score for station MRC78 presented in Figure 8-77 was derived by using WSII values for the Northwestern Great Plains and not the Middle Rockies ecoregion.

The change in biological condition among Soldier Creek stations is illustrated in Figure 8-77. Biological condition decreased from the uppermost station MRC78 downstream to station NGP64. Station NGP64 had the lowest biological condition among Soldier Creek stations and ranked 3rd lowest out of a total of 23 stations assessed for biological condition in the Project area (including the 4 Soldier Creek stations). Station NGP63 ranked 6th lowest for biological condition in the Project area. In contrast, Soldier Creek stations MRC78 and NGP-- ranked 2nd and 4th highest, respectively, out of a total of 23 stations assessed for biological condition in the Project area.

Based on WSII scores determined from WDEQ benthic macroinvertebrate sampling, Soldier Creek appears to support aquatic life use from station MRC78 in the Bighorn Mountain foothills downstream to station NGP-- located on the PK Ranch. Biological condition decreases and aquatic life use was not supported at downstream station NGP63 located at the County Road 330 bridge and station NGP64 located near its confluence with Goose Creek in Sheridan.

Further evaluation of the biological condition data from WDEQ benthic macroinvertebrate samples using the "weight of evidence" approach described in WDEQ (2002b) to confirm attainment of aquatic life use support was limited to station GC4 (near WDEQ station NGP64) sampled during the current Project. WDEQ collected single instantaneous water quality grab samples during sampling at each benthic macroinvertebrate station in 1999 and the limited water quality data was insufficient as supporting information to determine aquatic life use support. However, WDEQ data when combined with data from station GC4 sampled during the current Project provided sufficient data to indicate non-support of aquatic life use at Soldier Creek station GC4. WDEQ benthic macroinvertebrate data collected at station NGP63 at the County Road 330 bridge indicated non-support for aquatic life use, but this could not be confirmed because of lack of supporting information including water quality data. Using a conservative assessment approach, it should be assumed that aquatic life use was not supported from Soldier Creek station NGP-- downstream to the confluence with Goose Creek until additional data are collected. It is recommended that Soldier Creek be sampled in the future to better determine attainment of aquatic life use and other applicable Wyoming water quality beneficial uses.

Planning and possible remedial measures to restore aquatic life use support in lower Soldier Creek are presented in Section 9.

8.2.2 BIG GOOSE CREEK

Big Goose Creek water quality generally decreased from upstream to downstream monitoring stations. During the assessment, no pH samples were collected below 6.5 or greater than 9.0 standard units (Table 8-2 and 8-3). All conductivity measurements were less than 3,000 µmhos/cm, which met irrigation suitability recommendations by the NRCS (2000). Turbidity and TSS data did not indicate sediment problems within Big Goose Creek. Alkalinity levels increased along the longitudinal gradient and indicated that Big Goose Creek is a well buffered system and not prone to sudden changes in pH.

Hardness results indicated water in Big Goose Canyon was relatively soft, but became very hard (often >300 mg/L) in the lower reaches (see Tables 8-2 and 8-3). Chloride and sulfate levels increased from upstream to downstream and showed that beneficial uses relating to these parameters were met in Big Goose Creek. No exceedences of the ammonia water quality standard were found. Average total nitrate nitrogen was less than the national background levels of 0.60 mg/L (USGS, 1999). Big Goose Creek total phosphorus levels were less than the 0.10 mg/L national background level for undeveloped areas (USGS, 1999). However, EPA (1977) recommends a limit of 0.05 mg/L for streams entering reservoirs, which was often exceeded in Big Goose Creek (see Tables 8-2 and 8-3). No pesticides or herbicides were detected in Big Goose Creek at site BG3 during the June 2002 sampling event.

A DO measurement of 4.81 mg/L was recorded at Big Goose Creek site BG5 on July 30, 2002. A temporary irrigation dam was constructed across the channel upstream from the sampling station prior to this sampling event. Stream discharge was estimated at 2.2 cfs during the event, which was the lowest recorded discharge during the two-year assessment. All other DO measurements on Big Goose Creek were greater than the 5.0 mg/L limit required for aquatic life (WDEQ, 2001a).

USGS Station Number 06302000 recorded discharge data in Big Goose Canyon from 1930 through 2000, but was removed during this project. A new station (Number 06301850) was constructed about ½ mile upstream and was located above the PK Ditch diversion. This station was available to record discharge from April through September, 2000. During the comparable period of April through September, Station Number 06301850 recorded 67.8 cfs less discharge on an average basis than was normally observed for this period at Station Number 06302000. A comparison of instantaneous discharge measurements collected during the GCWA showed the uppermost site BG18 to have the highest average discharge for similar 2001 and 2002 monitoring days (Figure 8-28). Site BG14 near Beckton had the lowest average discharge indicating most seasonal dewatering of Big Goose Creek occurred in this upper reach.

Water temperatures in Big Goose Creek were often found to exceed the 20°C limit set forth in the Wyoming water quality standards. Instantaneous measurements with field meters occasionally recorded temperatures in excess of 20°C (Tables 8-2 and 8-3), however, the time at which samples were taken often did not correspond with maximum daily water temperatures. Continuous water temperature data were collected at sites BG2, BG6, and BG18 during 2001 and 2002 with the use of continuous temperature data loggers. The lower Big Goose Creek sites (BG2 and BG6) exceeded 20°C on a number of occasions during both years. Site BG18 never recorded temperatures in excess of 20°C. For the same reasons discussed in Section 8.2.1, water temperature exceedences of 20°C are estimated to occur during "normal" flow years on lower Big Goose Creek. This suggests that lower Big Goose Creek does not meet its intended use as a cold-water fishery.

Lower Big Goose Creek sites BG1 through BG4 each exceeded the fecal coliform standard of 200 CFU/100 mL on at least one occasion. Sites BG1 through BG3 each exceeded the standard during August 2001 and August 2002. Site BG4 exceeded the standard during May 2001 only. Big Goose Creek proper sites BG5 through BG18 did not exceed the standard during any month (see Tables 8-2 and 8-3). Current and historical WDEQ monitoring generally revealed higher fecal coliform concentrations in Big Goose Creek than those found during the GCWA. WDEQ 1998 and 1999 monitoring found Big Goose Creek to be impaired from its mouth upstream to the canyon (GCWA site BG18). Monthly fecal coliform samples collected by WDEQ during the 1993-1994 Salt Monitoring Project revealed fecal coliform concentrations greater than 400 CFU/100 mL in individual samples on lower Big Goose Creek. USGS 1989-1998 fecal coliform monitoring at Station Number 06302000 did not reveal any fecal coliform concentrations greater than 400 CFU/100 mL.

8.2.2.1 BIG GOOSE CREEK TRIBUTARIES – BEAVER CREEK, PARK CREEK, AND RAPID CREEK

Water quality in Beaver Creek, Park Creek, and Rapid Creek was generally not as good as Big Goose Creek. Average conductivity, total alkalinity, total chloride, and total nitrate nitrogen were higher in these tributaries than in nearby Big Goose Creek sites. Park Creek and Beaver Creek averaged higher turbidity and TSS than adjacent Big Goose Creek sites. However, these parameters did not exceed applicable Wyoming water quality standards. Park Creek had the highest average total phosphorus, and all tributaries often exceeded the EPA recommended limit of 0.05 mg/L for streams entering lakes or reservoirs.

Park Creek had the lowest average DO of all Big Goose Creek monitoring stations. A DO measurement of 4.70 mg/L was recorded at the Park Creek site BG13 on May 22, 2001. However, Park Creek was dry during a scheduled sampling event six days earlier on May 16, 2001. All other tributary DO measurements met Wyoming water quality standards.

Rapid Creek was the only Big Goose Creek tributary with an instantaneous measurement greater than 20°C. However, as mentioned in earlier sections, water quality monitoring was usually not conducted during daily high water temperatures. Continuous water temperature data were collected on Beaver Creek during 2002. These data show that during 45 days in 2002, Beaver Creek water temperatures exceeded 20°C.

During this assessment, Beaver Creek did not have a fecal coliform geometric mean greater than 200 CFU/100 mL. However, it nearly exceeded the standard on four occasions with geometric means of 193, 195, 169, and 196 CFU/100 mL. Park Creek exceeded the fecal coliform standard twice and Rapid Creek exceeded the standard during one month only. Beaver Creek and Rapid Creek both exceeded the proposed *E. coli* standard of 126 CFU/100 mL during August 2002. During August 2002, *E. coli* samples were not collected on Park Creek because the stream was dry. WDEQ fecal coliform monitoring in 1999 found all three tributaries to exceed the fecal coliform standard. Figure 8-69 shows 1998-1999 WDEQ and 2001-2002 GCWA fecal coliform monitoring at comparable sites. Park Creek was not included in the comparison because it was dry during August 2001 and August 2002 and could not be compared to similar WDEQ data.

8.2.2.2 BIG GOOSE CREEK BENTHIC MACROINVERTEBRATES SUMMARY

A total of fifteen benthic macroinvertebrate samples were collected from seven Big Goose Creek stations (BG2, BG4, BG8, BG10, BG14, BG15 and BG18) during 2001 and 2002. Included in the total number of samples was one duplicate sample. The duplicate sample was used for QA/QC purposes, construction of taxa lists and for general discussion of macroinvertebrate results. The duplicate sample was not used for the determination of biological condition.

Biological condition was determined for each Big Goose Creek station by year. Biological condition was also determined using the mean biological condition score for samples collected in 2001 and 2002. Taxa lists for Big Goose Creek benthic macroinvertebrate samples are presented in Appendix Tables L-13 through L-27. The list of metrics for each sample is presented in Appendix Tables M-1 and M-2. Comparable historical and current benthic macroinvertebrate samples collected by WDEQ at Big Goose Creek were also evaluated for biological condition. A historical WDEQ taxa list for a single Big Goose Creek benthic macroinvertebrate sample is presented in Appendix Table J-1. The list of metrics for the sample is presented in Appendix Table K-1. Samples collected by WDEQ within five years from the start of this Project were termed "current" samples. Taxa lists for four current WDEQ Big Goose Creek benthic macroinvertebrate samples were presented in Appendix Tables L-49 through L-52. The lists of metrics for each sample are presented in Appendix Table M-4.

A total of nineteen historical and current benthic macroinvertebrate samples were evaluated for biological condition. Determination of biological condition for each station is presented in Table 8-16 and illustrated in Figure 8-78. Biological condition was fair, good, or very good at each Big Goose Creek station. No poor biological condition ratings were observed as was noted at Goose Creek stations located in and just downstream of Sheridan. Biological condition scores derived from the WSII (Jessup and Stribling, 2002) for stations located in the Northwestern Great Plains ecoregion (all stations downstream of Big Goose Creek station BG18) ranged from a low of 45.8 at station BG2 in 2002 to a high of 79.7 at station BG10 in 2001. Biological condition at Bighorn Mountain foothill station BG18 using WSII values for the Middle Rockies ecoregion was 51.4 in 2002 and 55.7 in 2001. Biological condition at station BG18 was fair during both years. Biological condition at station BG18 was also determined using WSII values for the Northwestern Great Plains ecoregion to allow comparison to remaining Big Goose Creek stations located downstream.

The highest average WSII score among Big Goose Creek stations downstream of station BG18 was at station BG10 (average = 71.3) located about 50 yards upstream of the County Road 81 bridge and the lowest average score was at station BG2 (average = 49.4) located in Sheridan upstream of the footbridge at Works and Elk street. The change in biological condition among Big Goose Creek stations is illustrated in Figure 8-80.

Biological condition decreased from the uppermost station BG18 downstream to stations BG15 and BG14. Biological condition increased from station BG 14 to station BG10, then decreased to station BG 8, increased slightly to station BG4, then decreased at station BG2. Changes in biological condition along the longitudinal gradient of Big Goose Creek was in contrast to changes in biological condition at Goose Creek where biological condition decreased from the uppermost station (GC3) upstream of the Fort Road bridge in Sheridan to station GC1A, then increased to the lowermost station GC1. Biological condition at Little Goose Creek stations (Figure 8-79) and Soldier Creek stations (Figure 8-77) generally decreased from upstream stations to downstream stations.

There was some variability in biological condition between 2001 and 2002. Biological condition increased at two stations (BG4 and BG15) during 2002 while four stations (BG2, BG8, BG10 and BG18) exhibited decreased biological condition from 2001 to 2002. There was little change in biological condition at station BG14 between 2001 (score = 61.4) and 2002 (score = 59.6).

Station BG2 had the lowest biological condition among Big Goose Creek stations, but ranked 10th out of a total of 23 stations assessed for biological condition in the Project area (including 4 Soldier Creek stations). All other Big Goose Creek stations ranked in the upper 50% for biological condition when compared to all stations in the Project area (Figure 8-80). Station BG10 ranked 3rd best for biological condition among all stations. These observations indicated that biological condition in Big Goose Creek was better than Goose Creek and the majority of Soldier Creek, but similar to biological condition in Little Goose Creek.

WDEQ benthic macroinvertebrate samples collected at Big Goose Creek stations in 1994 and 1998 found generally better biological condition when compared to benthic macroinvertebrate samples collected during the Project. WDEQ sampled in 1994 and 1998 at Big Goose Creek station NGPI21. This station was the same as Big Goose Creek station BG2 for the current Project. The biological condition score for the 1994 samples was 51.4 and the biological condition score for the 1998 sample was 64.5 (Table 8-16). Biological condition was fair in 1994 and good in 1998 compared to fair biological condition ratings during sampling in 2001 and 2002. The biological condition ratings in 1994, 2001 and 2002 indicated non-support for aquatic life use whereas the biological condition rating in 1998 indicated support for aquatic life use.

WDEQ collected benthic macroinvertebrates at three other Big Goose Creek stations in 1998. WDEQ Big Goose Creek station NGPI49 was located at Normative Services west of Sheridan. This is the same station as BG4 for the current Project. The biological condition score for the 1998 samples was 67.3 compared to biological condition scores of 58.5 and 62.8 during 2001 and 2002, respectively (Table 8-16). Biological condition was good in each year indicating full support of aquatic life use.

WDEQ Big Goose Creek station NGPI47 was sited downstream from the Beckton road bridge. This station is near BG14 for the current Project. The biological condition score for the 1998 samples was 79.6 compared to biological condition scores of 61.4 and 59.6

during 2001 and 2002, respectively. Biological condition was very good in 1998 and good in 2001 and 2002 indicating full support of aquatic life use.

WDEQ Big Goose Creek station MRCI48 was sited in the Big Goose Creek canyon on the T-T Ranch near USGS gage station number 06302000. This station was near BG18 for the current Project. The biological condition score for the 1998 samples using WSII values for the Middle Rockies ecoregion was 70.4 compared to biological condition scores of 55.7 and 51.4 during 2001 and 2002, respectively. Biological condition was good in 1998 indicating full support of aquatic life use, but fair in 2001 and 2002 indicating non-support of aquatic life use. Non-support of aquatic life use at Big Goose Creek station BG18 observed during sampling in 2001 and 2002 appeared not to be related to poorer water quality, but to reduced flow caused by ongoing drought that resulted in reduced habitat. Station BG18 exhibited the highest percentage of silt (14%) and the highest percentage of sand (10%) among Big Goose Creek stations during this Project (see Section 8.22). The mean embeddedness (amount of silt covering cobble and gravel) was 87.0 and indicated that about 20% of cobble and gravel were covered by silt. The lack of higher spring "flushing" flows during spring 2001 and 2002 to remove sediment accumulated in and on substrate from the previous year appeared to negatively affect benthic macroinvertebrate populations at station BG18.

Based on WSII scores derived from current and historical benthic macroinvertebrate sampling, Big Goose Creek appears to attain aquatic life use from station BG18 in the canyon on the T-T Ranch downstream to station BG4 located at Normative Services. It should be noted that although aquatic life use support occurs through the reach from station BG18 to BG4, water quality and habitat stressors appeared to negatively affect biological condition at stations BG15, BG14, BG8 and BG4, but not to the degree to result in non-attainment of aquatic life use. Biological condition was reduced between station BG4 and BG2 in Sheridan indicating non-support of aquatic life use within this stream reach. Further, it is likely the stream reach from station BG2 to the confluence with Little Goose Creek in Sheridan did not support aquatic life use (see Appendix Map A-12). Evaluation of information presented in Final Report Sections 3.3, 8.2 through 8.20, 8.22, 8.23 and 8.24 was combined with the biological condition data to support this conclusion. Planning and possible remedial measures to restore aquatic life use support in Big Goose Creek within the reach from station BG4 to the confluence with Little Goose Creek in Sheridan are presented in Section 9.

Additional discussion for benthic macroinvertebrate community composition at Big Goose Creek stations is presented in Section 8.21.

8.2.3 LITTLE GOOSE CREEK

As with Big Goose Creek, Little Goose Creek water quality decreased from upstream to downstream sites. During the assessment, no pH samples were collected below 6.5 or greater than 9.0 standard units (Table 8-4 and 8-5). All conductivity measurements were less than 3,000 µmhos/cm, which met irrigation suitability recommendations by the NRCS (2000). All DO measurements met WDEQ standards for aquatic life. Turbidity and TSS data did not indicate sediment problems within Little Goose Creek. Alkalinity levels increased along the longitudinal gradient and indicated that Little Goose Creek is a well buffered system and not prone to sudden changes in pH. Hardness results indicated water in Little Goose Canyon was relatively soft, but became very hard (often >300 mg/L) in the lower reaches (see Tables 8-4 and 8-5). Chloride and sulfate levels increased from upstream to downstream and showed that beneficial uses relating to these parameters were met in Little Goose Creek. No exceedences of the ammonia water quality standard were found. Average total nitrate nitrogen was less than the national background levels of 0.60 mg/L (USGS, 1999). Little Goose Creek total phosphorus levels were less than the 0.10 mg/L national background level for undeveloped areas (USGS, 1999). However, the EPA recommended limit of 0.05 mg/L for streams entering reservoirs was often exceeded in Little Goose Creek (Tables 8-2 and 8-3). No pesticides or herbicides were detected in Little Goose Creek at site LG5 during the June 2002 sampling event.

USGS Station Number 06303500 located in Little Goose Canyon has recorded discharge data from April 1941 through September 2002. Between the April 1st and September 30th period, 2001 discharge was below average every day and 2002 discharge was at or above average discharge on seven days. During this period, 2001 discharge averaged 41.4% of normal and 2002 discharge was 54.6% of normal. Instantaneous discharge data collected during 2001-2002 monitoring indicated the uppermost Little Goose Creek site LG22 had the highest average discharge. Of four sites compared along Little Goose Creek (see Figure 8-29), site LG13 at the County Road 60 bridge had the lowest average discharge. This is likely the result of seasonal dewatering in this upper reach of Little Goose Creek.

Water temperatures in Little Goose Creek were often found to exceed the 20°C limit set forth in the Wyoming water quality standards. Instantaneous measurements with field meters occasionally recorded temperatures in excess of 20°C (Tables 8-4 and 8-5); however, the time at which samples were taken often did not correspond with maximum daily water temperatures normally occurring in the late afternoon. Continuous water temperature data were collected at sites LG2, LG8, and LG22 during 2001 and 2002 with the use of continuous temperature data loggers. The lower Little Goose Creek sites (LG2 and LG8) exceeded 20°C on a number of occasions. The uppermost site, LG22, exceeded 20°C during portions of two days in 2001. For the reasons discussed in Section 8.2.1, water temperature exceedences of 20°C are suspected to occur during "normal" flow years on lower Little Goose Creek. This suggests that lower Little Goose Creek does not meet its intended use as a cold-water fishery.

Lower Little Goose Creek proper sites LG1 through LG12, except LG5, exceeded the fecal coliform standard during at least one month. A significant increase in fecal coliform concentrations occurred between lower Little Goose Creek stations LG2 and LG1. LG1 was the only site on the mainstems (Goose Creek, Big Goose Creek, and Little Goose Creek) to exceed the standard during three of the eight fecal coliform monitoring months. Little Goose Creek proper sites LG13 through LG22 did not exceed 200 CFU/100 mL during any month. WDEQ fecal coliform monitoring on Little Goose Creek during 1998-1999 showed Little Goose Creek to be impaired from its mouth upstream to the canyon (GCWA site LG22). Monthly fecal coliform samples collected by WDEQ during the 1993-1994 Salt Monitoring Project revealed fecal coliform concentrations greater than 400 CFU/100 mL in individual samples on lower Little Goose Creek throughout Sheridan. The USGS collected fecal coliform samples at Station Number 06304500 (near site LG2) from 1979 through 1998. During this period, approximately 18% of all USGS samples exceeded 400 CFU/100 mL.

The Coffeen Avenue storm drain (site LG3) generally had very poor water quality. However, the volume of water from this storm drain entering Little Goose Creek was only about 35 gpm (0.08 cfs) on average. Conductivity, total sulfate, total chloride, total nitrate nitrogen, and total hardness were highest at this site during the GCWA. This storm drain had fecal coliform geometric means greater than 1,100 CFU/100 mL during both August 2001 and August 2002.

8.2.3.1 LITTLE GOOSE CREEK TRIBUTARIES – McCORMICK CREEK, KRUSE CREEK, JACKSON CREEK, AND SACKETT CREEK

Little Goose Creek tributary water quality was generally not as good as Little Goose Creek. Average conductivity, turbidity, TSS, total alkalinity, and total phosphorus were generally higher in these tributaries than in nearby Little Goose Creek sites. Average DO was lowest in Jackson Creek (8.94 mg/L), however, all Little Goose Creek tributary measurements met aquatic life requirements for DO. Average total nitrate nitrogen in these tributaries was less than the national background levels of 0.60 mg/L (USGS, 1999). Each tributary had total phosphorus concentrations that often exceeded the EPA recommended limit of 0.05 mg/L for streams entering lakes or reservoirs.

Kruse Creek and Jackson Creek each had four instantaneous temperature measurements greater than 20°C. However, GCWA water quality monitoring was usually not conducted to coincide with daily high water temperatures. Continuous water temperature data were collected on Jackson Creek during 2002. These data show that during 45 days in 2002, Jackson Creek water temperatures exceeded 20°C (Table 8-8).

During the GCWA, each of the four Little Goose Creek tributaries had fecal coliform geometric means greater than 200 CFU/100 mL during at least one month. Jackson Creek exceeded the fecal coliform standard during 3 months, McCormick Creek and Sackett Creek exceeded the standard during 2 months, and Kruse Creek exceeded the standard during one month. *E. coli* geometric means were greater than 126 CFU/100 mL in each of the tributaries during August 2002. WDEQ fecal coliform monitoring in 1999 found Kruse Creek, Jackson Creek, and Sackett Creek to exceed the fecal coliform standard. WDEQ did not perform water quality monitoring on McCormick Creek during 1999.

8.2.3.2 LITTLE GOOSE CREEK BENTHIC MACROINVERTEBRATES SUMMARY

A total of fifteen benthic macroinvertebrate samples were collected from seven Little Goose Creek stations (LG2A, LG5, LG7, LG10, LG18A, LG21 and LG22) during 2001 and 2002. Included in the total number of samples was one duplicate sample. The duplicate sample was used for QA/QC purposes, construction of taxa lists and for general discussion of macroinvertebrate results. The duplicate sample was not used for the determination of biological condition.

Biological condition was determined for each Little Goose Creek station by year. Biological condition was also determined using the mean biological condition score for samples collected in 2001 and 2002. Taxa lists for Little Goose Creek benthic macroinvertebrate samples are presented in Appendix Tables L-28 through L-42. The list of metrics for each sample is presented in Appendix Tables M-3 and M-4. Comparable historical and current benthic macroinvertebrate samples collected by WDEQ at Little Goose Creek were also evaluated for biological condition. WDEQ taxa lists for benthic macroinvertebrate samples collected in 1994 at two Little Goose Creek stations are presented in Appendix Tables J-7 and J-8. The list of metrics for the samples is presented in Appendix Table K-1. Samples collected by WDEQ and WEST within five years from the start of this Project were termed "current" samples. Taxa lists for six current WDEQ Little Goose Creek benthic macroinvertebrate samples (including one duplicate sample) were presented in Appendix Tables L-53 through L-57 and Appendix Table L-61. The list of metrics for each sample is presented in Appendix Tables M-5 and M-6. Taxa lists for two WEST samples collected in 1997 were presented in Appendix Tables L-59 and L-60. The list of metrics for each sample is presented in Appendix Table M-5.

A total of twenty-four historical and current benthic macroinvertebrate samples were evaluated for biological condition. Determination of biological condition for each station is presented in Table 8-16 and illustrated in Figure 8-79. Biological condition was fair, good, or very good among Little Goose Creek stations. No poor biological condition ratings were observed as was noted at Goose Creek stations located in and just downstream of Sheridan. Biological condition scores derived from the WSII (Jessup and Stribling, 2002) for stations located in the Northwestern Great Plains ecoregion (all stations downstream of Little Goose Creek station LG22) ranged from a low of 39.2 at station LG2A in 2001 to a high of 73.7 at station LG21 in 2001. Biological condition at Bighorn Mountain foothill station LG22 using WSII values for the Middle Rockies ecoregion was 71.0 in 2001 and 67.6 in 2002. Biological condition at station LG22 was good during both years. Biological condition at station LG22 was also determined using WSII values for the Northwestern Great Plains ecoregion to allow comparison to remaining Little Goose Creek stations located downstream. Biological condition scores for station LG22 presented in Figure 8-79 were from using WSII values for the Northwestern Great Plains and not the Middle Rockies ecoregion.

The highest average WSII score among Little Goose Creek stations downstream of station LG22 was at station LG21 (average = 68.4) located upstream of the County Road 103 bridge near Bradford Brinton Memorial and the lowest average score was at station LG2A (average = 40.6) located in Sheridan downstream of the Coffeen Avenue bridge and near a storm water discharge. The change in biological condition among Little Goose Creek stations is illustrated in Figure 8-79. Biological condition decreased from the uppermost station LG22 downstream to station LG2A. Consistent change in biological condition along the longitudinal gradient of Little Goose Creek was in contrast to changes in biological condition at Goose Creek where the general trend was a decrease in biological condition from the uppermost station (GC3) upstream of the Fort Road bridge in Sheridan to station GC1A, then increasing to the lowermost station GC1. Biological condition at Big Goose Creek stations (Figure 8-78) generally decreased from upstream to downstream stations, but not in the consistent manner noted for Little Goose Creek stations. Soldier Creek stations sampled by WDEQ (Figure 8-77) consistently decreased from upstream stations to downstream stations.

There was some variability in biological condition between 2001 and 2002. Biological condition decreased at upper stations LG22, LG21 and LG18 during 2002 while biological condition increased at lower stations LG2A and LG5 during 2002. There was little change in biological condition at station LG10 between 2001 (score = 49.9) and 2002 (score = 49.6).

Station LG2A and station LG5 had the lowest biological condition among Little Goose Creek stations, but ranked 7th and 8th, respectively, out of a total of 23 stations assessed for biological condition in the Project area (including 4 Soldier Creek stations). Station LG7 ranked 11th and station LG10 ranked 12th out of a total of 23 stations assessed for biological condition in the Project area. Remaining Little Goose Creek stations ranked in the upper 50% for biological condition when compared to all stations in the Project area (Figure 8-80). Station LG22 ranked 1st and station LG21 ranked 5th best for biological condition among all stations. These observations indicated that biological condition in Little Goose Creek was better than Goose Creek and the majority of Soldier Creek, and was similar to biological condition in Big Goose Creek.

WDEQ benthic macroinvertebrate samples collected at Little Goose Creek stations in 1994, 1996 and 1998 found generally better biological condition at comparable sample stations when compared to benthic macroinvertebrate samples collected during the Project. WDEQ collected macroinvertebrates in 1994 and 1996 at Little Goose Creek station NGPI26 located downstream of the Coffeen Avenue bridge and below a large storm drain discharge. The samples were collected at the same location as LG2A for the current Project. WEST collected macroinvertebrate samples at this station in 1997. The biological condition score for the 1994 samples was 35.2, the biological condition score for the 1997 samples was 39.4 and the biological condition score for the 1998 samples was 44.1 (Table 8-16). Biological condition scores at station LG2A were 39.2 in 2001 and 42.0 during 2002. Biological condition was poor in 1994 and fair during 1997, 1998, 2001 and 2002. The poor and fair biological condition ratings at station LG2A over the years indicated non-support for aquatic life use.

WDEQ collected benthic macroinvertebrate samples in 1998 at Little Goose Creek station NGPI36 located just upstream of the Coffeen Avenue bridge in Sheridan. This station was about 200 yards upstream of WDEQ Little Goose Creek station NGPI26 and station LG2A for this Project. WEST sampled this same station in 1997. The biological condition score for the 1997 samples was 40.5 and the biological condition score for the 1998 samples was 45.7 (Table 8-16). Biological condition was fair during both years indicating non-support for aquatic life use.

Little Goose Creek station NGPI20 located upstream of the Brundage Lane bridge was sampled by WDEQ for benthic macroinvertebrates in 1994 and 1998. Samples were collected at the same location as LG5 for the current Project. The biological condition score for the 1994 samples was 30.5, the biological condition score for the 1998 samples was 46.7 (Table 8-16). Biological condition scores at LG5 were 39.6 in 2001 and 46.3 during 2002. Biological condition was poor in 1994 and fair during 1998, 2001 and 2002. The poor and fair biological condition ratings at station LG5 over the years indicated non-support for aquatic life use.

Duplicate samples were collected by WDEQ in 1998 at Little Goose Creek station NGPI52 located upstream of the Highway 87 bridge. This station is at Little Goose Creek station LG10 for the current Project. The biological condition score for the 1998 samples was 53.9. Biological condition scores at LG10 were 55.1 in 2001 and 53.9 during 2002. Biological condition was good in 2001, but fair in 1998 and 2002. The good biological condition rating at station LG10 during 2001 indicated full support for aquatic life use whereas the fair biological condition ratings in 1998 and 2002 indicated non-support for aquatic life use.

Little Goose Creek station MRC38 located in the foothills at the Little Goose Creek canyon was sampled by WDEQ in 1996 and 1998. WDEQ station MRC38 was identified by WDEQ as a reference station indicating that water quality, biological condition and habitat were among the best for Middle Rockies ecoregion foothill streams in Wyoming (Jessup and Stribling, 2002). This is the same station as Little Goose Creek station LG22 for the current Project. The biological condition score using WSII values for the Middle Rockies ecoregion was 69.4 in 1996 and 66.8 in 1998 compared to biological condition scores of 71.0 and 66.8 during 2001 and 2002, respectively. The minor range in biological condition values of 4.2 among the four samples indicated little change in benthic macroinvertebrate communities regardless of variable flow conditions affecting the site over the years. Biological condition was good during each year indicating full support of aquatic life use. The reader should note that the biological condition values presented in Figure 8-79 were determined using WSII values for the Northwestern Great Plains ecoregion to allow comparison to remaining Little Goose Creek stations located downstream.

Based on WSII scores derived from current and historical benthic macroinvertebrate sampling, Little Goose Creek appears to support aquatic life use from upstream station LG22 downstream to station LG10 located about 20 yards upstream of the Highway 87 bridge. Biological condition at station LG10 indicated marginal aquatic life support during 2001 sampling, but non-support for samples collected in 1998 and 2002. Biological condition decreased and aquatic life use was not supported at each consecutive station downstream from station LG10 into Sheridan. This observation was supported by fisheries data in Section 8.23, which found a shift from cold water fish species to more non-game and warm water game species from the Highway 87 bridge downstream to the Woodland Park bridge near Little Goose Creek station LG7 for this Project. Biological condition continued to decline from station LG7 downstream to station LG2A in Sheridan and non-support of aquatic life use was indicated.

Additional evaluation of the biological condition data using the "weight of evidence" approach described in WDEQ (2002b) by incorporating chemical, physical, and biological data in addition to consideration of soils, geology, hydrology, climate, geomorphology, and stream succession, supported the finding that Little Goose Creek did not support aquatic life use from station LG10 downstream to station LG2A. It is probable the stream reach from station LG2A downstream to the Big Goose Creek confluence did not support aquatic life use. Further, the biological condition at station LG10 indicated full support for aquatic life, but there was a downward trend indicating potential non-support in the near future. It was recommended that the stream reach from station LG18 to downstream station LG10 be described as fully supporting, but threatened for aquatic life use support (see Appendix Map A-12). Planning and possible remedial measures to restore aquatic life use support in Little Goose Creek are presented in Section 9.

Additional discussion for benthic macroinvertebrate community composition at Little Goose Creek stations is presented in Section 8.21.

8.3 WATER TEMPERATURE

Instantaneous water temperature measurements were collected during 2001 and 2002 at all GCWA sampling sites during each sampling event. These data are presented in Appendix Tables E-2 through E-47. Summary statistics for temperature at each site are provided in Appendix Tables Q-2 through Q-47. Continuous water temperature data were collected at sites GC1, BG2, BG6, BG18, LG2, LG8, and LG22 during 2001 and 2002. During 2002, continuous water temperature data were also collected at tributary sites GC4 (Soldier Creek), BG9 (Beaver Creek), and LG17 (Jackson Creek). Time-series graphs for all of the 2001 and 2002 continuous water temperature data are presented in Appendix Figures F-1 through F-17.

8.3.1 SUMMARY OF INSTANTANEOUS WATER TEMPERATURE DATA

Average annual instantaneous temperature measurements have been plotted for all GCWA sites in Figures 8-1 and 8-2. When using these data, it should be noted that these data represent an average of <u>instantaneous</u> measurements. Due to the large number of sites that were required to be sampled on a daily basis, the instantaneous temperature measurements were taken at similar times on each sampling day and do not necessarily represent daily minimum, maximum, or even average temperatures. For example, sampling on Little Goose Creek began at approximately 7:00 a.m. each day at site LG1 and concluded at site LG22 usually between 1:30 p.m. and 3:30 p.m. Continuous water temperature data obtained at site LG2 (approximately ¼ mile upstream from LG1) showed minimum water temperatures usually occurred between 8:00 a.m. and 10:00 a.m. In addition, continuous water temperature data obtained at site LG22 showed maximum water temperature normally occurred between 3:00 p.m. and 6:00 p.m. Consequently, instantaneous temperature readings at site LG1 often <u>approached</u> daily minimum temperatures and instantaneous temperature readings at site LG22 often <u>approached</u> daily maximum temperatures. The remainder of the sites (LG2 through LG21) were usually sampled at times somewhere between daily minimum and maximum temperatures. This same general scenario holds true for Goose Creek and Big Goose Creek instantaneous temperature data.

Continuous temperature data show that diurnal temperature fluctuations at the lower plains sites (GC1, BG2, and LG2) often changed from 6 to 9°C during the warmer summer months and from 2 to 5°C during the spring and fall. Diurnal temperature ranges of around 6°C are fairly common in streams during summer (Hynes, 1970) and changes as great as 14°C have been reported for smaller plains streams (Mackichan, 1967).

WDEQ has established a maximum stream temperature of 20 °C for Class 1 and 2 cold water fisheries (WDEQ, 2001a). Tables 8-1 through 8-5 show the number of instantaneous temperature measurements exceeding 20 °C for each site during 2001 and 2002. The number of instantaneous measurements exceeding 20 °C in these tables is probably a conservative estimate when considering the time samples were taken and that summer temperature fluctuations often ranged from 6 to 9 °C.

A comparison of average annual temperatures shows a decrease in annual average temperature at each site, except LG6, from 2001 to 2002. This could be due in part to 34 of 43 comparable sites having a higher annual average discharge in 2002. Another factor could be that average monthly air temperatures between April and October for the Sheridan County Airport were 2.4 °F warmer than normal in 2001 and 1.2 °F cooler than normal in 2002 (Table 8-6).

Average annual water temperature in Soldier Creek appears much cooler than adjacent Goose Creek sites in 2001 (Figure 8-1). However, Soldier Creek was dry during three sampling events in August 2001; this likely has skewed the data to appear much cooler in 2001. A similar situation exists in the Park Creek temperature data (Figure 8-1). Park Creek was dry during the warm summer months of 2001 and 2002. Therefore, the average annual temperature represents mainly instantaneous temperature measurements taken during the spring and fall.

Figure 8-1 shows a significant decrease in average annual water temperature from site BG17 to BG18. Average annual water temperatures increased 2.8 °C during both 2001 and 2002 as Big Goose Creek flowed approximately 2 miles from BG18 to BG17. Similarly, Figure 8-2 shows a significant decrease in average annual water temperature from site LG21 to LG22. Average annual water temperatures increased 2.2 °C during 2001 and 2.7 °C during 2002 as Little Goose Creek flowed approximately 2.5 miles from LG22 downstream to LG21. Water temperatures in most mountain streams will increase from upstream to downstream along the longitudinal gradient. The effect of these stream waters leaving relatively dark, shaded canyons and entering the relatively open plains is evident when observing the water temperatures of Big Goose Creek and Little Goose Creek.

8.3.2 SUMMARY OF CONTINUOUS WATER TEMPERATURE DATA

The continuous temperature data provided in Figures F-1 through F-17 show the expected trend of stream water warming during the spring, reaching maximum temperatures during July and August, and then cooling again in the fall. Diurnal (daily) temperature fluctuations are also obvious as water warms during the day and then cools at night. Diurnal fluctuations were usually more dramatic during summer as a result of longer daylight hours and lower stream flows.

As shown in Figure F-1, water temperatures at Goose Creek site GC1 warmed steadily until the end of June 2001. A maximum daily temperature of 30.17 °C was reached on July 14, 2001 and again on August 4, 2001. On July 13, 2002, the 2002 maximum daily temperature of 30.36 °C was reached at site GC1 (Figure F-2). Table 8-8 summarizes the number of days when daily maximum and minimum water temperature exceeded 20 °C. During 2001, 20°C was exceeded on 103 days and during 2002 the standard was exceeded on 93 days. This equates to 28% of all days exceeding 20°C during 2001 and 25% of all days exceeding 20°C during 2002.

Water temperature at site GC4 (Soldier Creek) was monitored on a continuous basis during 2002 only (Figure F-3). Diurnal temperature fluctuations were not as severe on Soldier Creek as on Goose Creek (GC1). When compared to Goose Creek, Soldier Creek has a much narrower stream channel that allows more of the stream to be shaded and may account for the reduced temperature variations. Nonetheless, a maximum water temperature of 24.48 °C was reached on August 6, 2002 and 34 days (9%) exceeded the 20°C water temperature standard (Table 8-8). The GC4 temperature logger was partially buried in stream sediment from June 3, 2002 until June 27, 2002 and did not accurately record water temperatures. Therefore, data from this period were not included in this Final Report. A greater number of days that exceeded 20°C would likely have been reported for Soldier Creek if the temperature logger had not been buried in substrate.

Appendix Figures F-4 and F-5 provide continuous temperature data for Big Goose Creek site BG2 during 2001 and 2002, respectively. The 2001 maximum daily temperature of 29.88°C was recorded on August 6th. On July 8th, the 2002 maximum daily temperature of 29.14°C was observed. Table 8-8 shows that 92 days (25%) of all 2001 days exceeded the temperature standard and 76 days (21%) of all 2002 days exceeded the temperature standard.

Big Goose Creek site BG6 was monitored for continuous water temperature during 2001 and 2002 (Figure F-6 and F-7). The continuous recorder showed that temperatures at this site were often warmer than the downstream site BG2. The 2001 maximum daily temperature of 30.52°C was observed on August 2nd . In 2002, the highest temperature observed was 31.67°C on July 14th. Water temperature exceeded 20°C on 100 days (27%) during 2001 and on 90 days (25%) during 2002 (see Table 8-8).

A continuous temperature recorder was added to Beaver Creek site BG9 during 2002. The recorded data for this site are provided in Figure F-8. Water temperatures in Beaver Creek exceeded the 20°C temperature standard on 45 days (12%) during 2002 (see Table 8-8). The maximum temperature observed for the year was 24.42°C on July 14th.

Big Goose Creek site BG18 continuous water temperature data are presented in Figures F-9 and F-10 for 2001 and 2002, respectively. Water temperatures at this site were found to approach, but never exceed, the 20°C water temperature standard. Diurnal temperature fluctuations were significantly less at this site than those observed at downstream sites BG2 and BG6.

Site LG2 is the most downstream station on Little Goose Creek to be equipped with a continuous temperature logger. The 2001 and 2002 continuous temperature data for this site are presented in Figures F-11 and F-12. During 2001, the 20°C temperature standard was exceeded on 110 days (30%) and the maximum daily temperature of 29.93°C occurred on June 29th. During 2002, the 20°C temperature standard was exceeded on 88 days (24%) and the maximum daily temperature of 29.21°C occurred on June 26th.

Little Goose Creek site LG8 continuous water temperature data for 2001 and 2002 are presented in Figures F-13 and F-14, respectively. The 2001 maximum daily temperature of 27.29°C occurred on July 5th. During 2002, the highest observed temperature was 27.65°C as recorded on July 14th. As shown in Table 8-8, the 20°C temperature standard was exceeded on 90 days (25%) in 2001 and was exceeded on 63 days (17%) in 2002.

A continuous temperature logger was utilized during 2002 on lower Jackson Creek (site LG17). Continuous temperature data for this site are provided in Figure F-15. A maximum daily temperature of 25.92°C was recorded on July 14th. During 2002, Jackson Creek exceeded the 20°C temperature standard on 45 days (12%).

Site LG22 was the most upstream Little Goose Creek site to be equipped with a continuous temperature recorder. Continuous temperature data for this site are provided in Figures F-16 and F-17. Water temperatures at LG22 exceeded 20°C on two, non-consecutive days during 2001. This represents approximately 0.5% of all 2001 days exceeding the standard. During 2002, water temperatures approached, but never exceeded, the 20°C temperature standard. Maximum daily temperatures observed during 2001 and 2002 were 20.62°C and 18.51°C, respectively.

Daily averages of all continuous water temperature data were calculated to compare temperatures observed during 2001 and 2002. Figures 8-3 through 8-9 show average daily temperatures for 2001 and 2002 at sites GC1, BG2, BG6, BG18, LG2, LG8, and LG22. At all sites, 2001 and 2002 average daily temperatures were found to be very similar. However, water temperatures observed in 2002 appeared to be somewhat cooler in general than the 2001 water temperatures.

Daily averages of continuous water temperature data were also used to compare 2002 water temperatures observed in the tributary sites GC4, BG9, and LG17. Figure 8-10 shows that daily average temperatures in Soldier Creek, Beaver Creek, and Jackson Creek were nearly identical. Funds were not available to continuously monitor all eight tributaries studied in this assessment, but these data may allow for general conclusions to be made about the remaining five tributaries.

8.3.3 COMPARISON OF 2001 AND 2002 WATER TEMPERATURE DATA TO 2001 AND 2002 STREAM DISCHARGE AND AMBIENT AIR TEMPERATURE DATA

One factor known to have an effect on water temperatures is stream discharge. Generally, larger waterbodies respond slower to changes in air temperatures and smaller waterbodies show a quicker response. During 2001 and 2002, much of the western United States experienced moderate to severe drought conditions. Sheridan County and the Goose Creek watershed were also affected by below average precipitation and warmer than normal summer air temperatures.

Table 8-7 provides an example of the reduced stream flows experienced within the Goose Creek watershed during 2001 and 2002. Data from the USGS Station Number 06305700 (Goose Creek Near Acme, WY) are presented to show a comparison of mean monthly flows leaving the watershed. The months of April through October (2001 and 2002) are presented because these months correspond with GCWA monitoring. Every month during this period observed mean monthly flows well below the 19 year average. Nineteen years is not an extensive reference period, however, 2001 flows for this period were only 20.3% of normal and 2002 flows were 27.2% of normal. These greatly reduced flows likely had an effect on mid-summer water temperatures. However, a lack of historical continuous temperature data prevents comparing water temperatures observed during “normal” flow years to those observed during the 2001-2002 GCWA.

Figure 8-11 illustrates the timing and effect of stream discharge on water temperature. In this figure, daily average water temperature is compared to daily discharge at GCWA site GC1 (same site as USGS Station Number 06305700). During both 2001 and 2002, maximum water temperatures coincided with minimum stream flows from late June through late August. Obviously, discharge was not the only factor influencing stream temperatures. As summer air temperatures peaked in June, July, and August, so did stream water temperatures. However, Table 8-6 shows that five of the six summer months observed (June 2001, July 2001, August 2001, June 2002, and July 2002) were warmer than normal.

Figures 8-12 and 8-13 illustrate the effect air temperatures had on Goose Creek water temperatures during 2001 and 2002. The result was daily average water temperatures followed daily average air temperatures very closely. Water temperatures were expected to be generally cooler than air temperatures, however, the average of these daily temperatures was very similar.

8.3.4 STREAM REACHES IMPAIRED BY ELEVATED WATER TEMPERATURES

As described in Section 4, WDEQ has classified Goose Creek, Big Goose Creek, and Little Goose Creek as Class 2AB, cold-water fisheries (WDEQ, 2001b) and requires a maximum in stream temperature of 20°C for these waters. Optimal water temperatures for salmonids (including trout) are approximately 12°C to 14°C (MacDonald et al., 1991). Bjornn and Reiser (1991) indicated the optimal upper water temperature for most salmonids was 13°C to 16°C. Lethal water temperatures may vary according to the duration that fish are exposed to high temperatures and their acclimation to high temperatures, but is generally in the range of 20°C to 25°C.

The instantaneous and continuous water temperature data provided in this Final Report suggest that trout would not be able to withstand summer water temperatures experienced in the lower reaches of the watershed. WGFD data also suggest that Goose Creek, lower Big Goose Creek, and lower Little Goose Creek are not likely productive trout fisheries under current conditions. WGFD classifies the entire reach of Goose Creek, Big Goose Creek from the Little Goose Creek confluence to the Beaver Creek confluence, and Little Goose Creek from the Big Goose Creek confluence to the Highway 87 crossing as Class 5 trout waters. Class 5 waters are considered by WGFD to have very low trout production and are often incapable of sustaining a trout fishery. Therefore, these waters are either improperly classified as cold-water fisheries or do not meet their intended beneficial uses in their current condition. The magnitude to which the 2001-2002 drought and seasonal irrigation dewatering has affected the stream temperatures monitored during the GCWA is unknown. Even though stream flows were below normal, it is likely that water temperatures within the watershed do normally exceed the 20°C threshold. Map A-11 shows the stream reaches found during the GCWA to have regularly exceeded 20°C as measured with the continuous temperature recorders.

8.4 pH

Summary statistics for instantaneous pH measurements have been provided for each monitoring station in Appendix Tables Q-2 through Q-47. The maximum pH value observed was 8.89 SU at Little Goose Creek site LG20 during 2002. Park Creek (BG13) had the lowest instantaneous reading of 7.17 SU during 2001. Little variability was found in pH values from station to station and from year to year. In general, the pH values observed for tributary stations were very similar to or slightly lower than those observed in Goose Creek, Big Goose Creek, and Little Goose Creek. However, average annual pH at the Kruse Creek station (LG11) and the Beaver Creek station (BG9) were slightly higher than those found in adjacent sites in Little Goose Creek and Big Goose Creek, respectively.

Average annual pH has been plotted for each site in Figures 8-14 and 8-15. Average annual pH ranged from 7.68 SU at Park Creek (BG13) in 2001 to 8.43 SU at Little Goose Creek sites LG15 and LG16 in 2002. The pH measurements recorded in 2002 were generally higher than those recorded in 2001, possibly due to the greater abundances of aquatic plants observed during 2002. The relatively high pH values found throughout the Goose Creek watershed are likely due to the abundance of underlying geologic formations comprised of carbonate minerals.

All instantaneous pH measurements recorded during this project were within the Wyoming water quality standards of 6.0 to 9.0 SU.

8.5 CONDUCTIVITY

Appendix Tables Q-2 through Q-47 provide summary statistics for conductivity at each monitoring station. As is normal in most waterbodies, the conductivity values increased from upstream to downstream on Goose Creek, Big Goose Creek, and Little Goose Creek (see Figures 8-16 and 8-17). The highest average conductivity and highest single conductivity value observed were at the Coffeen Avenue storm drain with values of 2,291 µmhos/cm and 3,160 µmhos/cm, respectively. The uppermost Big Goose Creek site (BG18) recorded the lowest average and single conductivity values of 108 µmhos/cm and 41 µmhos/cm, respectively. At LG22, the uppermost Little Goose Creek site, the average conductivity was 119 µmhos/cm and the lowest single measurement was 49 µmhos/cm.

Sites BG18 and LG22 had very low conductivity considering that Feth et al. (1964) reported conductivities of melted snow in the Western United States ranging from about 2 to 42 µmhos/cm. Whitehead and Feth (1964) observed conductivity values of greater than 100 µmhos/cm in several rainstorms in Menlo Park, California. By contrast, sea water has an approximate conductivity of 50,000 µmhos/cm (Hem, 1992).

Conductivity values were generally much higher within the tributaries, but did not appear to have a significant impact on the receiving waterbodies (Figures 8-16 and 8-17). When considering upstream and downstream sites, the major waterbodies experienced the following changes in average conductivity after mixing with the tributaries (and one storm drain):

- A 3.4% decrease was observed in Goose Creek after receiving Soldier Creek;
- A 6.7% increase was observed in Big Goose Creek after receiving Beaver Creek;
- A 2.1% increase was observed in Big Goose Creek after receiving Park Creek;
- A 30.4% increase was found in Big Goose Creek after receiving Rapid Creek;
- A 2.0% increase was found in Little Goose Creek after receiving the Coffeen Avenue storm drain (LG3);

- A 10.3% increase was found in Little Goose Creek after receiving McCormick Creek;
- A 5.6% increase was found in Little Goose Creek after receiving Kruse Creek;
- A 2.4% increase was found in Little Goose Creek after receiving Jackson Creek; and
- A 19.1% increase was found in Little Goose Creek after receiving Sackett Creek.

These changes in the average conductivity of the receiving waterbodies are not wholly explained by the contributing tributary waters. Additional unknown sources (natural and anthropogenic), irrigation diversions and returns, and natural stream processes may also change conductivity values from upstream to downstream sites. For example, for Sackett Creek to have increased the average conductivity of Little Goose Creek by 19.1%, it would have required an average conductivity 2.7 times higher than actually measured.

Conductivity normally has an inverse relationship with discharge. Figure 8-18 provides and example of the general relationship between conductivity and discharge at Little Goose Creek site LG6. A linear regression of this data shows that 60.6% of the variation in conductivity values can be attributed to discharge ($R^2 = 0.6056$).

Although there was no Wyoming water quality standard for conductivity, data gathered during the GCWA suggest conductivity values were generally low for a watershed of this size and were within the range required to support aquatic life. However, as mentioned in Section 6.3.1.3, quality standards are established for Wyoming groundwater such that TDS concentrations for domestic, agriculture, or livestock use shall not exceed 500 mg/l, 2000 mg/l, or 5000 mg/l, respectively. The NRCS recommends upper conductivity limits for irrigation waters of 3,000 µmhos/cm to prevent soil salinity problems (NRCS, 2000).

8.6 DISSOLVED OXYGEN

DO summary statistics for each monitoring station are presented in Appendix Tables Q-2 through Q-47. Average annual DO was lowest at the Park Creek (BG13) site (7.3 mg/L) and highest at the Little Goose Creek site LG14 (12.1 mg/L). Average annual DO is plotted for each site in Figures 8-19 and 8-20.

Soldier Creek (GC4), Park Creek (BG13), and Jackson Creek (LG17) exhibited a substantially lower average DO concentration than the waterbodies they entered. The mean 2001 and 2002 DO concentrations for Soldier Creek were 9.39 and 8.75 mg/L, for Park Creek were 7.33 and 7.74 mg/L, and for Jackson Creek were 8.96 and 8.91 mg/L, respectively.

When Big Goose Creek and Little Goose Creek join, resulting DO concentrations are greatly increased in Goose Creek. These concentrations remain high in Goose Creek downstream to the Fort Road bridge (GC3), after this point the levels decrease sharply. Even so, all average annual DO levels in Goose Creek proper sites remained above 9.0 mg/L.

As a general rule, the equilibrium concentration of DO is a function of temperature and pressure, and to a lesser degree, the concentration of other solutes. DO levels usually decrease with increasing water temperature and also decrease with increasing altitude (less atmospheric pressure). As expected, DO levels throughout the watershed were generally higher during the spring and fall months when air temperatures were cooler and when stream discharges were higher. Higher and more turbulent stream levels may capture and entrain atmospheric oxygen into the water column whereas relatively slow moving or stagnant waters cannot. Figure 8-21 provides an example of the water temperature/DO relationship at Big Goose Creek site BG1. A linear regression of this data shows that approximately 85% ($R^2 = 0.849$) of the variation in DO can be explained by temperature alone.

Chapter 1 of the Wyoming Water Quality Rules and Regulations sets limits of 5.0 mg/L and 4.0 mg/L for "Early Life Stages" and "Other Life Stages", respectively. No DO measurements below 4.0 mg/L were recorded during this assessment. However, three dissolved oxygen measurements below 5.0 mg/l were recorded during the assessment and represented 0.14% (3 of 2,090) of all samples taken. A discussion of each of these samples is provided below:

- A DO measurement of 4.97 mg/L was recorded at Goose Creek site GC1 on August 6, 2001. Stream discharge was estimated at 5.1 cfs during the sampling event, which was the lowest recorded discharge during the two-year project. Normal discharge for August 6 at USGS Station Number 06305700 (same site as GC1) is 62.5 cfs.

- A DO measurement of 4.81 mg/L was recorded at Big Goose Creek site BG5 on July 30, 2002. A temporary irrigation dam was constructed across the channel upstream from the sampling station prior to this sampling event. Stream discharge was estimated at 2.2 cfs during the event, which was the lowest recorded discharge during the assessment.

- A DO measurement of 4.70 mg/L was recorded at the Park Creek site BG13 on May 22, 2001. However, Park Creek was dry during a scheduled sampling event six days earlier on May 16, 2001.

Drought conditions experienced during 2001 and 2002 created lower than normal discharge and higher than normal summer air temperatures as discussed in Section 8.3.3. These combined conditions undoubtedly had a direct effect on the dissolved oxygen levels observed during this assessment. When considering the low occurrence of samples containing less than 5.0 mg/L DO during these drought conditions, it is concluded that DO depletion seldom occurs within the watershed.

8.7 TOTAL RESIDUAL CHLORINE

As mentioned in Section 8.1.2, the results of TRC monitoring were found to be highly unreliable. A HACH Pocket Colorimeter was used to analyze the field samples.

According to the manufacturer, HACH Company, several surface water characteristics may interfere with the field analysis and/or create “false positives”. Characteristics that may falsely indicate the presence of chlorine include:

- Samples containing more than 250 mg/L alkalinity as $CaCO_3$ may inhibit full color development, or the color may fade instantly.
- Bromine, iodine, ozone, and oxidized forms of magnesium and chromium may also react with the reagent to indicate chlorine.
- Turbid samples may interfere with the photometer and create false positives.

These interferences were verified during a 2/11/02 phone conversation with a Technical Services Representative from HACH Company. Alkalinity samples taken during the project were often analyzed with greater than 250 mg/L alkalinity as $CaCO_3$. However, turbidity was suspected to cause the majority of errors with the field meter.

During June 2002, an attempt was made to determine the quality of the TRC data. Duplicate samples were obtained from the monitoring stations identified in Table 6-9 for simultaneous analysis with the HACH Pocket Colorimeter and with the City of Sheridan WWTP titration equipment. While performing the laboratory titrations, the WWTP was found to be using color-producing reagents that were susceptible to the same stream water interferences found with the Colorimeter. Consequently, the titration analysis could not be used to validate the field data.

TRC data collected during the assessment have not been included in this Final Report because an unknown number of false positives were present in the data set. The GCDAG decided not to include these data because they were not of known quality and should not be used to make future management decisions.

8.8 DISCHARGE

Discharge was measured during each sampling event with the use of calibrated staff gauges as described in Section 6.5.2. Additional discharge measurements were recorded during routine site visits to obtain continuous temperature data, survey staff gauges, collect macroinvertebrate samples, and during staff gauge calibrations. Instantaneous discharge data are provided in Appendix Tables E-2 through E-47 and summary statistics are provided in Appendix Tables Q-2 through Q-47.

The USGS has collected historical and current discharge data at several stations within the Goose Creek watershed. Data from seven sites on Goose Creek, Big Goose Creek, and Little Goose Creek have been summarized and presented in Appendix P. Mean monthly discharge has been tabulated in Tables P-1 through P-7 and mean daily discharge has been plotted in Figures P-1 through P-7. The location of USGS stations are identified on Map A-7.

8.8.1 SUMMARY OF USGS CONTINUOUS DISCHARGE DATA

8.8.1.1 USGS STATION NO. 06305700 – GOOSE CREEK NEAR ACME, WY

Daily discharge measurements have been collected at USGS Station Number 06305700 (Goose Creek near Acme, WY) since May 1984. GCWA site GC1 is located at this USGS station. Table P-1 and Figure P-1 summarize Station Number 06305700 mean monthly discharge and mean daily discharge, respectively. Average annual discharge at this station is 158.4 cfs. During 2001, discharge averaged 48.6 cfs, which is 30.7% of the annual average discharge for the period of record. At the time this Final Report was written, 2002 discharge data were available for January through September. Average discharge for this period was 52.5 cfs, which is 29.1% of normal for these months.

Table 8-7 summarizes 2001 and 2002, USGS Station Number 06305700 discharge data for the months of April through October. These months correspond with GCWA monitoring and indicate that 2001 discharge was 168.0 cfs less than normal and 2002 discharge was 171.4 cfs less than normal for this period. During each month that monitoring was conducted for the GCWA, discharge at this station was less than normal.

Figure 8-22 provides a graphical display of 2001 and 2002 daily discharge compared to normal daily discharge at Station Number 06305700. Below-normal 2001 and 2002 discharge for this site was a combined result of lower than normal mountain snow pack, below average precipitation in lower reaches of the watershed, and a drought increased demand for urban and agricultural irrigation water.

8.8.1.2 USGS STATION NO. 06305500 – GOOSE CREEK BELOW SHERIDAN

Mean monthly discharge and mean daily discharge data from October 1941 through September 1984 are available for this station in Appendix Table P-2 and Appendix Figure P-2, respectively. This USGS station was located near the Sheridan WWTP outfall. GCWA site GC2 is located approximately 200 yards downstream from the WWTP outfall.

Mean annual discharge at this site for 43 years of record was 183.9 cfs. While in operation (1941-1984), June 16th observed the highest daily average flow of 913 cfs and August 9th had the lowest daily average flow of 46.1 cfs.

8.8.1.3 USGS STATION NO. 06302200 – BIG GOOSE CREEK ABOVE PARK CREEK, NEAR SHERIDAN, WY

Mean monthly discharge and mean daily discharge data from July 1999 through September 2000 are available for this station in Appendix Table P-3 and Appendix Figure P-3, respectively. GCWA site BG14 was located at this USGS station.

While in operation (1999-2000), maximum daily average discharge of 763 cfs occurred on May 30th and minimum daily average discharge of 1.7 cfs occurred on August 20th.

8.8.1.4 USGS STATION NO. 06302000 – BIG GOOSE CREEK NEAR SHERIDAN, WY AND USGS STATION NO. 06301850 – BIG GOOSE CREEK ABOVE PK DITCH, IN CANYON, NEAR SHERIDAN, WY

USGS Station Number 06302000 was located near the mouth of Big Goose Canyon at the T-T Ranch and recorded discharge data from April 1930 through September 2000. Project site BG18 was located at this station. Mean monthly discharge data are presented in Appendix Table P-4 and mean daily discharge data are presented in Appendix Figure P-4. Beginning in 1972 and continuing through 2000, discharge data were recorded for the months of April through September only. Maximum daily average discharge of 516 cfs occurred on June 16th and minimum daily average discharge of 9.03 cfs occurred on February 29th. This station was removed during October 2002.

USGS Station Number 06301850 was constructed approximately ½ mile upstream from Station Number 06302000. Daily average discharge data for Station Number 06301850 were only available for the April through September, 2002 period at the time of this report. Figure 8-23 was constructed to show the low flows experienced at this site during 2002. Station Number 06301850 would be expected to carry more stream water than was normally recorded at Station Number 06302000 during the irrigation period because the PK Ditch diverts water from Big Goose Creek between the two stations. However, Figure 8-23 shows significantly less water was available at Station Number 06301850 during 2002 due to the drought conditions. During the comparable period of April through September, Station Number 06301850 recorded 67.8 cfs less discharge on an average basis than was normally observed for this period at Station Number 06302000.

8.8.1.5 USGS STATION NO. 06301500 – WEST FORK BIG GOOSE CREEK NEAR BIG HORN, WY

Discharge data for this station (located in the BHNF) have been recorded from October 1953 through September 2002 at the time of this report. Mean monthly discharge data are presented in Appendix Table P-5 and mean daily discharge data are presented Appendix Figure P-5. Figure 8-24 provides a comparison of 2001 and 2002 daily discharge to average daily discharge for the period of record. During May 15 through September 30, 2001, daily discharge averaged 34.5 cfs, which is 43.5% of normal for this period. Between May 1 and September 30, 2002 daily discharge averaged 41.9 cfs, which is 56.5% of normal for this period.

8.8.1.6 USGS STATION NO. 06303700 – LITTLE GOOSE CREEK ABOVE DAVIS CREEK , NEAR BIG HORN, WY

Mean monthly discharge and mean daily discharge data from July 1999 through September 2000 are available for this station in Appendix Table P-6 and Appendix Figure P-6, respectively. GCWA site LG22 was located at this USGS station.

While in operation (1999-2000), maximum daily average discharge of 358 cfs occurred on May 18th and minimum daily average discharge of 4.2 cfs occurred on November 2nd.

8.8.1.7 USGS STATION NO. 06303500 – LITTLE GOOSE CREEK IN CANYON, NEAR BIG HORN, WY

Station Number 06303500 is located in Little Goose Canyon above the Peralta Ditch. Discharge data have been recorded at this station from April 1941 through September 2002 and are available as monthly mean flow in Appendix Table P-7 and as daily mean flow in Appendix Figure P-7. Figure 8-25 provides a time-series graph of 2001 and 2002 actual daily discharge and average daily flow for the 62 years of record.

Between the April 1st and September 30th period, 2001 discharge was below average every day and 2002 discharge was at or above average discharge on only seven days. During this period, 2001 discharge averaged 41.4% of normal and 2002 discharge was 54.6% of normal. Average daily discharge for the period was 113.5 cfs.

8.8.1.8 SEASONAL DEWATERING EFFECTS ON STREAM DISCHARGE

Seasonal dewatering normally occurs in the Goose Creek watershed as it does in many areas of Wyoming. Local surface waters have been used historically, and continue to be used, for domestic water supplies, stock water supplies, agricultural irrigation, and for urban/domestic uses such as lawn and landscape watering. To supplement these requirements, mountain reservoirs have been constructed to store agricultural and domestic waters for timed release throughout the year. Nonetheless, these combined uses create a demand on stream flow that can be observed through continuous USGS discharge data.

As illustrated in Figure 8-26, there were periods in 2002 when stream discharge was greater in upper Big Goose Creek (Station Number 06301850) and/or upper Little Goose Creek (Station Number 06303500) than observed in lower Goose Creek (Station Number 06305700). During 2002, the demands of seasonal dewatering became apparent by mid-May and were evident through the end of September. Table 8-9 shows that lower Goose Creek averaged less discharge between April 1st and September 30th than either station on upper Big Goose Creek or upper Little Goose Creek. Please note that these simple comparisons do not consider natural stream flow gains or losses, the effect of tributaries between these stations, regulated flows in stream channels, or other possible natural and/or anthropogenic effects.

8.8.2 SUMMARY OF GCWA INSTANTANEOUS DISCHARGE DATA

All instantaneous discharge data recorded during the GCWA are provided in Appendix Tables E-2 through E-47. Summary statistics are provided in Appendix Tables Q-2 through Q-47.

Figure 8-27 provides a comparison of discharges observed on the same days at lower Goose Creek (GC1) and upper Goose Creek (GC6). Seasonal dewatering did not appear to have a noticeable affect on Goose Creek. Average discharge was 45.7 cfs at site GC1 and 40.7 cfs at site GC6 for comparable days during 2001 and 2002.

Figure 8-28 presents comparable discharges observed on the same days at four Big Goose Creek sites (BG1, BG6, BG14, and BG18). These sites show the effects of seasonal dewatering along the Big Goose Creek drainage. During portions of 2001 and 2002, the uppermost station (BG18) had the highest discharge. The lowest discharge was often observed at site BG14 (south of Beckton) indicating dewatering losses were most significant in this upper reach of Big Goose Creek. Figure 8-101 is a photograph taken at site BG15 (upstream from Beckton) during August 2002, which shows these low stream flows resulting from seasonal dewatering and the drought. Average discharge for comparable days was 24.8 cfs at BG1, 25.4 cfs at BG6, 22.0 cfs at BG14, and 29.3 cfs at BG18.

Instantaneous discharge measurements are compared at four Little Goose Creek sites (LG1, LG6, LG13, and LG22) for similar days during 2001 and 2002 in Figure 8-29. The seasonal dewatering trend along the longitudinal gradient of Little Goose Creek is similar to that of Big Goose Creek. Highest flows were often observed at the uppermost site (LG22) and low flows were often recorded at site LG13 (at the County Road 60 bridge). This is likely a result of flow diversion into the major irrigation ditches between LG22 and LG13. Average discharge for comparable days was 15.2 cfs at LG1, 17.9 cfs at LG6, 12.4 cfs at LG13, and 28.3 cfs at LG22.

8.9 TURBIDITY

Turbidity data for the GCWA are presented in Appendix Tables E-2 through E-47. Summary statistics for this data have been calculated and are provided in Appendix Tables Q-2 through Q-47.

Turbidity generally increased from upstream to downstream within the watershed and was generally higher in the tributaries. Increases in turbidity along the longitudinal gradient are normally expected in most surface waters. Increases in turbidity can also be caused by surface run-off from construction projects, crop tilling, irrigation return flows, and various other anthropogenic sources. Figures 8-30 and 8-31 provide a graphical display of average annual turbidity by site for Goose Creek, Big Goose Creek, and Little Goose Creek. The lowest average turbidity for the project was found at the uppermost Big Goose Creek site BG18 (1.2 NTU). Jackson Creek (LG17) had the highest average turbidity of 32.2 NTU.

During the assessment, average annual turbidity values on Goose Creek proper ranged from 5.5 NTU (GC3 in 2002) to 8.9 NTU (GC1 in 2002). Soldier Creek (GC4) had relatively higher turbidity concentrations (average 14.1 NTU) but did not appear to adversely affect Goose Creek turbidity levels. Average annual turbidity on Big Goose Creek ranged from 1.1 NTU at site BG18 during 2002 to 7.6 NTU at site BG2 during 2001. Park Creek had the highest average turbidity concentration of any tributary contributing to Big Goose Creek (6.4 NTU). None of the tributaries had a significant impact on Big Goose Creek turbidity levels. The greatest average increases in turbidity were between sites BG3 and BG2 (2.5 NTU) during 2001 and between sites BG4 and

BG3 (3.1 NTU) during 2002. The cause(s) for these increases is unknown. Average annual turbidity on Little Goose Creek ranged from 1.4 NTU at site LG22 during 2001 to 13.6 NTU at site LG7. Jackson Creek had the highest one-year average turbidity of 38.3 NTU in 2002. However, a geometric mean of this 2002 data was calculated at 18.1 NTU. Of the tributaries studied, Kruse Creek appeared to have the most impact on Little Goose Creek turbidity. Increases in turbidity from upstream (LG12) to downstream (LG10) were 2.0 NTU in 2001 and 3.0 NTU in 2002. Figure 8-102 provides an example of higher turbidity Sackett Creek stream water mixing with lower turbidity Little Goose Creek stream water.

Variations in turbidity can often be explained by stream discharge. As discharge increases, bed sediments are disturbed, which can increase turbidity several fold. Sediment and other contributing materials begin to settle as stream discharge is lowered. An example of the effect discharge has on turbidity levels is provided in Figure 8-32. A linear regression of these data shows that turbidity levels were correlated to stream discharge. Approximately 81% (R^2=0.8141) of the variability in turbidity levels can be attributed to discharge at Little Goose Creek site LG4.

The Wyoming water quality standards do not allow an increase of more than 10 NTU as a result of man-influenced activities. This standard was not exceeded at any of the stations monitored during this project. The relatively higher levels of turbidity in the tributaries could not be explained because only one lower station was monitored on each tributary. Irrigation return flows may account for turbidity increases in the lower reach of each drainage. Since stream discharge was lower than normal during 2001 – 2002 monitoring (see Section 8.8), higher turbidity levels may be encountered during a "normal" flow year with greater discharge.

8.10 TOTAL SUSPENDED SOLIDS

TSS data were collected monthly at each station from April through October, 2001 and 2002. These data are provided in Appendix Tables E-2 through E-47 and statistical summaries are provided in Appendix Tables Q-2 through Q-47.

TSS concentrations were relatively low for most stations and many TSS values at the upper stations were below the detection limit of 5 mg/L. As stated in Section 7.9.1, random numbers (i.e. 1, 2, 3, or 4 mg/L) were assigned to non-detectable samples so that summaries and statistics could be compiled. Figures 8-33 and 8-34 depict average annual TSS by site for Goose Creek, Big Goose Creek, and Little Goose Creek.

TSS concentrations seemed to follow the same general trends revealed by the turbidity data. TSS increased from upstream to downstream and was incrementally higher in the tributaries. As with the turbidity data, Jackson Creek had the highest average TSS concentration of 26 mg/L. Other stations with a relatively high average TSS were Goose Creek site GC1 (17 mg/L), Soldier Creek site GC4 (18 mg/L), and Kruse Creek site LG11 (18 mg/L). Kruse Creek appeared to have the greatest impact onto a receiving waterbody. Average TSS increased from the above (LG12) to the below (LG10) sites on Little Goose Creek by 5 mg/L, which approximately doubled its TSS load.

An example of the turbidity and TSS association is provided in Figure 8-35. A correlation exists between these two parameters for the Goose Creek proper sites. Approximately 75% (R^2=0.7469) of the variation in TSS may be attributed to turbidity. Because of the normally strong correlation between these parameters, turbidity is often used as a surrogate indicator of TSS in water quality monitoring.

The Wyoming water quality standards do not set numeric limits on TSS. However, narrative standards require that floating, suspended, and/or settable solids do not significantly degrade aesthetic values, aquatic life, public water supplies, agricultural or industrial water use, plant life, or wildlife. No indications were found that these narrative standards were violated.

8.11 TOTAL ALKALINITY

Total alkalinity samples were taken on a monthly basis from April through October during 2001 and 2002. These data are provided in Appendix Tables E-2 through E-47 and summary statistics may be found in Appendix Table Q-2 through Q-47. Figures 8-36 and 8-37 provide Goose Creek, Big Goose Creek, and Little Goose Creek mean annual total alkalinity concentrations expressed by mg/L as $CaCO_3$.

Alkalinity concentrations increased quickly in Big Goose Creek and Little Goose Creek as these streams left their respective canyons and entered the foothills and plains. Average concentrations continued to rise further downstream and throughout Goose Creek. As with many of the water quality parameters, the tributaries contained incrementally higher concentrations of alkalinity than the receiving streams. Soldier Creek had the highest average alkalinity (377 mg/L), followed closely by Beaver Creek (355 mg/L), McCormick Creek (345 mg/L), and Park Creek (341 mg/L). Average alkalinity ranged from 229 mg/L (GC6) to 253 mg/L (GC1) on Goose Creek, from 37 mg/L (BG18) to 237 mg/L (BG8) on Big Goose Creek, and from 45 mg/L (LG22) to 300 mg/L (LG6) on Little Goose Creek.

Beaver Creek alkalinity appeared to have the greatest impact of any tributary on a receiving water body. Average alkalinity concentrations increased approximately 36 mg/L (15%) from upstream (BG10) to downstream (BG8) stations on Big Goose Creek.

Wyoming has not established water quality standards for alkalinity. EPA (1986) suggests a minimum of 20 mg/l alkalinity is required for adequate productivity in streams. Only two out of a total 637 samples (0.31%) contained less than 20 mg/L alkalinity. One sample was from the uppermost station on Big Goose Creek (BG18) and the other was from the uppermost station on Little Goose Creek (LG22). In general, alkalinity data suggested that the streams should be productive for aquatic life, able to withstand sudden changes in pH, and unlikely to pose human health risks.

8.12 TOTAL SULFATE

Total sulfate samples were collected monthly from April through October during 2001 and 2002. Results of this sampling are presented in Appendix Tables E-2 through E-47 and summary statistics have been calculated as shown in Appendix Tables Q-2 through Q-47. Figures 8-38 and 8-39 show mean annual total sulfate concentrations by site for Goose Creek, Big Goose Creek, and Little Goose Creek.

Total sulfate concentrations generally increased from upstream sites to downstream sites, which may reflect mineral weathering, evapoconcentration of irrigation return water, urban run-off, and/or other human-related activities. The tributaries, except Rapid Creek, contained an incrementally higher concentration of sulfate than their receiving water bodies. McCormick Creek appeared to have the most impact on a receiving water body resulting in a 33% (24.9 mg/L) average increase in sulfate from upstream (LG10) to downstream (LG8) stations. However, Soldier Creek had the highest average concentration of any tributary (279 mg/L). Sulfate concentrations were highest in the Coffeen Avenue storm drain (LG3), which had an average of 1,090 mg/L, a geometric mean of 1,024 mg/L, and a range of 315 mg/L to 1,560 mg/L. An average increase of 21 mg/L (14%) in sulfate concentration occurred from stations upstream (LG4) to downstream (LG2) in Little Goose Creek. However, the storm drain (LG3) may not be solely responsible for this increase due to the 1-1/2 miles of urban lands that separate sites LG2 and LG4. Average concentrations ranged from 131 mg/L (GC2) to 151 mg/L (GC1) on Goose Creek, from 11 mg/L (BG18) to 160 mg/L (BG1) on Big Goose Creek, and from 11.7 mg/L (LG21) to 151 mg/L (LG1) on Little Goose Creek.

Wyoming does not have surface water quality standards for sulfate. However, EPA has an established secondary drinking water standard of 250 mg/L for sulfate (EPA, 2000). Generally, with seasonal exceptions, stream waters within the watershed meet the designated beneficial uses for drinking water. Sulfate levels generally met water quality requirements for macroinvertebrate productivity and aquatic life use.

8.13 TOTAL CHLORIDE

Samples were taken for total chloride on a monthly basis from April through October, 2001 and 2002. Results of this sampling are presented in Appendix Tables E-2 through E-47 and summary statistics have been calculated as shown in Appendix Tables Q-2 through Q-47. Figures 8-40 and 8-41 show mean annual total chloride concentrations by site for Goose Creek, Big Goose Creek, and Little Goose Creek.

Total chloride concentrations generally increased from upstream sites to downstream sites on Little Goose Creek and Big Goose Creek. No samples contained detectable levels (1.0 mg/L) of chloride at the uppermost Little Goose Creek site LG22. Average concentrations increased downstream reaching a maximum average concentration of 4.9 mg/L at the lowermost station LG1. The two uppermost Big Goose Creek sites (BG17 and BG18) did not record any samples with detectable levels of chloride. Concentrations slowly increased downstream with a maximum average value of 3.1 mg/L reached at

BG1 in Kendrick Park. The tributaries generally contained higher concentrations of chloride, but did not appear to have a significant impact on the receiving water bodies. The Coffeen Avenue storm drain (LG3) had the highest average chloride concentration of 20.9 mg/L. Chloride levels ranged from 6.1 mg/L to 55.4 mg/L at this station.

The relatively high, 2002 chloride values shown on Figure 8-40 for the upper Goose Creek sites (GC5 and GC6) are the result of April 2, 2002 sampling, which recorded 95.7 mg/L at GC6 and 60.2 mg/L at GC5. Site GC3 also recorded its maximum concentration of 15.5 mg/L on this date. The high chloride concentrations noted on this day may have been caused by salting of ice-covered streets, a direct discharge, or some other unknown influence. Reference to field logs for the day indicate that April 2, 2002 was a cold day (16°F high temperature), with no precipitation, and relatively turbid waters in Goose Creek. The 2002 geometric means for chloride at sites GC5 and GC6 were 4.6 mg/L and 4.2 mg/L, respectively.

Concentrations of chloride were considered to be low overall and were well below Wyoming water quality standards. These low concentrations suggest that beneficial uses for aquatic life use are being met.

8.14 TOTAL NITRATE NITROGEN

Total nitrate nitrogen ($NO_2 + NO_3$) sampling was conducted on a monthly basis from April through October during 2001 and 2002. Results of this sampling are presented in Appendix Tables E-2 through E-47 and summary statistics have been calculated as shown in Appendix Tables Q-2 through Q-47. Figures 8-42 and 8-43 show mean annual total nitrate nitrogen concentrations by site for Goose Creek, Big Goose Creek, and Little Goose Creek.

Nitrate nitrogen levels on Big Goose Creek were generally low. Average nitrate nitrogen was less than 0.04 mg/L for all Big Goose Creek proper sites. The Big Goose Creek tributaries contained relatively higher concentrations of nitrate nitrogen. Rapid Creek had the lowest average nitrate nitrogen concentration (0.038 mg/L), followed by Beaver Creek (0.121 mg/L), and Park Creek (0.205 mg/L). Of these tributaries, Beaver Creek appeared to have the greatest impact on Big Goose Creek. From upstream (BG10) to downstream (BG8) sites, nitrate nitrogen was increased an average of 0.017 mg/L (47%) in Big Goose Creek. However, these slightly elevated levels seemed to dissipate by downstream site BG7.

Little Goose Creek nitrate nitrogen levels were slightly higher than Big Goose Creek, but were still considered to be relatively low. When compared to adjacent Little Goose Creek stations, the nitrate nitrogen levels in McCormick and Sackett were quite similar, with Jackson Creek and Kruse Creek being somewhat elevated. Of these tributaries, Kruse Creek (average 0.299 mg/L) had the largest impact on Little Goose Creek. A 0.08 mg/L (58%) increase was noticed from upstream (LG12) to downstream (LG10) Little Goose Creek stations. Nonetheless, nitrate nitrogen levels in Little Goose Creek declined steadily downstream and by site LG7, average concentrations were lower than site LG12.

Nitrate nitrogen levels were increased an average of 0.11 mg/L (75%) from Little Goose Creek sites LG14 to LG13 for unknown reasons.

Goose Creek nitrate nitrogen concentrations were slightly higher than either Big Goose Creek or Little Goose Creek. Soldier Creek concentrations were generally elevated (average 0.191 mg/L) as was the case with several other tributaries. Soldier Creek did not have a noticeable impact on Goose Creek nitrate nitrogen levels. Average concentrations increased substantially (0.24 mg/L) between sites GC3 and GC2. At site GC2, downstream Sheridan WWTP, concentrations ranged from non-detectable levels (<0.01 mg/L) to 1.01 mg/L. The geometric mean of GC2 nitrate nitrogen samples was 0.142 mg/L.

The Coffeen Avenue storm drain (LG3) had the highest average nitrate nitrogen levels of any station (1.24 mg/L). All samples were well above detection limits, and ranged from 0.24 mg/L to 1.91 mg/L. This storm drain did not appear to have an effect on Little Goose Creek.

Average nitrate nitrogen levels throughout the watershed were considerably lower than the Wyoming water quality standard of 10 mg/L for human health and drinking water uses. Data indicated that nitrate nitrogen levels for the watershed were less than the background concentration of nitrate nitrogen (approximately 0.60 mg/L) found in streams in undeveloped areas (i.e. least impacted reference type streams) throughout the United States (USGS, 1999). Full support for all designated uses applicable to nitrate nitrogen was indicated.

8.15 TOTAL PHOSPHORUS

Total phosphorus monitoring was conducted on a monthly basis from April through October during 2001 and 2002. Results of this sampling are presented in Appendix Tables E-2 through E-47 and summary statistics have been calculated as shown in Appendix Tables Q-2 through Q-47. Figures 8-44 and 8-45 show mean annual total phosphorus concentrations by site for Goose Creek, Big Goose Creek, and Little Goose Creek.

Average phosphorus concentrations in Big Goose Creek were less than 0.10 mg/L although individual samples often exceeded this level. Beaver Creek and Park Creek contained relatively higher phosphorus concentrations with averages of 0.15 mg/L and 0.43 mg/L, respectively. These tributaries appeared to have a limited effect on Big Goose Creek phosphorus levels.

All stations on Little Goose Creek and its four tributaries averaged less than 0.10 mg/L phosphorus. However, 2002 sampling on McCormick Creek and Kruse Creek revealed average phosphorus concentrations, which were slightly higher, 0.11 mg/L and 0.12 mg/L, respectively. The Coffeen Avenue storm drain averaged 0.14 mg/L total phosphorus.

Goose Creek, from its origin to the Fort Road bridge, had similar phosphorus levels to Big Goose Creek and Little Goose Creek. Phosphorus levels then increased an average of 0.29 mg/L (5.8 fold) from site GC3 to site GC2. Phosphorus levels then decreased an average of 0.15 mg/L to 0.19 mg/L at the lowermost Goose Creek site, GC1. Soldier Creek averaged 0.11 mg/L total phosphorus, but did not appear to adversely affect Goose Creek.

Wyoming has not established surface water quality standards for phosphorus. However, EPA water quality criteria recommend that phosphorus should not exceed 0.05 mg/L for streams entering lakes or reservoirs, 0.025 mg/L within a lake or reservoir, and 0.1 mg/L within streams not discharging to lakes or reservoirs to control algal growth (EPA, 1986). These EPA recommendations are somewhat contradictory to USGS data from NAWQA monitoring, which indicate that national background levels for phosphorus in undeveloped areas was about 0.10 mg/L (USGS, 1999). Upper Goose Creek, Big Goose Creek, and Little Goose Creek contained phosphorus at concentrations similar to the USGS national background levels. Lower Goose Creek, Soldier Creek, Beaver Creek, and Park Creek averaged higher than national background concentrations.

Historical USGS sampling at Station Number 06305700 (same site as GC1) was conducted for total phosphorus between 1983 and 1989. In total, 38 samples were collected averaging 0.21 mg/L; this was similar to the results 2001 – 2002 samples collected at GC1 (average 0.19 mg/L). USGS Station Number 06305500 was located approximately 200 yards upstream from site GC2. From 1973 to 1994, 187 total phosphorus samples were collected averaging 0.32 mg/L. This compares quite well to total phosphorus data collected at site GC2 (average 0.34 mg/L). Therefore, these comparable concentrations at comparable sites on lower Goose Creek probably represent at least a 20 year trend in phosphorus water quality.

8.16 TOTAL AMMONIA

Total ammonia (NH_3 + NH_4) monitoring was conducted on a monthly basis from April through October during 2001 and 2002. Results of this sampling are presented in Appendix Tables E-2 through E-47 and summary statistics have been calculated as shown in Appendix Tables Q-2 through Q-47. Figures 8-46 and 8-47 show average annual total ammonia concentrations by site for Goose Creek, Big Goose Creek, and Little Goose Creek.

Ammonia concentrations varied significantly between sites and from 2001 to 2002. Well established trends in ammonia levels were not apparent on a spatial or temporal basis. This may be a result of the rapid oxidation of ammonia to nitrite and nitrate. In total, 637 ammonia samples were collected during the 2001 – 2002 GCWA. None of these samples were found to exceed the Wyoming surface water quality standards found in the Chapter 1, Appendix C tables. These tables provide ammonia toxicity levels that vary with the pH and temperature of the stream. All beneficial uses that apply to ammonia within the Goose Creek watershed appear to be fully supported.

8.17 TOTAL HARDNESS

Total hardness samples were collected on a monthly basis from April through October during 2001 and 2002. Results of this sampling are presented in Appendix Tables E-2 through E-47 and summary statistics have been calculated as shown in Appendix Tables Q-2 through Q-47. Figures 8-48 and 8-49 show average annual total hardness concentrations by site for Goose Creek, Big Goose Creek, and Little Goose Creek.

Water hardness in Big Goose Creek and Little Goose Creek increased quickly as the streams left their respective canyons and entered the foothills and plains. The uppermost sites on these streams contained hardness levels that would be considered soft water by Table 6-6. Further downstream, Big Goose Creek, Little Goose Creek, and Goose Creek waters become hard to very hard according to Table 6-6 classifications. Most of the tributaries contained much harder water than the major streams.

Average hardness ranged from 58 mg/L (LG22) to 389 mg/L on Little Goose Creek, from 49 mg/L (BG18) to 333 mg/L (BG4) on Big Goose Creek, and from 317 mg/L (GC2) to 350 mg/L (GC1) on Goose Creek. Of the tributaries, Soldier Creek averaged the hardest water (572 mg/L), followed by McCormick Creek (492 mg/L), Beaver Creek (468 mg/L), and Park Creek (445 mg/L). The Coffeen Avenue storm drain averaged 1,425 mg/L total hardness.

The relatively hard water in the watershed is likely a result of underlying geologic formations containing carbonate minerals. Wyoming has not established water quality standards for hardness. Collected data indicate full support of designated uses.

8.18 BIOCHEMICAL OXYGEN DEMAND

Samples were collected during April through October, 2001 for BOD. BOD data are presented in Appendix Tables E-2 through E-47; statistical summaries of this data are provided in Appendix Tables Q-2 through Q-47. Approximately 96% of BOD samples collected during 2001 were analyzed as non-detectable (<2 mg/L). Because of the high rate of samples analyzed as non-detectable and the relatively high cost for analysis, BOD sampling was not conducted during 2002.

BOD was detected in 5 of 35 Goose Creek samples, 1 of 6 Soldier Creek samples, 1 of 105 Big Goose Creek samples, 2 of 3 Park Creek samples, 2 of 7 Kruse Creek samples, 1 of 7 Jackson Creek samples, and 2 of 126 Little Goose Creek samples. BOD was not detected in Beaver Creek, Rapid Creek, McCormick Creek, or Sackett Creek. Detectable samples ranged from 2 mg/L at Little Goose Creek site LG7 to 12 mg/L in Soldier Creek.

Wyoming has not established water quality standards for BOD. Overall, BOD concentrations were generally low and not considered to be a potential problem within the watershed. With the exception of the one Soldier Creek sample, no samples were analyzed above 5 mg/L.

8.19 PESTICIDES AND HERBICIDES

During 1999 and 2000, the USGS sampled 15 wells for pesticides and herbicides in areas of Sheridan County deemed to be vulnerable to contamination (USGS, 2001). Seven of these wells were located within the Goose Creek watershed, five of which recorded detectable levels of pesticides and/or herbicides. The selection of pesticides and herbicides that were monitored during the GCWA was based upon these USGS findings and additional recommendations by the Sheridan County Weed and Pest District and the Sheridan County Extension Office.

Pesticide and herbicide sampling was conducted at three sites during June 2002 for seven herbicides and six pesticides. Sites GC3, BG3, and LG5 were selected in an attempt to differentiate concentrations based upon varying types of land use. June was selected for sampling because this is normally a time when chemical applications and surface run-off events may coincide. The analytical results of this sampling are provided in Appendix Tables H-1 and H-2. None of the 13 pesticides or herbicides were detected at the three monitoring stations. Further sampling was not conducted because of these results and due to the high costs for sample analysis. This single observation indicated that no evidence of pesticide or herbicide contamination existed in Goose Creek, Big Goose Creek, or Little Goose Creek during this sampling event.

8.20 FECAL COLIFORM AND *Escherichia Coli*

8.20.1 RESULTS OF FECAL COLIFORM BACTERIA MONITORING

Fecal coliform bacteria samples were collected during five separate 24-hour periods during the months of April, May, August, and October 2001 and 2002. During each of these months, the five samples were collected within a 30-day period. The results of this sampling are provided in Appendix Tables E-2 through E-47. Summary statistics were calculated on an annual basis and are provided in Appendix Tables Q-2 through Q-47.

The geometric means for each of the monthly sampling events (consisting of five separate samples) were calculated and are provided for Goose Creek sites in Table 8-10, for Big Goose Creek sites in Table 8-11, and for Little Goose Creek sites in Table 8-12. To calculate the geometric means, analytical values of less than 1 colony forming unit per 100 mL (<1 CFU/100 mL) were replaced with a value of 1. Geometric means cannot be calculated for data containing zero values (0). IML processed and analyzed fecal coliform samples at varying dilutions to accurately determine colony counts. As a result, none of the fecal coliform analytical data for the project contained data qualifiers such as: actual value was greater than value observed (i.e. >900 CFU/100 mL), too numerous to count (TNTC), or count outside optimal range.

Fecal coliform geometric means (FC) were generally low in the upper reaches of Big Goose Creek and Little Goose Creek. FC increased with intensifying land use along the longitudinal gradients of Big Goose Creek and Little Goose Creek. FC in Goose Creek stations were high and generally similar, but a decrease was noticed in the lowermost

Goose Creek site (GC1). FC were generally higher in the tributary sites and in the Coffeen Avenue storm drain (LG3). Figures 8-50 through 8-55 provide a monthly, by-site comparison of FC in Goose Creek, Big Goose Creek, and Little Goose Creek.

Table 8-13 summarizes the sites that exceeded the Wyoming water quality standard for fecal coliform bacteria. The standard requires that FC shall not exceed 200 CFU/100 mL (based on a minimum of not less than 5 samples obtained during separate 24-hour periods during any 30-day period). Lower Big Goose Creek sites BG1 through BG4 exceeded the standard on at least one occasion. Sites BG1 through BG3 each exceeded the standard during August 2001 and August 2002. Site BG4 exceeded the standard during May 2001 only. Big Goose Creek proper sites BG5 through BG18 did not exceed the standard during any month.

The tributaries Park Creek and Rapid Creek each exceeded 200 CFU/100 mL during at least one month. During the scheduled fecal coliform sampling, Park Creek was dry during portions of October 2001 and May 2002, and during the months of August 2001 and August 2002. The 2002 Rapid Creek sampling is more representative of in stream water quality because 2001 samples were diluted with Big Goose Creek irrigation waters through Ditch Number 9 (see Table 6-2). Beaver Creek FC did not exceed the standard during any month, however, FC during four months approached 200 CFU/100 mL (193, 195, 169, and 196 CFU/100 mL).

Lower Little Goose Creek proper sites LG1 through LG12 (except LG5) exceeded the standard during at least one month. A significant increase in FC occurred between lower Little Goose Creek stations LG2 and LG1. LG1 was the only site on the major streams (Goose Creek, Big Goose Creek, and Little Goose Creek) to exceed the standard during three of the eight fecal coliform monitoring months. During August 2002, FC at site LG7 was 3,505 CFU/100 mL. Individual samples for LG7 during the month ranged from 820 to 18,800 CFU/100 mL (see Appendix Table E-32). Little Goose Creek proper sites LG13 through LG22 did not exceed 200 CFU/100 mL during any month.

Each of the four Little Goose Creek tributaries exceeded the standard during at least one month. Jackson Creek exceeded the standard during three months, McCormick Creek and Sackett Creek exceeded the standard twice, and Kruse Creek exceeded 200 CFU/100 mL during August 2002 only. The Coffeen Avenue storm drain (LG3) had an FC greater than 1,100 CFU/100 mL in August 2001 and August 2002. The storm drain never had a FC greater than 37 CFU/100 mL during the months of April, May, and October—possibly due to colder water temperatures.

Goose Creek sites GC2, GC3, GC5, and GC6 exceeded 200 CFU/100 mL during at least one month. FC in Goose Creek appeared to decrease from site GC6 downstream to site GC3, increase slightly at site GC2, and then decrease again at the lowermost site GC1. Site GC1 did not exceed the fecal coliform standard during this project. Soldier Creek exceeded the standard during four months; each exceedence occurred during May and August. Soldier Creek's highest geometric mean was 2,972 CFU/100 mL during August

2001, however, the creek was dry part of the month and this geometric mean is based upon two samples only.

When considering 2001 and 2002 fecal coliform sampling, 44 exceedences of the water quality standard were encountered. The majority of these occurred when water temperatures were warmer and more conducive to the survival of bacteria. Seven of these exceedences were during May and 35 of these exceedences were during August. Table 8-14 shows the number of fecal coliform geometric means exceeding 200 CFU/100 mL on a monthly basis. In addition, Tables 8-1 through 8-5 show the number of fecal coliform samples at each site that were greater than or equal to 400 CFU/100 mL.

Based upon the fecal coliform geometric means calculated for GCWA data only, Appendix Map A-10 was created to show the fecal coliform impaired stream segments within the watershed. Goose Creek is impaired from site GC1 upstream to the Big Goose Creek and Little Goose Creek confluence. Site GC1 did not exceed the standard, therefore, from this site downstream to the Tongue River confluence is implied to be in compliance with the fecal coliform standard. Big Goose Creek is impaired from its mouth upstream to site BG5. Monitoring sites on Big Goose Creek from BG5 upstream did not exceed the standard. Little Goose Creek is impaired from its mouth upstream to site LG13. Site LG5 did not exceed the standard, however, upstream (LG6) and downstream (LG4) sites did exceed the standard and the reach of Little Goose Creek above and below site LG5 complying with the standard is not discernable. Monitoring sites on Big Goose Creek from site LG13 upstream did not exceed the standard. Soldier Creek, Park Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek are impaired from their mouths along their entire main channel to their headwaters. Lack of upstream monitoring stations on these streams prevented the ability to show that any possible upstream segment(s) may not be impaired. This procedure for identifying impaired stream segments within the Goose Creek watershed follows WDEQ procedures previously used in making 303(d) Lists of Impaired Waterbodies.

Fecal coliform loading was calculated using the geometric mean of monthly samples taken during May and August, 2001 and 2002, and by using the average discharge for these corresponding sampling events. Figures 8-56 through 8-60 show stream loading (colony forming units per day) for each of the 46 monitoring sites. Given the relatively high FC in the tributaries and the Coffeen Avenue storm drain, these loading figures indicate these sources are minor contributors of bacteria when considering total daily loads. Bacteria loads were often higher during May, however, the increased discharge usually diluted concentrations below the 200 CFU/100 mL standard. For example, during May 2002 at site LG12, fecal coliform loading was approximately 3.5 times higher than August 2002. However, the geometric mean during May was 50 CFU/100 mL and during August 2002 was 274 CFU/100 mL.

8.20.2 FECAL COLIFORM IN BED SEDIMENT

Fecal coliform in bed sediment was conducted at sites GC2, LG8, and BG18 on April 1, 2002 and September 4, 2002 following the methods described in Section 6.5.1.1. Data collected during these events are provided in Appendix G. The results for each sampling event were presented in Figures 8-61 through 8-66 to show the changes in turbidity and fecal coliform concentrations after disturbing the bed sediment. Two samples were collected immediately before raking the bed sediment and were averaged to give the ambient stream concentrations (time = 0 seconds). Samples analyzed as <1 CFU/100 mL were assigned a value of 1.

Data collected from sites LG8 and BG18 during the April 1, 2002 sampling events did not reveal high concentrations of bacteria dwelling within the bed sediment. This could be due in part to the cold water temperatures during sampling, which ranged from 1.8°C to 3.3°C. However, bacteria at site GC2 did become slightly elevated after disturbing the stream bed. A two-fold increase from ambient bacteria concentrations was noticed after 45 seconds of raking.

The September 4, 2002 sampling was conducted during much warmer water temperatures. Temperatures ranged from 15.2°C to 21.5°C and may have been partially responsible for these increased bacteria concentrations. A three-fold increase was observed from ambient water concentrations at site GC2. Concentrations increased nearly two-fold at site LG8. A negligible change in bacteria concentrations was observed at site BG18 as the concentrations varied from 4 to 6 CFU/100 mL.

Results of this sampling were not as conclusive as anticipated, however, increases in fecal coliform concentrations were observed after disturbing the stream bed. Observing the results of the April 1, 2002 sampling, it is unlikely that high concentrations of bacteria survive the winter months in bed sediment—at least in the upper reaches of the watershed. However, increases in stream discharge occurring during warmer water temperatures is likely to suspend bed materials thereby increasing turbidity and fecal coliform concentrations.

8.20.3 RESULTS OF *Escherichia Coli* MONITORING

Escherichia Coli (E. coli) samples were collected once during the months of April, May, and October, and five times during August 2002 at 19 designated sites (see Table 6-9). The results of this sampling are provided in Appendix Tables E-2 through E-47 and summary statistics are presented in Appendix Tables Q-2 through Q-47. Geometric means of the August data have been calculated and are given in Table 8-15.

In general, monitoring stations that were found during the assessment to exceed the fecal coliform standard also exceeded the proposed *E. coli* standard of 126 CFU/100 mL for Full Body Contact recreational waters (WDEQ, 2002a). Of the 19 sites monitored during August, 10 stations exceeded the proposed *E. coli* standard and existing fecal coliform standard. However, station GC2 exceeded only the *E. coli* standard and BG1 exceeded the only fecal coliform standard (see Figure 8-67).

A total of 145 fecal coliform and *E. coli* samples were collected during similar sampling events. Of these “paired” samples, fecal coliform averaged 257 CFU/100 mL and *E. coli* averaged 198 CFU/100 mL. Neither the fecal coliform data nor the *E. coli* data were normally distributed necessitating use of non-parametric statistical tests. The non-parametric Spearman's Rank Correlation was used after ranking the paired values from 1 to 145. After the data were ranked and regressed, the Correlation Coefficient was +0.825245. This correlation was moderately strong and indicated there was a statistically significant relationship between *E. coli* (ranked values) and fecal coliform (ranked values) at the 99% confidence level.

Figure 8-68 shows the general relationship between all *E. coli* and fecal coliform bacteria. A linear regression of all paired data shows that approximately 80% (R^2=0.8015) of the variability in *E. coli* is associated with fecal coliform bacteria. *E. coli* concentrations may be estimated from fecal coliform data using the equation shown in Figure 8-68. For this equation, *E. coli* is the independent variable (y) and fecal coliform is the dependent variable (x).

8.20.4 COMPARISON OF GCWA BACTERIA DATA TO CURRENT AND HISTORICAL DATA

As previously discussed in Section 5.2.2, WDEQ collected fecal coliform samples within the Goose Creeks watershed during 1998 and 1999. Map A-8 identifies the locations of the WDEQ monitoring stations. GCWA monitoring stations that coincided with these earlier WDEQ stations have been described in Table 5-1. Fecal coliform data have been collected by WDEQ and during the GCWA at 22 comparable stations during similar times of the year. Figures 8-69 and 8-70 have been created to compare these data and utilize GCWA site names for reference.

Samples collected by WDEQ generally contained higher fecal coliform counts than those collected during the GCWA. Higher fecal counts observed by WDEQ may have been caused by higher discharge during 1998 and 1999 sampling. GCWA assessment samples were usually collected during periods of below average discharge and WDEQ samples were generally collected during periods of above average discharge. The monitoring by WDEQ showed that fecal coliform impairments occurred in reaches of the watershed further upstream than those observed during the GCWA. WDEQ sampling showed Big Goose Creek to be impaired from its mouth upstream to the canyon (BG18) and showed Little Goose Creek to exceed the standard from its mouth to the canyon (LG22). WDEQ monitoring during 1998 also suggested fecal coliform impairments were evident on Goose Creek at stations GC2 (Below Sheridan WWTP), Above KOA, and Below KOA. The GCWA did not have comparable water quality stations to the WDEQ Above and Below KOA stations. Data for these stations are provided in Appendix Table C-4.

Monthly water quality samples including fecal coliform bacteria were collected by WDEQ from 7 locations on Goose Creek, Big Goose Creek, and Little Goose Creek during the 1993-1994 "Salt Monitoring Project". WDEQ stations for this project are identified in Table 5-2. Water quality data for this project are available in Appendix Tables B-12 through B-18 and the individual fecal coliform sample results have been graphed in Figure 8-71. Although these individual samples are not directly comparable to GCWA fecal coliform geometric means (of 5 individual samples), the same general trends in fecal coliform concentrations are evident. Fecal coliform concentrations near Sheridan routinely exceeded 200 CFU/100 mL during the warmer, recreational-use months. Many samples often exceeded EPA's recommended limit of 400 CFU/100 mL for a single sample:

- Site A1 (near GCWA site LG5) exceeded 400 CFU/100 mL during 2 of 12 sampling events;
- Site A2 exceeded 400 CFU/100 mL during 4 of 11 sampling events;
- Site A3 (near GCWA site LG1) exceeded 400 CFU/100 mL during 5 of 12 sampling events;
- Site A4 (near GCWA site BG2) exceeded 400 CFU/100 mL during 2 of 11 sampling events;
- Site A5 (near GCWA site BG1) exceeded 400 CFU/100 mL during 2 of 12 sampling events;
- Site A6 (near GCWA site GC6) exceeded 400 CFU/100 mL during 2 of 11 sampling events; and
- Site A7 at the north end of Sheridan exceeded 400 CFU/100 mL during 5 of the 12 sampling events.

As part of the Salt Monitoring Project, WDEQ also collected fecal coliform samples from four storm drains located in Sheridan. Please refer to Appendix Tables B-19 through B-22 to view these data. In summary, fecal coliform concentrations ranged from 8 to 5,500 CFU/100 mL at the Coffeen Avenue storm drain (SW1), from 10 to 178,000 CFU/100 mL at the storm drain near East 1st Street and North Gould Street (SW2), from 2 to 61,500 CFU/100 mL at the eastern 5th Street storm drain (SW3), and from 10 to 60,000 CFU/100 mL at the western 5th Street storm drain (SW4). The SW1 storm drain was the same station as Little Goose Creek site LG3 for the current project.

The USGS has collected current and/or historical fecal coliform samples at Station Number 06305700 (Goose Creek Near Acme, WY), Station Number 06305500 (Goose Creek Below Sheridan), Station Number 06302000 (Big Goose Creek Near Sheridan), and from Station Number 06304500 (Little Goose Creek at Sheridan). These data are presented in Appendix Tables B-3, B-4, B-8, and B-9, respectively. To illustrate these data, the individual fecal coliform concentrations have been plotted in Figures 8-72 through 8-75. These individual fecal coliform concentrations are not directly comparable to GCWA fecal coliform geometric means, but do allow for relative comparisons in fecal coliform levels. Nonetheless, 12 of 33 historical USGS samples at Station Number 06305700 exceeded 400 CFU/100 ml, whereas 0 of 40 water quality samples exceeded 400 CFU/100 mL at comparable site GC1 during the GCWA. Figure 8-73 provides a time series plot of USGS fecal coliform data at Station Number 06305500, which is located downstream from the Sheridan WWTP. Upgrades to the WWTP facilities were made in 1983 and 1984, which have had tremendous effects on downstream water quality. Before the plant upgrade, the average of 101 USGS fecal coliform samples taken below the discharge was 49,367 CFU/100 mL. After January 26, 1983, 100 USGS samples have been taken averaging 1,144 CFU/100 mL. As a result, the WWTP remodeling has decreased the average fecal coliform concentration by 98% in this reach of Goose Creek. Figure 8-74 shows the relatively low, 1989-1998 fecal coliform concentrations in Big Goose canyon, which were similar to those obtained during the GCWA at site BG18. No individual samples exceeded 400 CFU/100 mL at Station Number 06302000. USGS Station Number 06304500 was located near site LG2 and appears to have provided similar fecal coliform counts. From 1979 to 1998, 18 of 102 samples exceeded 400 CFU/100 mL at this site.

During June 27-29, 2000, the USGS collected fecal coliform samples at 24 stations within the Goose Creek watershed. These data have been downloaded from the USGS website and are summarized in Appendix Table C-2. Of the 24 single samples, 8 samples (33%) were greater than 400 CFU/100 mL. As with the 2001-2002 GCWA sampling, fecal coliform concentrations were higher in the lower reaches of the watershed. However, two USGS samples collected in the upper reaches of the watershed contained relatively high fecal coliform counts. Tepee Creek Near Campground (Station Number 443638107070201) had 360 CFU/100 mL and East Fork Big Goose Creek on Forest Service Road 26 (Station Number 443559107122501) contained 530 CFU/100 mL. These individual samples suggest occasional fecal coliform sources may originate within the BHNF possibly from wildlife, livestock, or recreational sources.

8.21 BENTHIC MACROINVERTEBRATES

8.21.1 OVERVIEW OF THE GOOSE CREEK WATERSHED

A total of 42 benthic macroinvertebrate samples was collected during the Project. Twelve samples were collected from five Goose Creek stations (GC1, GC1A, GC1B, GC2 and GC3), fifteen samples were collected from seven Big Goose Creek stations (BG2, BG4, BG8, BG10, BG14, BG15 and BG18) and fifteen samples were collected from seven Little Goose Creek stations (LG2A, LG5, LG7, LG10, LG18A, LG21 and LG22). Goose Creek station GC1 was the most downstream benthic macroinvertebrate sample station proceeding upstream to station GC3, which was the most upstream Goose Creek station. Big Goose Creek station BG2 was the most downstream benthic macroinvertebrate sample station on Big Goose Creek proceeding upstream to station BG18, which represented the most upstream Big Goose Creek station. Little Goose Creek station LG2A was the most downstream benthic macroinvertebrate sample station on Little Goose Creek proceeding upstream to station LG22, which was the most upstream Little Goose Creek station.

The total number of samples collected from stations in the Middle Rockies (MR) ecoregion was 4 (two each from Big Goose Creek station BG18 and Little Goose Creek station LG22). The remaining 38 samples were collected from stations in the Northwestern Great Plains (NGP) ecoregion. All samples collected from Goose Creek were from the NGP ecoregion.

A total of 164 benthic macroinvertebrate taxa was collected during the Project (Table 8-18). All taxa have been previously identified from north central Wyoming streams and rivers with the exception of the mayfly genus *Asioplax*, the cranefly genera *Pseudolimnophila* and *Erioptera*, the crayfish genus *Orconectes*, and the soldier fly genus *Caloparyphus* (King, 2004). The genus *Asioplax* was recently revised by Wiersema and McCafferty (2000). This mayfly genus is closely related to the common mayfly genus *Tricorythodes* and will probably be identified from more Wyoming plains streams due to the taxonomic revision. *Asioplax* occurred only at Goose Creek stations GC2 and GC3. *Pseudolimnophila* and *Erioptera* are widespread throughout the United States (Merritt and Cummins, 1996) and will likely be found in other north central Wyoming streams with additional sampling. *Pseudolimnophila* was found only at Big Goose Creek station BG18 and *Erioptera* was found only at Little Goose Creek station LG5. *Orconectes* is common throughout the United States (Pennak, 1989), but normal riffle and run stream sampling methods probably underestimate its distribution in Wyoming streams and rivers. *Orconectes* was found only at Little Goose Creek station LG7. *Caloparyphus* is widely distributed in the United States (Merritt and Cummins, 1996) and will be identified from more north central Wyoming streams as more plains streams are sampled. *Caloparyphus* was found at Little Goose Creek station LG10 and Big Goose Creek stations BG8 and BG14.

Water mites (Acari), chironomidae pupae, oligochaete worms and the caddisfly *Helicopsyche borealis* were the only taxa present at all sample stations. The riffle beetle genus *Zaitzevia*, chironomidae genus *Rheotanytarsu*s, mayfly species *Tricorythodes minutus* and Turbellaria flatworms were present at all but one sample station.

The Diptera family Chironomidae had the greatest number of taxa in the Project area (N = 39 midge taxa), followed by the order Trichoptera (N = 29 caddisfly taxa), the order Ephemeroptera (N = 26 mayfly taxa), the order Plecoptera (N = 13 stonefly taxa), the Diptera family Tipulidae (N = 9 cranefly taxa) and the Coleoptera family Elmidae (N = 8 riffle beetle taxa) (Table 8-18).

Little Goose Creek had the highest number of caddisfly taxa (N = 23), the highest number of mayfly taxa (N = 22) and the highest number of stonefly taxa (N=12) among streams in the Project area. Big Goose Creek had 19 caddisfly taxa, 17 mayfly taxa and 5 stonefly taxa (N=12) while Goose Creek had 8 caddisfly taxa, 8 mayfly taxa and 0 stonefly taxa. Big Goose Creek had the highest number of midge fly taxa (N = 32) followed by Little Goose Creek (N =29) and Goose Creek (N =23).

8.21.2 GOOSE CREEK MACROINVERTEBRATE COMMUNITIES

Goose Creek had the lowest number of total taxa (N = 72) followed by Big Goose Creek (N = 123) and Little Goose Creek (N = 128). The lower number of taxa observed at Goose Creek was probably related to the lower number of samples collected (N = 12) when compared to Big Goose Creek and Little Goose Creek (both N = 15 samples) and to a lack of cool water habitats present in the upper Big Goose Creek and Little Goose Creek watersheds. Several cool water and pollution intolerant taxa including the cranefly *Antocha*, the caddisflies *Arctopsyche*, *Brachycentrus americanus, Dolophilodes, Glossosoma*, *Rhyacophila Brunnea* group, *Rhyacophila Coloradensis* group, *Rhyacophila*

Hyalinata group, *Rhyacophila pellisa*, the mayflies *Drunella doddsi*, *Epeorus grandis*, the stoneflies *Doroneuria*, *Zapada cinctipes* and the riffle beetle *Narpus* were identified only at upper Little Goose Creek station LG22. Cool water and pollution intolerant taxa identified only at upper Big Goose Creek station BG18 included the snipe fly *Atherix* and the cranefly *Pseudolimnophila*. Taxa identified only in Goose Creek were warm water and pollution tolerant including the mayfly *Asioplax* found at stations GC2 and GC3, the midge fly *Chironomus* found at stations GC2 and GC3 and the leech *Helobdella stagnalis* found at station GC2. No stoneflies were identified at Goose Creek stations.

The mayfly *Tricorythodes minutus* was the dominant macroinvertebrate taxon in the GCWA Project area based on mean abundance. *T. minutus* averaged 2,535 organisms per square meter (m^2) and was the dominant taxon in Goose Creek, 3rd most dominant taxon in Big Goose Creek and 4th most dominant organism in Little Goose Creek (Table 8-20). *T. minutus* was often dominant at stations not supporting aquatic life use. The riffle beetle *Microcylloepus* was the 2nd most dominant taxon in the GCWA Project area averaging 2,517 organisms per m^2. *Microcylloepus* was the 3rd most dominant taxon in Goose Creek and the most dominant taxon in both Big Goose Creek and Little Goose Creek. SCCD (2000b) reported *T. minutus* and *Microcylloepus* among the dominant taxa in the Tongue River near Ranchester where they represented two of the five most dominant macroinvertebrate taxa. King (2004) reported *T. minutus* as the 2nd most common mayfly in north central Wyoming plains streams (behind *Baetis tricaudatus*) and *Microcylloepus* as the 3rd most common riffle beetle in Wyoming plains streams (behind *Dubiraphia* and *Optioservus*). Both taxa were common in warmer water Wyoming plains streams affected by increased siltation. The presence of *T. Minutus* in streams in the western United States has been associated with increased sediment deposition (Winget and Mangum, 1991). *Microcylloepus* appears to favor Wyoming streams with higher sediment deposition when compared to the riffle beetle taxon *Heterlimnius*, found in mountain and foothill streams and *Optioservus*, found in intermediate elevation and lowland Wyoming streams. The remaining top ten most dominant taxa in the Project area and by water body are listed in Table 8-20.

The benthic community at Goose Creek was comprised of warm water taxa generally tolerant of silt deposition, poorer water quality and habitat quality. The water mites Acari, the riffle beetle genera *Microcylloepus*, *Dubiraphia*, *Stenelmis*, the midge fly larvae *Cricotopus Bicinctus* group, *Cricotopus Trifascia* group, *Pseudochironomus*, *Rheocricotopus*, *Rheotanytarsus*, the blackfly *Simulium*, the mayflies *Fallceon quilleri*, *Tricorythodes minutus*, the snail *Physella*, the leeches Hirudinea, nematode worms, oligochaete worms, the flatworms Turbellaria and the caddisfly *Helicopsyche borealis* occurred in 100% of samples collected from Goose Creek (Table 8-19). No cold water taxa were identified from Goose Creek samples.

T. minutus dominated the Goose Creek benthic community followed in order of decreasing abundance by the midge fly genus *Cricotopus*, *Microcylloepus*, the midge fly *Rheotanytarsus* and the snail *Fossaria* (Table 8-20).

Several macroinvertebrate metrics used in the WSII (Jessup and Stribling, 2002) were evaluated to determine biological condition and aquatic life use support discussed in Section 8.2.1.2 for Goose Creek. Among Goose Creek stations, the mean total number of taxa ranged from 24 at station GC1B to 33 taxa and 34 taxa at stations GC1 and GC2, respectively (Figure 8-81). The mean total number of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) taxa combined into the EPT metric ranged from 10 taxa at station CG1 to 3 taxa at station GC1B. The EPT taxa are probably the most intolerant macroinvertebrate groups to agricultural runoff (McCafferty, 1978; Lenat, 1984). The total number of taxa and EPT taxa generally ranked low when compared to other plains streams in the Northwestern Great Plains ecoregion of Wyoming.

Functional feeding group metrics were evaluated at Goose Creek stations. There were no shredder taxa identified in Goose Creek (Figure 8-82). Lack of shredder taxa confirmed the lack of quality riparian zone habitat at most Goose Creek stations (see Section 8.22) because shredders chew leaves and other coarse organic material usually from riparian zone origin.

The scraper functional feeding group ranged from 34.8% at station GC1 to 7.3% and 7.6% at stations GC1B and GC2, respectively (Figure 8-82). The percent of scrapers was also relatively high at station GC3 (31.4%). The relationship between percent scrapers and weighted embeddedness (silt covering cobble and gravel substrate) was noted by SCCD (2000b) in an assessment of streams in the Tongue River watershed. It was believed increased embeddedness decreases scraper populations because sediment covers periphyton and other potential food sources residing on cobble and gravel that scrapers utilize for food. The relationship between the percent composition of scrapers in the total benthic population and weighted embeddedness values (degree of silt deposited on cobble and gravel substrate) was relatively weak, but statistically significant at Goose Creek stations (Figure 8-83). The correlation coefficient was +0.4644; $P<0.05$ for all Goose Creek stations indicating percent scrapers increased as the amount of silt on stream bottom substrate decreased. The correlation coefficient appeared to be lessened due to the some stations with high embeddedness and high % scraper densities. SCCD (2000b) noted certain locations in the Tongue River watershed impacted by sediment deposition had high % scrapers because submerged aquatic vegetation provided a “two story” benthic habitat allowing organisms to scrape food from exposed vegetation instead of from the minimal food source presented by sediment covered cobble and gravel substrate. The rooted submerged aquatic vegetation habitat provided refuge and a food source for macroinvertebrates compared to the poorer quality sediment covered substrate. Stations GC1 and GC3 had relatively high embeddedness values, but high % scrapers apparently due to the extensive submerged aquatic vegetation present at both stations.

Multivoltinism refers to the number of generations an organism has each year. It is believed that organisms with more than one generation per year (multivoltine taxa) are better adapted to streams affected by water quality and physical stressors than are univoltine taxa (one generation each year) and semivoltine taxa (one generation every two or more years). The lower the percent composition of multivoltine taxa, the better the water quality and physical habitat. Percent multivoltine organisms was lowest at Goose Creek stations GC3 (13.29%) and GC1 (19.38%) and highest at stations GC1B (43.01%) and GC1A (41.39%) (Figure 8-82).

The Hilsenhoff Biotic Index (HBI), developed by Hilsenhoff (1982; 1987), is based on the sensitivity of an organism to organic pollution. Although developed in Wisconsin, use of the HBI in Wyoming appears to act as a more holistic measure of water quality rather than just for organic pollution because stream reaches where organic pollution may be present are also stream reaches likely impacted by change in water temperature, sediment deposition and habitat quality. Of all macroinvertebrate metrics in the WSII used to determine biological condition for this Project, the HBI was the best predictor for non-support of aquatic life use. Mean HBI values are presented for each Goose Creek, Big Goose Creek and Little Goose Creek in Figure 8.21-4. The relation between HBI values and WSII biological condition scores was strong and significant (Correlation Coefficient = -0.7235; $P<0.01$; see Figure 8-85). The negative correlation indicated increased HBI values resulted in decreased WSII values.

Mean HBI values at Goose Creek ranged from a low of 5.74 at station GC1 to a high of 6.55 at station GC1B. Only Big Goose Creek stations BG2, BG4, BG8 and Little Goose Creek stations LG2A, LG5 and LG7 had comparable high HBI values to HBI values at Goose Creek stations. Non-support of aquatic life use at Goose Creek was previously discussed in Section 8.2.1.2 l, in Section 8.2.2.2 for Big Goose Creek and Section 8.2.3.2 for Little Goose Creek. When the mean HBI value was greater than 5.60 at any one station, non-support of aquatic life use occurred 82% of the time. This was an important observation because the HBI value alone could send a signal to the resource manager to more effectively target monitoring resources, or BMP implementations, prior to conducting the full “weight of evidence” approach using chemical, physical, and biological data (in addition to consideration of soils, geology, hydrology, climate, geomorphology, or stream succession) before a conclusive determination for attainment of aquatic life use could be made (see Table 8-17 *from* Table 3, Page 18 *in* WDEQ, 2002b).

The presence of oligochaete worms at 100% of Goose Creek samples was of concern because these groups are strong indicators of water pollution. Increased density of oligochaete worms may be associated with organic pollution (Klemm, 1985), pollution from feedlots (Prophet and Edwards, 1973), and pollutants contained in urban storm water runoff (Lenat et al., 1979; Lenat and Eagleson, 1981a). Mean percent oligochaete composition ranged from 1.98% at station GC1 to 12.12% at station GC1B (Appendix Tables M-2 and M-3). Percent oligochaetes was also high at station GC1A (6.12%). The percent oligochaetes at station GC1B was the highest among all stations in the Project area followed by Little Goose Creek stations LG7 (10.88%) and LG5 (10.02%), then Goose Creek station GC1A (6.12%).

SCCD (2000b) found the percent contribution of Oligochaeta to the total benthic macroinvertebrate community was a reliable predictor for identification of fecal coliform bacteria contamination at monitoring stations within the Tongue River watershed in the

Dayton and Ranchester area. Regression analyses using the average percent contribution of Oligochaeta and the average fecal coliform bacteria concentration revealed a statistically significant correlation coefficient (+0.886; $P<0.05$) indicating that increase in percent Oligochaeta was associated with increase in fecal coliform bacteria level. The relationship between mean percent oligochaetes and mean fecal coliform bacteria concentration in the Goose Creek Watershed Project area was moderately strong (correlation coefficient = +0.520137; $P<0.05$) and statistically significant. The correlation may have been more robust, but mean percent Oligochaeta from Goose Creek stations GC1A and GC1B (the 1st and 4th highest percent Oligochaeta in the Project area) were excluded from the regression since no fecal coliform bacteria samples were collected at these stations.

Although the association between oligochaetes and fecal coliform bacteria was significant and strong, there was no apparent direct cause and effect relationship indicating that increased oligochaetes caused increased fecal coliform bacteria levels or vice versa. Rather, the association was indirect because environmental conditions required for oligochaete populations to flourish (i.e. organic material from human and animal sources and increased sediment) were similar to conditions expected for the occurrence of higher fecal coliform bacteria levels (i.e. human and animal sources of excrement and generally higher turbidity). The application of this relationship for water quality monitoring should be explored further because general use of oligochaete populations to identify sources of fecal contamination to estimate fecal coliform bacteria levels would represent major savings in manpower and monitoring costs.

Evaluation of the macroinvertebrate populations in Goose Creek found organisms were warm water taxa tolerant of water pollution, sediment deposition and poorer habitat quality. Among Goose Creek stations, most downstream station GC1 had the highest quality macroinvertebrate community. Goose Creek station GC1B had the poorest macroinvertebrate community followed by stations GC 2, GC1A and GC3. Although biological condition based on benthic macroinvertebrate populations improved downstream of Sheridan between Goose Creek station GC1A and GC1, all of Goose Creek, with perhaps the exception of the Placheck Pit, did not support the narrative WDEQ water quality standard for aquatic life use (see Section 8.2.1.2).

A combination of factors appears to negatively influence Goose Creek macroinvertebrate populations. Upstream stations GC3, GC2, GC1B and GCA are affected by channelization that has occurred over the years related to the Sheridan flood control project. Channelization has widened the stream, increased water temperature, and affected the dynamics of stream flow that disrupt stream habitat downstream from the immediate channelized reaches. Dewatering during the summer irrigation period reduces discharge combining to further reduce habitat and accelerate the increase in water temperature. Periodic storm drain discharge, probable septic tank discharge and other urban runoff further affects macroinvertebrate communities by introducing water pollutants. Dewatering during the summer months may increase the impact of the Sheridan WWTP on Goose Creek because discharge from the facility may comprise a large proportion of stream flow.

Goose Creek macroinvertebrate communities appear to recover downstream of Sheridan from station GC1A to GC1. After exiting Sheridan and past the Big Horn Mountain KOA, Goose Creek enters lands unaffected by urban land use. The potential water quality effects from channelization and combined storm water, Sheridan WWTP, septic tanks, and urbanization related discharges appear to be reduced. Water quality, stream habitat and macroinvertebrate populations subsequently improve.

8.21.3 BIG GOOSE CREEK MACROINVERTEBRATE COMMUNITIES

The benthic community in Big Goose Creek was comprised of a mixture of cool water and warm water taxa in the upper reaches, primarily warm water taxa in the middle reaches, and warm water taxa in the lower reaches. The water mites Acari, the riffle beetle genus *Zaitzevia*, the midge fly larvae *Cricotopus*, *Rheotanytarsus* and *Thienemannimyia* complex and the mayfly *Tricorythodes minutus* occurred in 100% of samples collected from Big Goose Creek (Table 8-19).

The riffle beetle *Microcylloepus* dominated the Big Goose Creek benthic community followed in order of decreasing abundance by the caddisfly *Helicopsyche borealis, Tricorythodes minutus*, the caddisfly *Lepidostoma Pluviale* group, the midge fly genus *Rheotanytarsus* and the snail *Fossaria* (Table 8-20). The remaining top ten most dominant taxa in Big Goose Creek are listed in Table 8-20.

Microcylloepus averaged 2,403 organisms per square meter (m^2) and was the 3rd most dominant taxon in Goose Creek and the 1st most dominant taxon in Little Goose Creek. King (2004) reported *Microcylloepus* as the 3rd most common riffle beetle in north central Wyoming plains streams (behind *Dubiraphia* and *Optioservus*). *Microcylloepus* appears to favor Wyoming streams with higher sediment deposition when compared to the riffle beetle taxon *Heterlimnius*, found in mountain and foothill streams and *Optioservus*, found in intermediate elevation and lowland Wyoming streams. *Helicopsyche borealis* dominated at station BG4 (21.24% of organisms), station BG8 (20.43 % of organisms), BG14 (24.34% of organisms) and station BG15 (30.52% of organisms). King (2004) reported that *H. borealis* does not occur in north central Wyoming mountain streams, but occurred in 27.7% of foothill steam stations and 30.5% of plains streams. *H. borealis* ranked 5th for occurrence among all caddisfly taxa in north central Wyoming plains streams. Its widespread distribution in north central Wyoming, as well as throughout the Big Goose Creek watershed, may be related to its wide tolerance in water temperature. Wiggins (1996) reported collecting *H. borealis* in thermal streams of Yellowstone National Park, where water temperatures ranged up to 34^0C and no other caddisflies were found. *H. borealis* ranked 14th in abundance in Goose Creek and 15th in abundance in Little Goose Creek (Table 8-20).

Several macroinvertebrate metrics used in the WSII (Jessup and Stribling, 2002) were evaluated to determine biological condition and aquatic life use support discussed in Section 8.2.2.2 for Big Goose Creek. The range in mean number of total taxa among Big Goose Creek stations was relatively narrow ranging from 34.5 taxa at station BG14 to

43.5 taxa at station BG4 (Figure 8-87). The mean total number of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) taxa combined into the EPT metric ranged from 11 taxa at station BG2 to 18.5 taxa at station BG10.

Functional feeding group metrics were evaluated at Big Goose Creek stations. Shredder taxa were present only at upper Big Goose Creek stations BG15 and BG18 (Figure 8-88). Shredders comprised only 0.28% of total organisms at station BG15, but comprised 33.56% of organisms at station BG18. Station BG18 ranked 1st among all stations in the Project area for percent shredders. The dominance of shredders at BG18 indicated presence of a quality riparian zone by contribution of leaves and coarse particulate organic material to the stream. The general lack of shredder taxa from stations BG15 downstream to station BG2 in Sheridan indicated the lack of quality riparian zone habitat (see Section 8.22) because shredders chew leaves and other coarse organic material usually from riparian zone origin.

The scraper functional feeding group ranged from 30.7% at station BG10 to 46.8% at station BG4 (Figure 8-88). Percent scrapers was also relatively high at station BG15 (46.2%) and BG14 (42.4%). The high percent scrapers at station BG4 occurred despite the high degree of embeddedness (silt cover on cobble and gravel) at this station (see Section 8.22 and Figure 8-96). The high percent scrapers appeared to be due to the abundant submerged aquatic vegetation that provided habitat for periphyton colonization and a food source for macroinvertebrates.

Multivoltinism refers to the number of generations an organism has each year and the lower the percent composition of multivoltine taxa, the better the water quality and physical habitat. Percent multivoltine organisms was lowest at Big Goose Creek station BG18 (7.3%) and gradually increased downstream to station BG8 (27.7%) with a subsequent decrease to downstream BG2 (9.2%).

Mean HBI values at Big Goose Creek ranged from a low of 4.54 at station BG18 to a high of 6.31 at station BG4. As indicated in Section 8.21.2, when the mean HBI value was greater than 5.60 at any one station in the Goose Creeks watershed, non-support of aquatic life use occurred 82% of the time. Stations BG2 (mean HBI = 6.00), BG4 (mean HBI = 6.31) and BG8 (mean HBI = 6.12) exceeded the apparent threshold HBI value. As indicated in Section 8.2.2.2, aquatic life use was not supported from station BG4 downstream to station BG2. Further, although it was noted that aquatic life use support occurs through the reach from station BG18 to BG4, water quality and habitat stressors appeared to negatively affect and threaten biological condition at stations BG15, BG14, BG8 and BG4.

The presence of oligochaete worms at 100% of Big Goose Creek samples was concerning because these groups are strong indicators of water pollution. Mean percent oligochaete composition ranged from 7.36% at station BG15 and 6.94% at station BG18 to 0.58% at station BG10. Stations BG2 (5.91%) and BG4 (4.57%) also had relatively high mean percent oligochaeta values. The high percent oligochaete values at stations BG18, BG15, BG4 and BG2 indicated environmental conditions were present for oligochaete populations to flourish (i.e. organic material from human and animal sources and increased sediment) suggesting attendant higher fecal coliform concentrations were present. Fecal coliform concentration was lowest at station BG18 (mean average = 8 per 100/ml) among all Big Goose Creek stations. However, mean fecal coliform concentrations were highest in Big Goose Creek at station BG15 (mean average = 113 per 100/ml), station BG4 (mean average = 116 per 100/ml) and at station BG2 (mean average = 174 per 100/ml) (Appendix Q). The mean percent oligochaeta data combined with the fecal coliform bacteria data to suggest the presence of sediment and fecal coliform bacteria sources between station BG18 to downstream station BG15 and between station BG8 and downstream stations BG4 and BG2. Predominant land uses within these stream reaches suggest potential wildlife, livestock grazing and rural residential septic tank sources.

Evaluation of the macroinvertebrate populations in Big Goose Creek found fewer cold water taxa in the upper reaches (stations BG18 and BG15) than expected. The cool water mayfly taxa *Drunella grandis/spinifera*, *Epeorus* and *Ephemerella inermis/infrequens* were present at station BG18, but disappeared at downstream station BG15 and did not occur elsewhere in Big Goose Creek. No cold water caddisflies in the genus *Rhyacophila* were present at any Big Goose Creek station whereas 5 *Rhyacophila* species groups were present at the upper Little Goose Creek station LG22. The benthic community from station BG15 downstream to station BG2 in Sheridan gradually shifted to a warm water community. The last suggestion of a cold water habitat was observed at station BG10 with the occurrence of the cool water mayfly *Rhithrogena* and the stonefly *Acroneuria*. No other cool water benthic macroinvertebrate taxa were found downstream of station BG10 located about 40 yards upstream from the County Road 81 bridge and just upstream of the confluence with Beaver Creek. This observation indicated the transition zone between cold water and warm water habitat probably began an unknown distance upstream from BG10. Further, the benthic macroinvertebrate data indicates the transition to a warm water habitat appears complete at station BG2. This observation was supported by water temperature data presented in Section 8.3.2.

The benthic macroinvertebrate data combined with chemical, physical and other supporting information indicated full support for aquatic life use from station BG18 to downstream station BG4. However, water quality and habitat stressors appeared to negatively affect and threaten biological condition at stations BG15, BG14, BG8 and BG4, but not to the degree to result in non-attainment of aquatic life use. Using criteria developed by WDEQ (2002) to determine narrative aquatic life use (see Table 8-17), it was proposed that the reach from station BG18 to downstream station BG14 be described as fully supporting, but threatened for aquatic life use support; and the reach from station BG10 to downstream station BG4 be described as fully supporting, but threatened for aquatic life use support Biological condition was reduced between station BG4 and BG2 in Sheridan indicating non-support of aquatic life use within this stream reach.

A combination of factors appears to negatively influence Big Goose Creek macroinvertebrate populations. Channelization, although not evident at many locations in the upper and middle reaches of Big Goose Creek, has occurred over the years.

Improperly constructed and maintained irrigation diversions may cause localized disruption of stream habitat and flow patterns. The lower reaches of Big Goose Creek have been channelized for the Sheridan flood control project. Channelization has widened the stream in some areas increasing water temperature and in other areas has been artificially constricted and isolated from the normal floodplain affecting the dynamics of stream flow and disrupting stream habitat at and downstream from the immediate channelized reaches.

Dewatering during the summer irrigation period appears to impact the stream especially at the upper and middle reaches of Big Goose Creek. Reduced stream discharge further reduces habitat and accelerates the increase in water temperature. Periodic storm drain discharge, probable septic tank discharge, and other runoff from the urbanized portion of the stream in Sheridan further affects macroinvertebrate communities by introducing water pollutants.

The upper reaches of Big Goose Creek in the vicinity of BG18, BG15, and BG14 appear to be affected by sources of organic material and fecal coliform bacteria beyond the expected minimal contribution of coarse particulate organic material from an undisturbed riparian zone. Irrigation return, inefficient or malfunctioning septic systems, livestock grazing and small animal feeding operations, wildlife and rural development, especially in the middle and lower reaches from station BG4 to station BG2 and probably to the confluence with Little Goose Creek in Sheridan, may be involved in the dynamics of fecal coliform bacteria concentration in Big Goose Creek. Biological condition improved from station BG14 located just upstream of the Beckton Road to downstream station BG10 located just upstream of the confluence with Beaver Creek. The reasons for the increase in biological condition are unknown, but warrant further investigation to determine if the land use characteristics or land management techniques in this reach could be implemented elsewhere in the Big Goose Creek watershed. The benthic macroinvertebrate community data and habitat data indicated a reduction in biological condition and habitat from station BG10 to station BG8 located about 75 yards downstream from the Beaver Creek confluence. Flow from Beaver Creek may augment discharge in Big Goose Creek during the summer months, but the discharge appeared to contain pollutants and slightly increased water temperature that negatively affected biological communities.

8.21.4 LITTLE GOOSE CREEK MACROINVERTEBRATE COMMUNITIES

Cool water taxa were more abundant at Little Goose Creek upper stations (LG21 and LG22) than at Big Goose Creek upper stations (BG18 and BG15). No cool water taxa were present in Goose Creek. A mixture of cool water and warm water taxa were present in the middle reaches and warm water taxa dominated at lower Little Goose Creek stations. The water mites Acari, the clam *Pisidium*, the riffle beetle *Zaitzevia*, the midge fly larvae *Eukiefferiella*, the blackfly *Simulium*, oligochaete worms and the caddisflies *Helicopsyche borealis*, *Hydropsyche* and *Oecetis* occurred in 100% of samples collected from Little Goose Creek (Table 8.21-2).

The riffle beetle *Microcylloepus* dominated the Little Goose Creek benthic community followed in order of decreasing abundance by the caddisflies *Hydropsyche* and *Chimarra*, the mayfly *T. minutus* and the snail *Fossaria*. *Microcylloepus* ranked 1st in dominance in Big Goose Creek and 3rd in dominance at Goose Creek. *Microcylloepus* averaged 2,339 organisms per square meter (m^2). *Hydropsyche* was the 15th most abundant taxa in Big Goose Creek and the 41st most abundant organism in Goose Creek. King (2004) found *Hydropsyche* was the most frequently occurring caddisfly in north central Wyoming streams occurring in 53.9% of samples. *Hydropsyche* ranked 2nd for frequency of occurrence in plains samples (61.2% of samples), 4th in foothill samples (86.1% of samples), and 80th in mountain samples (11.7% of samples). The genus appears to thrive not in cold water or warm water, but in the warm water / cool water transition zone as evidenced by its dominance at Little Goose Creek stations LG10 (18.78% of total organisms), LG18A (19.93% of total organisms) and Big Goose Creek station BG10 (13.73% of total organisms). The remaining top ten most dominant taxa in Little Goose Creek are listed in Table 8.21-3.

Several macroinvertebrate metrics used in the WSII (Jessup and Stribling, 2002) were evaluated to determine biological condition and aquatic life use support discussed in Section 8.2.3.2 for Little Goose Creek. The range in mean number of total taxa among Little Goose Creek stations was from 49 and 45 taxa at stations LG5 and LG22, respectively, to 31 taxa at station LG10 (Figure 8.21-9). The mean total number of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) taxa combined into the EPT metric generally decreased progressively from most upstream station LG22 to most downstream station LG2A (Figure 8.21-9). The mean total number of EPT taxa ranged from 26.5 taxa at station LG22 to 6 taxa at station LG2A.

Functional feeding group metrics were evaluated at Little Goose Creek stations. Shredder taxa were present at middle and upper Little Goose Creek stations and absent from stations LG5 and LG2A located in the lower reaches (Figure 8.21-10). Mean percent shredders was highest at uppermost stations LG22 (32.4%) and decreased progressively downstream at stations LG21 (10.4%), LG18 (0.7%), LG10 (0.08%) and LG7 (0.06%). Station LG22 ranked 2nd highest and station LG21 ranked 3rd highest among all stations in the Project area for percent shredders behind Big Goose Creek station (BG18). The higher mean percent shredders at stations LG22 and LG 21 indicated presence of a quality riparian zone. The lack of shredder taxa at stations LG2A and LG5 indicated a lack of quality riparian zone habitat because shredders chew leaves and other coarse organic material usually from riparian zone origin.

The scraper functional feeding group ranged from 8.0% at station LG5 to 46.9% at station LG21 (Figure 8.21-10). Percent scrapers was also relatively high at station LG18 (28.8%), station LG22 (25.3%) and station LG2A (24.8%). The relatively high percent scrapers at station LG2A occurred despite the highest degree of embeddedness (silt cover on cobble and gravel) measured at any Little Goose Creek station (see Section 8.22). The high percent scrapers at station LG2A appeared to be due to the abundant submerged aquatic vegetation that provided habitat for macroinvertebrates and areas for periphyton to inhabit thus serving as food for scrapers.

Multivoltinism refers to the number of generations an organism has each year and the lower the percent composition of multivoltine taxa, the better the water quality and physical habitat. Percent multivoltine organisms was lowest at Little Goose Creek station LG21 (9.3%) and gradually increased downstream to station LG5 (28.8%) with a subsequent decrease to downstream station LG2A (22.8%).

Mean HBI values at Little Goose Creek ranged from a low of 3.73 at station LG21 and 3.77 at station LG22 to a high of 6.19 at station LG7. The mean HBI values at stations LG21 and LG22 were the two lowest HBI values for stations in the GCWA Project area. As indicated in Section 8.21.2, when the mean HBI value was greater than 5.60 at any one station in the Project area, non-support of aquatic life use occurred 82% of the time. Stations LG7 (mean HBI = 6.19), LG5 (mean HBI = 5.93) and LG2A (mean HBI = 5.92) exceeded the apparent threshold HBI value. As indicated in Section 8.2.3.2, aquatic life use was not supported from station LG10 downstream to station LG2A. Although it was noted that aquatic life use support occurred through the reach from station LG18A to LG10, water quality and habitat stressors appeared to negatively affect and threaten biological condition at station LG10.

The higher percent composition of oligochaete worms at middle and lower Little Goose Creek stations was concerning because these groups are strong indicators of water pollution. Mean percent oligochaete composition ranged from 0.1% at station LG22 to 10.9% and 10.0% at stations LG7 and LG5, respectively (Figure 8.21-6). The percent oligochaetes at station LG22 ranked lowest among all stations in the GCWA Project area. Station LG21 ranked 3rd lowest and station LG10 ranked 4th lowest among all stations for percent oligochaetes. In contrast, station LG7 ranked 2nd highest and station LG5 ranked 3rd highest among all stations for percent oligochaetes. The high percent oligochaete values at stations LG7 and LG5 indicated environmental conditions were present for oligochaete populations to flourish (i.e. organic material from human and animal sources and increased sediment) suggesting attendant higher fecal coliform concentrations were present. Mean fecal coliform concentration for 2001 and 2002 combined was lowest at stations LG21 (mean = 27 CFU/ 100 mL) and LG18A (mean = 34 CFU/ 100 mL). Uppermost station LG22 had a mean fecal coliform concentration of 94 CFU/ 100 mL, but the mean was significantly increased by a single large concentration of 2,800 per 100/ml from a sample collected October 03, 2002. Excluding this single fecal coliform sample would result in a mean fecal coliform concentration less than the mean fecal coliform concentration at station LG21. The highest mean fecal coliform concentration among Little Goose Creek stations and all stations in the Project area was at station LG7 located just upstream of the Highway 87 bridge at Woodland Park. The mean fecal coliform concentration at station LG7 was 976 CFU/ 100 mL. The geometric mean fecal coliform concentration was 73 CFU/ 100 mL, which ranked 2nd highest among all sample stations in the Project area (Goose Creek station GC2 located downstream of the Sheridan WWTP had the highest geometric mean for fecal coliform bacteria). The mean percent oligochaeta data combined with the fecal coliform bacteria data indicated the presence of sediment and fecal coliform bacteria sources upstream of Little Goose Creek station LG7. Predominant land uses within this stream reach suggested rural residential septic systems, irrigation return, wildlife and livestock grazing as potential sources for fecal coliform bacteria.

Evaluation of the macroinvertebrate populations in Little Goose Creek found more cold water taxa in the upper reaches (stations LG22 and LG21) than at any other station in the Project area. These cold water taxa included the stonefly taxa *Zapada cinctipes, Pteronarcella*, *Doroneuria Claassenia sabulosa*, the caddisfly taxa *Brachycentrus americanus, Dolophilodes, Arctopsyche grandis*, *Glossosoma*, *Rhyacophila Angelita* group, *Rhyacophila Brunnea* group, *Rhyacophila Coloradensis* group, *Rhyacophila Hyalinata* group, *Rhyacophila pellisa*, the riffle beetles *Narpus* and *Lara avara*, the craneflies *Antocha* and *Hesperoconopa* and the mayflies *Epeorus grandis* and *Drunella doddsi*. The majority of the cold water taxa disappeared at downstream station LG18A and all were absent at station LG10 and at other downstream reaches. The benthic community from station LG18A downstream to station LG2A in Sheridan gradually shifted to a warm water community. The last indication of a cool water habitat was observed at station LG10 with the occurrence of the semi-cold water stonefly taxa *Malenka* and *Skwala*. Although present, both taxa were considered rare since each comprised only 0.02% of the total benthic community. No other cool water benthic macroinvertebrate taxa were found downstream of station LG10 situated about 20 yards upstream from the County Road 87 bridge. This observation indicated the transition zone between cold water and warm water habitat probably began an unknown distance upstream from station LG10 to station LG18A. Further, the benthic macroinvertebrate data indicated the transition to a warm water habitat appeared complete at downstream stations LG7 and LG5.

The benthic macroinvertebrate data combined with chemical, physical and other supporting information indicated full support for aquatic life use from station LG22 to downstream station LG10. However, water quality and habitat stressors appear to negatively affect and threaten biological condition at station LG10, but not to the degree to result in non-attainment of aquatic life use. Using criteria developed by WDEQ (2002b) to determine narrative aquatic life use (see Table 8.2.1.2-2), it was proposed that the reach from station LG18A to downstream station LG10 be described as fully supporting, but threatened for aquatic life use support. Biological condition was reduced between station LG10 and station LG2A in Sheridan indicating non-support of aquatic life use within this stream reach. It was likely that the stream reach from station LG2A downstream to the confluence with Big Goose Creek would not support aquatic life use.

A combination of factors appears to negatively influence Little Goose Creek macroinvertebrate populations and aquatic life use. Channelization, although not evident at many locations in the upper and middle reaches of Little Goose Creek, has occurred over the years. Improperly constructed and maintained irrigation diversions may cause localized disruption of stream habitat and flow patterns. The lower reaches of Little Goose Creek near and in Sheridan have been extensively channelized for the Sheridan flood control project. Channelization has widened the stream in some areas increasing water temperature and in other areas has been artificially constricted and isolated from the normal floodplain affecting the dynamics of stream flow and disrupting stream habitat at and downstream from the immediate channelized reaches.

Dewatering during the summer irrigation period appears to impact the stream, especially downstream of station LG21 and at the middle and lower reaches of Little Goose Creek. Reduced stream discharge further reduces habitat and accelerates the increase in water temperature. Periodic storm drain discharge, probable septic tank discharge and other runoff from the urbanized portion of the stream in Sheridan further affects macroinvertebrate communities by introducing water pollutants.

Based on benthic macroinvertebrate communities, the upper reaches of Little Goose Creek in the vicinity of stations LG22 and LG21 do not appear to be significantly affected by potential sources of organic material and fecal coliform bacteria. Stream and riparian habitat is among the best stream reaches in the Project area. The middle and lower reaches from station LG18A to station LG2A in Sheridan appear to be negatively affected by dewatering, irrigation return, inefficient or malfunctioning septic systems, livestock grazing, possible small animal feeding operations, wildlife, and rural development. Station LG7 appears troublesome due to habitat degradation, relatively high silt cover on substrate, high percent composition oligochaete worms and the highest fecal coliform bacteria concentration among Little Goose Creek stations. Further evaluation should be directed toward this stream reach to explore options to improve water quality, biological condition and habitat quality.

Dewatering of Little Goose Creek during the irrigation season appears to have a negative effect on biological condition, fisheries and water temperature. Water temperature will naturally increase during summer months, but dewatering appears to accelerate the increase in water temperature. Dewatering related water temperature increase provided more favorable conditions for inhabitation by warm water benthic macroinvertebrate and fish species than to cold water macroinvertebrate and trout species. The apparent effect of seasonal dewatering and increased water temperature was to allow warm water species to expand their range further upstream in Little Goose Creek than normal; the range for cold water macroinvertebrate taxa and fish species was thus reduced to reaches further upstream where favorable year around water temperature persisted. The reduction in habitat for cold water species represented a loss of cold water habitat, but a gain in warm water habitat for warm water macroinvertebrate and fish species. This observation was of concern because the entire length of Little Goose Creek within the Project area is classified by WDEQ as a Class 2AB cold water, water body. The stream classification indicates Little Goose Creek must be able to support cold water aquatic life and fisheries uses through its length. Failure to support cold water aquatic life species indicates the stream is not meeting beneficial uses.

8.22 HABITAT ASSESSMENTS

Qualitative habitat assessments were conducted annually in September at five Goose Creek stations. Results from habitat assessments are presented in Appendix N. Although several elements of the habitat assessments were subjective, the habitat data could identify general habitat quality change among sample stations and determine differences in habitat components such as stream channel and riparian zone characteristics, substrate composition and silt deposition.

The highest average total habitat score among Goose Creek stations was at station GC1 (average score = 122.8) and GC1A (average score = 122.5) and the lowest average total habitat score was at station GC3 (average score = 88.3) located just upstream of the Fort Road bridge in Sheridan (Table 8-21). The lower habitat score at GC3 was due primarily to channelization of Goose Creek in Sheridan and the changes in stream habitat related to channelization including reduction in undercut banks, lack of pools for fish, low width to depth ratio resulting in shallow water depth and lack of a defined riparian zone. The change in habitat among Goose Creek stations is illustrated in Figure 8-91. The general trend was a decrease in habitat quality from the uppermost station (GC3) in Sheridan to the lowermost station (GC1) located about 75 yards downstream of the Highway 339 bridge. The trend for increase in habitat quality downstream along the longitudinal gradient in Goose Creek was just the opposite as that observed for habitat quality at Big Goose Creek and Little Goose Creek stations where habitat quality generally decreased from upstream stations to downstream stations (Figure 8-92 and Figure 8-93).

There was some variability in habitat assessment scores between 2001 and 2002. Each Goose Creek station with the exception of station GC1A had a higher habitat score in 2002 than in 2001 (Figure 8-91). Generally higher habitat scores in 2002 than in 2001 at Goose Creek stations was similar to that observed for most Little Goose Creek stations, but was in contrast to the majority of stations at Big Goose Creek where generally lower habitat scores were observed in 2002 than in 2001. The variation in habitat scores between years at most stations appeared to be related to difference in annual stream discharge. Although habitat assessments were generally conducted on sampling dates within ± two (2) weeks of one another each year, differences in annual discharge affected scoring for some habitat parameters because they were flow dependent. Scores for instream cover, velocity / depth, channel flow status and width depth ratio will normally score higher when discharge is increased, but will score lower when discharge is decreased.

Habitat at each Goose Creek station ranked in the lower 50% for habitat at all stations assessed during the Project (Figure 8-94). Goose Creek station GC1 had the best habitat among Goose Creek stations, but ranked 12th out of 19 total stations (Figure 8-94). Station GC1 is shown in Figure 8-94. The worst habitat in the Project area was at Goose Creek station GC3 (score = 88.3). Goose Creek station GC3 is shown in Figure 8-103. Habitat at station GC3 ranked 12th lowest out of 129 other plains stream stations assessed in the Northwestern Great Plains ecoregion of Wyoming (King, 2004) placing it within the lower 10th percentile for habitat in north central Wyoming streams (Table 8-24). As previously indicated, the low habitat score was due primarily to channelization that altered the natural habitat at this station.

The semi-quantitative stream substrate particle size distribution varied little among Goose Creek stations (Table 8-23). The majority of stream substrate was comprised of cobble and coarse gravel. Average percent cobble ranged from 58% at station GC1B to 32% at station GC1A. Average percent coarse gravel ranged from 39% at station GC1A to 5% at station GC1B. Silt deposition was absent at station GC1A, but increased to 13% of substrate at station GC3 and 17% at station GC1B. No other station assessed during this Project, with the exception of Big Goose Creek station BG18 had silt comprising over 10% of stream substrate. Sand comprised 8%, 11%, 13%, 15% and 21% of the total substrate at the Goose Creek stations GC1A, GC3, GC1B, GC2 and GC1, respectively. Percent sand at station GC1 was higher than at any other station sampled in the Project area.

Weighted embeddedness (silt covering cobble and gravel) was highest at Goose Creek station GC1A (weighted embeddedness value = 64.5) and lowest at station GC1B (weighted embeddedness value = 34.9) (Table 8-21). It should be noted that the higher the embeddedness value, the lower the amount of silt covering cobble and gravel substrate. In contrast, the lower the embeddedness value, the higher the amount of silt covering cobble and gravel. For example, a weighted embeddedness value of 20.0 indicates that 100% of cobble and gravel are covered by silt (see Figure 6-17). A weighted embeddedness value of 100 indicates that 100% of cobble and gravel are free from silt deposition (see Figure 6-16). The embeddedness value of 64.5 at station GC1A indicates that about 50% of the cobble and gravel surface was covered by silt and the embeddedness value of 34.9 at station GC1B indicated that about 80% of cobble and gravel were covered by silt.

Embeddedness values at each Goose Creek station were higher in 2001 than in 2002 (Figure 8-95). Higher embeddedness values in 2001 than 2002 was observed at all Big Goose Creek stations (Figure 8-96) and at all but one Little Goose Creek station (Figure 8-97). The lower embeddedness values in 2002 observed at most stations were probably related to the lack of higher spring "flushing" flows during spring 2002 to remove sediment accumulated in and on substrate from the previous year. The lack of a flushing flow in 2002 was related to the ongoing drought affecting north central Wyoming and the Project area. Embeddedness in 2002 increased since sediment deposited in 2001 as well as 2002 was measured.

There was no large difference in current velocity among Goose Creek stations. The range in current velocity was from 1.2 fps at station GC2 to 1.9 fps at station GC3 (Table 8-21). Average current velocity measured at Goose Creek stations was equal to or greater than the current velocity measured at 57% of combined Big Goose Creek and Little Goose Creek stations. Because average water current velocity was usually higher at Goose Creek stations, increased silt deposition and higher embeddedness at the Goose Creek stations was not related to difference in current velocity among stations, but was due to increased amount of silt contained in the water column deposited on stream substrate. Deposition of silt is controlled by the amount of silt contained in the water column and by the current velocity. Silt deposition will normally increase as current velocity decreases. This observation was confirmed by higher turbidity measurements at Goose Creek stations compared to turbidity measurements at stations in Big Goose Creek and Little Goose Creek.

Habitat assessments were conducted annually in September at seven Big Goose Creek stations. The highest average total habitat score was at Big Goose Creek stations BG18 (average score = 156.0), BG10 (average score = 147.0) and BG15 (average score = 145.5) and the lowest average total habitat score was at station BG2 (average score = 108.0) located just upstream of the footbridge at Works and Elk Street in Sheridan (Table 8-22). Station BG18 and station BG2 are shown in Figure 8-104. The lower habitat score at station BG2 was due primarily to channelization of Big Goose Creek in Sheridan that reduced undercut banks, lack of pools and instream cover for fish, low width to depth ratio resulting in shallow water depth and lack of an extensive riparian zone. The change in habitat among Big Goose Creek stations is illustrated in Figure 8-92. The general trend was an increase in habitat quality from the lowermost station in Sheridan (BG2) to the uppermost station (BG18) located in the Big Goose Creek canyon at the T-T Ranch. However, the trend was not consistent due to lower habitat quality at station BG8 located about 75 yards downstream of the Beaver Creek confluence. Lower habitat quality at station BG8 was due to higher embeddedness, evident channelization, low width to depth ratio resulting in shallow water, low pool to riffle ratio and increased stream bank instability.

There was some variability in habitat assessment scores between 2001 and 2002. Each Big Goose Creek station with the exception of station BG2 and station BG8, had a higher habitat score in 2001 than in 2002 (Figure 8-92). Generally higher habitat scores in 2001 than in 2002 at Big Goose Creek stations was in contrast to habitat scores observed for most Goose Creek and Little Goose Creek stations where generally higher habitat scores were observed in 2002 than in 2001. The variation in habitat scores between years at most stations appeared to be related to difference in annual stream discharge. Although habitat assessments were generally conducted on sampling dates within ± two (2) weeks of one another each year, differences in annual discharge affected scoring for some habitat parameters because they were flow dependent. Scores for instream cover, velocity / depth, channel flow status and width depth ratio will normally score higher when discharge is increased, but will score lower when discharge is decreased.

Habitat at Big Goose Creek stations BG18, BG10 and BG15 ranked in the top four for habitat at all stations assessed during the Project (Figure 8-94). Stations BG14 and BG4 ranked in the top 50% and stations BG8 and BG2 ranked in the lower 50% for habitat at all stations assessed during the Project (Figure 8-94).

The semi-quantitative stream substrate particle size distribution varied little among Big Goose Creek stations (Table 8-23). Cobble dominated stream substrate at each station and comprised from 55% at station BG18 to 83% at station BG10. Average percent coarse gravel ranged from 5% at station BG10 to 17% at station BG15. Silt deposition was low at stations BG14 (1% of substrate), BG8 and BG10 (each 3% of substrate) and BG2 and BG15 (each 4% of substrate). Station BG18 exhibited the highest percentage of silt (14%) and the highest percentage of sand (10%).

Weighted embeddedness (silt covering cobble and gravel) values were highest at Big Goose Creek station BG14 (weighted embeddedness value = 90.0) and lowest at station BG2 (weighted embeddedness value = 42.8) (Table 8-22). The higher the embeddedness value, the lower the amount of silt covering cobble and gravel substrate. In contrast, the lower the embeddedness value, the higher the amount of silt covering cobble and gravel. For example, the weighted embeddedness value of 90.0 at station BG14 indicated that from 8% to 10% of the surface of cobble and gravel were covered by silt. The weighted embeddedness value of 42.8 at station BG2 indicated that about 75% of the surface of cobble and gravel were covered by silt. Embeddedness at station BG2 fell within the 50th to 60th percentile for embeddedness in north central Wyoming streams (Table 8-24). BG18 and BG15 had higher weighted embeddedness values of 87.0 and 75.0, respectively. Embeddedness (as well as habitat) at station BG18 could not be compared to embeddedness at other Northwestern Great Plains ecoregion plains streams in Wyoming because this station was located in the foothills of the Middle Rockies ecoregion. However, embeddedness at station BG15 fell within the 80th to 90th percentile for embeddedness in north central Wyoming streams.

Embeddedness values at each Big Goose Creek station were higher in 2001 than in 2002 (Figure 8-96). Higher embeddedness in 2001 than 2002 was observed at all but one Little Goose Creek station (Figure 8-97). The lower embeddedness values in 2002 indicating increased deposition of sediment observed at most stations were probably related to the lack of higher spring “flushing” flows during spring 2002 to remove sediment accumulated in and on substrate from the previous year caused by the ongoing drought affecting north central Wyoming and the Project area. Embeddedness measured in 2002 increased since it appeared sediment deposited in 2001 as well as 2002 was measured.

There was no large difference in current velocity among Big Goose Creek stations. The range in current velocity was from 0.8 feet per second (fps) at both stations BG15 and BG18 to 1.5 fps at station BG10 (Table 8-22). Average current velocity measured at Big Goose Creek stations were similar to average current velocity measured at Little Goose Creek stations, but were generally lower than the current velocity measured at Goose Creek stations.

Habitat assessments were conducted annually in September at seven Little Goose Creek stations. The highest average total habitat score was at Little Goose Creek station LG22 (average score = 157.8), followed by station LG5 (average score = 144.3) and LG21 (average score = 143.3) (Table 8-22). The lowest habitat score was at station LG2A (average score = 108.5) located just downstream of the Coffeen Avenue bridge and storm drain discharge in Sheridan. Station LG5 located about 100 yards upstream from the Brundage Lane bridge south of Sheridan represented the best habitat of any station in or near Sheridan (Figure 8-94). Other than the presence of relative high amounts of silt and sand and resultant high embeddedness apparently originating from upstream sources, the habitat score at this station would have approached the habitat score at station LG22. The lower habitat score at station LG2A was due primarily to channelization of Little Goose Creek in Sheridan that reduced undercut banks, lack of pools and instream cover for fish, low width to depth ratio resulting in shallow water depth and lack of a good riparian zone.

The change in habitat among Little Goose Creek stations is illustrated in Figure 8.22-3. There was a general trend for an increase in habitat quality from the lowermost station in Sheridan (LG2A) to the uppermost station (LG22) located in the Little Goose Creek canyon just upstream of the Canyon Ranch. However, the trend was not consistent due to lower habitat quality at station LG7 located about 75 yards upstream from the Highway 87 bridge crossing near Woodland Park and lower habitat quality at station LG18A located near the Bird Farm Road bridge at the town of Big Horn. Lower habitat quality at station LG7 was due to reduced instream cover for fish, higher embeddedness, low pool to riffle ratio, high width to depth ratio and lack of an extensive riparian zone. Lower habitat quality at station LG18A was due to higher embeddedness, low pool to riffle ratio, high width to depth ratio, reduced bank vegetation and lack of an extensive riparian zone.

There was some variability in habitat assessment scores between 2001 and 2002. Each Little Goose Creek station with the exception of station LG2A, had a higher habitat score in 2002 than in 2001 (Figure 8-93). This was in contrast to most Big Goose Creek stations where generally higher habitat scores were observed during 2001 than 2002. The variation in habitat scores between years at most stations appeared to be related to difference in annual stream discharge affecting flow dependant habitat parameters including instream cover, velocity / depth, channel flow status and width depth ratio.

Habitat at Little Goose Creek station LG22 was the best of any station assessed in the Project area (Figure 8-94). Station LG22 is shown in Figure 8-105. Station LG5 ranked 5th best and station LG21 ranked 6th best for habitat of all stations assessed. Habitat at stations LG5 and LG21 fell within the upper 80th to 90th percentile for habitat when compared to habitat at other north central Wyoming streams (Table 8-24). Habitat at station LG2A was the 2nd worse for all stations in the Project area. This station fell within the lower 20th to 30th percentile for habitat at north central Wyoming streams. Habitat at station LG10 fell within the upper 70th to 80th percentile, station LG7 fell within the lower 40th to 50th percentile and station LG18A fell within the lower 30th to 40th percentile when compared to habitat at other north central Wyoming plains streams.

The semi-quantitative stream substrate particle size distribution varied among Little Goose Creek stations (Table 8-23). Cobble dominated stream substrate at each station with the exception of stations LG5 (cobble = 20%) and LG7 (cobble = 30%). Coarse gravel dominated at station LG5 (coarse gravel = 47%) and station LG7 (coarse gravel = 36%). Combined percent silt and sand were lowest at upper watershed stations (LG22 and LG21) and increased downstream to the lower station in Sheridan (LG2A). Sand comprised 19% of substrate at LG2A.

Weighted embeddedness (silt covering cobble and gravel) values were highest at Little Goose Creek station LG22 (weighted embeddedness value = 98.7) and decreased progressively at downstream stations (Figure 8.22-7). The higher the embeddedness value, the lower the amount of silt covering cobble and gravel substrate. In contrast, the lower the embeddedness value, the higher the amount of silt covering cobble and gravel. For example, the weighted embeddedness value of 98.7 at station LG22 indicated that nearly 100% of the surface of cobble and gravel were free from silt cover. Embeddedness remained generally low from upstream station LG22 in the canyon to station LG10 located near the Highway 87 bridge. Embeddedness increased dramatically from station LG10 (weighted embeddedness value = 82.1) downstream a relatively short distance to station LG7 (weighted embeddedness value = 44.0) indicating an increase in sediment input within this stream reach. The low weighted embeddedness value of 32.6 at station LG2A represented the highest embeddedness observed at any station in the Project area. The low embeddedness value indicated that about 80 to 85% of the surface of cobble and gravel were covered by silt. This station fell within the lower 30th to 40th percentile for embeddedness when compared to embeddedness at other north central Wyoming streams (Table 8-24).

Embeddedness values at most Little Goose Creek stations were similar to or slightly lower in 2002 than in 2001 (Figure 8.22-7). A much wider range in embeddedness values was observed between years at most Goose Creek and Big Goose Creek stations. Little Goose Creek station LG7 exhibited the largest decrease in embeddedness values from 2001 (weighted embeddedness value = 56.8) to 2002 (weighted embeddedness value = 31.1).

There was no large difference in current velocity among Little Goose Creek stations. The range in current velocity was from 0.8 feet per second (fps) at station LG21 to 1.5 fps at both stations LG2A and LG7 (Table 8-22). Average current velocity measured at Little Goose Creek stations were similar to average current velocity measured at Big Goose Creek stations, but were generally lower than the current velocity measured at Goose Creek stations.

Good stream habitat is critical for the establishment and maintenance of good fishery and benthic macroinvertebrate populations. Habitat quality is directly related to biological condition at streams in the Goose Creek watershed (Figure 8-99). The relationship between habitat quality and biological condition is strong and significant (Correlation Coefficient = 0.7235; $p<0.99$). This relationship is important because improvement in habitat quality in the absence of effect due to water quality, will result in improved biological condition. Those Goose Creek, Big Goose Creek and Little Goose Creek stations exhibiting only fair or poor biological condition and non-support of aquatic life use may be improved by enhancing habitat quality. Habitat quality can be improved at minimal cost often by minor change in management of the riparian zone and stream corridor by landowners. Implementation of BMP’s to improve habitat quality also serve to reduce water pollutants from entering streams. BMPs can be effective if implemented consistently over time.

8.23 FISHERIES

Historical and current fishery data were compiled from WGFD records and literature search. A total of 47 fishery sampling events were compiled (see Appendix O) in addition to records, memorandum and supporting information. No fish sampling was conducted by SCCD during the current Project.

A total of 25 fish species representing 6 families were reported from the Project area since sampling began in 1938 (Table 8-25). The minnow family Cyprinidae had 7 species, the sunfish family Centrarchidae and trout family Salmonidae each had 5 species. The sucker family Catostomidae was represented by 4 species and the catfish family Ictaluridae and perch family Percidae each had 2 species. All fish species have been previously reported from Wyoming water bodies (Baxter and Simon, 1970). No fish species were considered as threatened, endangered, or of special concern (Williams et al., 1989). Of the 25 fish species reported, 15 species were native to Wyoming and 10 fish species were introduced to Wyoming.

WDEQ (2001a) classified Wyoming fish fauna as non-game species, warm water game species or cold water game species as the primary measure to classify Wyoming water bodies. There were 11 non-game species, 9 warm water game species, and 5 cold water game species in the Project area. Of the 9 warm water game species, only black bullhead and stonecat were native to Wyoming. Cutthroat trout was the only cold water game fish native to Wyoming.

As noted in Section 5.1.4, the occurrence and relative contribution of smaller non-game species presented in fish sampling results were probably underestimated because many historical fish surveys concentrated on the capture of game species. Some of the smaller minnow species were not routinely captured and identified during all fishery surveys. Further, the small size and often high density of smaller minnows (longnose dace and others) precluded good capture efficiency. Although frequency of occurrence data for game fish species appeared reliable, changes in trout abundance that may have occurred through the years could not be assessed due to differing sampling effort and variable capture efficiencies.

Of the 25 fish species identified in the Project area, 7 fish species were common to Goose Creek, Big Goose Creek and Little Goose Creek including longnose dace, longnose sucker, mountain sucker, white sucker, rock bass, brown trout, and rainbow trout. Seven fish species were reported only from Goose Creek including flathead chub, golden shiner, black bullhead, smallmouth bass, white crappie, sauger, and yellow perch. Bluegill were reported only from Little Goose Creek station 2 during WGFD sampling in 1958. WGFD station 2 was located an unknown distance upstream from the Woodland Park bridge. Brook trout were reported only from Little Goose Creek. Brook trout occurred in 40% of samples, but appeared to be restricted to the upper watershed from WGFD station 3 at the Gallatin bridge (near current Project station LG21) upstream to WGFD station 5 at Harrison's in the Little Goose Creek canyon (upstream of current Project station LG22). Brook trout probably occur in the upper Big Goose Creek watershed (near current Project station BG18), but were not reported in any fish samples.

The fish population in Goose Creek was dominated by non-game species and warm water game species. Non-game species including longnose sucker, northern redhorse, and white sucker occurred in 100% of samples. Carp and mountain sucker occurred in 88% and 62% of samples, respectively. Warm water game species occurring most frequently were rock bass (88% of samples), stonecat (75% of samples) and green sunfish (50% of samples). Sauger, yellow perch, and white crappie (all warm water game species) were each present in only one sample. A single Sauger was collected from Placheck Pit by WWRRI in 1977; yellow perch and white crappie were collected by WGFD at Goose Creek station 3 in 1959. Brown trout and rainbow trout were the only two cold water game species collected in Goose Creek. Brown trout were collected in 62% of samples and 2 rainbow trout were collected in gillnet samples from the Placheck Pit by WWRRI in 1977. Brown trout, when collected, were never abundant and ranged from only 1 fish to 3 fish per sample. This observation indicated brown trout populations were marginal at Goose Creek sample stations. The rainbow trout collected in the Placheck Pit, a former surface coal mine pit constructed in the main Goose Creek channel, were probably stocked or transients from upstream Goose Creek or downstream Tongue River and able to survive in the cooler water temperature refuge afforded by the pit.

Evaluation of fishery data indicated Goose Creek has been dominated by non-game fish species since formal fishery surveys began in the drainage in 1959. WGFD fish and habitat surveys in 1959 found Goose Creek in Sheridan was completely channelized for flood control and no fish habitat remained. Below Sheridan, pollution from gravel washing operations and inadequate treatment of domestic sewerage eliminated the fishery potential of the remaining eight miles of stream to its confluence with the Tongue River (WGFD, 1964). The only game fish collected below Sheridan during the 1959 surveys were rock bass and stonecats. A later WGFD inter-office memorandum dated July 28, 1960 from Mr. Cliff Bosley to Mr. John Mueller reported deposition of sludge in Goose Creek downstream of the Sheridan WWTP. The memorandum stated that the deposition of sludge below the plant would be reason for concern if any kind of game fish population were present.

Since 1959, water pollution in Goose Creek has probably been significantly reduced through the NPDES program implemented in the mid-1970's. Further upgrade to the Sheridan WWTP in 1983 resulted in better treatment of domestic sewage and reduced discharge of pollutants into Goose Creek. However, game fish populations were still dominated by warm water species during limited sampling since upgrade of the Sheridan WWTP. Cold water fish species now apparently occur throughout most of the length of Goose Creek, although populations are marginal, very low in abundance and never dominant. Dominant game fish in Goose Creek are comprised of warm water species. These observations indicate that although water quality in Goose Creek has probably improved over the years, the creek more closely approximates a warm water, water body instead of a cold water, water body as currently classified by WDEQ (WDEQ, 2001b). Based only on the occurrence and abundance of cold water game fish species in Goose Creek, the water body could be assumed to not be meeting its beneficial use for fish. However, continuous water temperature data combined with benthic macroinvertebrate data previously discussed in this report add further “weight of evidence” to support a warm water classification for Goose Creek. SCCD, in consultation with WDEQ, should further evaluate a possible reclassification of the entire length of Goose Creek from Class

2AB to Class 2AB warm water to better reflect the actual thermal regime and realistic expectations for establishment and maintenance of a cold water fishery.

The fish population in Big Goose Creek was dominated by both non-game species and cold water game species. Only 11 species were collected from Big Goose Creek compared to the total number of fish species collected in Goose Creek (N = 21 species) and Little Goose Creek (N = 15 species). Differences in the total number of samples collected could account for the difference in fish species between Big Goose Creek (N = 14 samples) and Little Goose Creek (N = 24 samples). However Goose Creek had the highest number of fish species with the lowest number of samples collected (N = 8 samples).

Warm water game species occurred less frequently in the upper Big Goose Creek drainage and were generally less abundant in Big Goose Creek than in Goose Creek. Warm water game species included stonecat (21% of samples) and rock bass (14% of samples). Non-game species including longnose sucker, mountain sucker, and longnose dace occurred in 64% of samples (Table 8.23-1). White sucker occurred in 50% of samples. Four cold water game species were present and included brown trout (93% of samples), rainbow trout (57% of samples), mountain whitefish (57% of samples) and cutthroat trout (7% of samples). Two cutthroat trout were captured by WGFD in 1988 at a station near the BHNF boundary. The station was upstream of the uppermost Big Goose Creek station BG18 monitored during this Project.

Brown trout were collected throughout the entire length of Big Goose Creek in the Project area except at a single station identified as "North Jefferson Street bridge in Sheridan" sampled by WGFD in 1957. Only five non-game fish species were collected at the station.

The occurrence and relative abundance of the trout species and whitefish varied along the longitudinal gradient of Big Goose Creek. Rainbow trout were most abundant at the uppermost WGFD sample station (near the BHNF boundary). Brown trout became more abundant in the reach from the T-T Ranch (near Big Goose Creek station BG18 for this Project) downstream to just upstream of the Beckton Road bridge (near station BG14 for this Project). Whitefish replaced brown trout in abundance from WGFD stations at the Beckton Road bridge downstream to just below the Beaver Creek confluence (near stations BG8 and BG10 for this Project). WGFD (1964) reported that irrigation diversions from near the domestic water diversions for Sheridan and the Veterans Hospital downstream at the canyon mouth to near Beckton are such that the stream may be nearly dry for approximately five miles. Irrigation return below Beckton keep some flowing water in the stream but water temperatures may become too high for trout survival.

Fish sampling occurred at only two stations from near the Big Goose Creek / Beaver Creek confluence downstream to Sheridan. Sampling by Patton (1997) at a ranch about 1 to 2 miles downstream of the Beaver Creek confluence yielded the highest diversity of combined cold water and warm water game species collected in Big Goose Creek

(Appendix Table O-10). Patton captured nine fish species of which three were cold water game species (rainbow trout, brown trout, and whitefish) and two were warm water game species (rock bass and stonecat). Higher species diversity is often encountered in rivers where there is an admixture of cold water and warm water fish species due to the transition from a cold water system to a warm water system (Funk, 1970). This observation indicated that the reach from the Patton sample station located in the NE1/4 of Section 1, T.55N., R.85W. downstream to Sheridan was the start of the transition zone from a cold water stream system to a warm water stream system. WGFD (1964) reported that just above the town of Sheridan and continuing through the town, the stream was completely channeled for flood control and no fish habitat remained. The lack of any cold water game fish at the lower Big Goose Creek sample station in Sheridan was probably related to lack of fish habitat in addition to higher water temperature.

Evaluation of fishery data indicated most of Big Goose Creek in the Project area contains populations of cold water game fish except in Sheridan where intensive channelization has occurred resulting in little to no fish habitat. The shift in cold water game fish species along the longitudinal gradient is apparent from the canyon downstream to below the Beaver Creek confluence near the Patton sample station. The transition from a cold water fishery to a warm water fishery appears to occur near the Patton site and continues downstream to the city of Sheridan. Cold water game species occur in the apparent warm / cold water transition zone although limited data suggest their abundance is not high.

Based only on the occurrence and abundance of cold water game fish species in Big Goose Creek, the water body in the Project area appears to be meeting its beneficial use for fish with the exception of an unknown distance of stream between the Patton sample site and the confluence of Big Goose Creek with Little Goose Creek in Sheridan. These observations indicate that the majority of Big Goose Creek is a cold water, water body as currently classified by WDEQ (WDEQ, 2001b). The reach of Big Goose Creek near and in the city of Sheridan may not meet the beneficial use as a cold water fishery because of two factors. First, this reach may be considered a warm water reach based on fish data, benthic macroinvertebrate data, and water temperature data presented in this final report. Additional fishery data collected from the Big Goose Creek / Beaver Creek confluence downstream to the city of Sheridan could better define the transition zone between cold water and warm water stream reaches. Second, a cold water game fishery (or a warm water fishery) may not be attainable due to historical channelization for flood control in Sheridan resulting in the elimination of fish habitat and the loss of a potential game fishery. WDEQ should be consulted to consider the potential to attain the beneficial use for fish in this reach of Big Goose Creek.

Fish populations in Little Goose Creek generally followed trends as those observed in Big Goose Creek for the distribution and abundance of cold water game species and warm water game species. Warm water game species present in Little Goose Creek included rock bass (14% of samples), green sunfish (8% of samples), and bluegill (4% of samples). The single occurrence of bluegill was at WGFD station 2 during 1958. No stonecat were reported from Little Goose Creek in contrast to their occurrence in both Big Goose Creek and Goose Creek. Channel catfish were stocked in Little Goose Creek near Sheridan in 1956 and 1958 (WGFD, 1964), but none have been collected during fishery surveys. No warm water game fish were reported in Little Goose upstream of Highway 87 (near Little Goose station LG10 for this Project) although limited sampling occurred between Highway 87 for a considerable distance upstream to the Gallatin Ranch bridge near the Bradford Brinton Memorial (near Little Goose station LG21 for this Project). Warm water game species were collected downstream of the Highway 87 bridge to near the Brundage Lane bridge south of Sheridan.

Non-game species occurring most frequently in Little Goose Creek included white sucker (48% of samples), longnose dace (36% of samples), mountain sucker (28% of samples) and longnose sucker (24% of samples) (Table 8-25). Other non-game species occurring less frequently included carp, creek chub, fathead minnow and lake chub. The single occurrence of lake chub was from WGFD sampling in 1964 at station 5 near Harrison's, the uppermost Little Goose Creek canyon location. White sucker occurred from the WGFD station in Sheridan upstream to the canyon at the Watts Smyth bridge (at Little Goose Creek station LG22 for this Project).

Four cold water game fish including brown trout, rainbow trout, brook trout and mountain whitefish were collected and occurred most frequently in the upper portion of Little Goose Creek from WGFD station 3 at the Gallatin Ranch bridge to upstream WGFD station 5 at Harrison's. Trout species were collected in each of 17 samples collected within this reach. Brown trout occurred most frequently, followed by rainbow trout and brook trout. Brook trout were collected in 40% of samples, but usually only 1 or 2 individuals were captured at a station. Mountain whitefish were collected infrequently occurring in only 8% of total samples.

Cold water game fish species decline dramatically from the Gallatin Ranch bridge downstream to the Highway 87 bridge. Two cold water game species (brown trout and rainbow trout) were collected by Patton (1994) in the vicinity of the Woodland Park bridge. The stream reach from the Woodland Park bridge upstream to the Highway 87 bridge appears to be a transition zone from a cold water, water body to a warm water, water body similar to that observed in Big Goose Creek. No cold water game species were collected during limited sampling from the Woodland Park bridge downstream to the city of Sheridan. WGFD (1964) reported that the lower reaches of Little Goose Creek tend to become warm and turbid from irrigation return. At the southern edge of Sheridan (just upstream from the Brundage Lane bridge), rock bass was the only game fish recovered. WGFD added that the sport fishery improved near the U.S. Highway 87 crossing at the Maverick Club (the Club and landmark was later destroyed by fire). In this area, brown trout out-numbered rainbow trout, rock bass and bluegill sunfish. They noted however, game fish were not abundant due to poor habitat condition associated with low water. The co-occurrence of warm water game fish species and cold water game fish species further suggests that this area is within the warm - cold water transition zone for fish species.

Evaluation of fishery data indicated most of Little Goose Creek in the Project area contains populations of cold water game fish except in Sheridan and upstream an unknown distance from the Brundage Lane bridge (near Little Goose Creek station LG5 for this Project) to the Woodland Park bridge (near Little Goose Creek station LG7 for this Project). The shift from non-game and warm water game species to more cold water game fish species is apparent from the Woodland Park bridge to the Highway 87 bridge. The shift to a primary cold water fishery probably is more evident from the Highway 87 bridge upstream to the Gallatin Ranch bridge south of the town of Big Horn although no fishery data exists to confirm this assumption. The reach of Little Goose Creek from the Gallatin Ranch bridge upstream is dominated by cold water game fish.

Based only on the occurrence and abundance of cold water game fish species in Little Goose Creek, the water body in the Project area appears to be meeting its beneficial use as a cold water fishery with the exception of an unknown distance of stream from the Woodland Park bridge to the confluence with Big Goose Creek in Sheridan. These observations indicate that the majority of Little Goose Creek is a cold water, water body as currently classified by WDEQ (WDEQ, 2001b). The reach of Little Goose Creek near and in the city of Sheridan may not meet the beneficial use as a cold water fishery because of the same two factors also affecting Big Goose Creek near Sheridan. First, this reach may be considered a warm water reach based on fish data, benthic macroinvertebrate data, and water temperature data presented in this Final Report. Additional fishery data collected from the Woodland Park bridge downstream to the city of Sheridan could better define the transition zone between cold water and warm water stream reaches. Second, a cold water game fishery (or a warm water fishery) may not be attainable due to historical channelization for flood control in Sheridan resulting in the elimination of fish habitat and the loss of a potential game fishery. WDEQ should be consulted to consider the potential to attain the beneficial use for cold water fish in this reach of Little Goose Creek.

8.24 PRECIPITATION AND AIR TEMPERATURE

Meteorological data for the Project were downloaded from the National Weather Service Forecast Office website. These data were collected at the Sheridan County Airport, which is located within the Goose Creek watershed. Therefore, this station provided data that were representative of the Project area. The meteorological data obtained include daily high, low, and mean temperatures; daily precipitation; normal daily high, low, and mean temperatures; and normal daily precipitation. These data are presented in Appendix Table H-1.

Appendix Figure H-1 shows mean daily air temperature for 2001 and 2002 as compared to the normal mean daily temperature. Appendix Figure H-2 displays cumulative annual precipitation for 2001 and 2002 as compared to normal precipitation. The Sheridan County Airport received 11.18 inches of precipitation in 2001 and 11.57 inches in 2002. Both years were approximately 3 inches below average precipitation. Table 8-6 provides a summary of mean monthly air temperatures for the 2001 and 2002 monitoring seasons and the departures from normal. During the GCWA monitoring seasons, the months of April through September 2001 were warmer than the average. June, July, and September 2002 were also warmer than normal.

Table 8-1. Summary of Water Quality Samples Exceeding a Water Quality Standard or Recommended Consumption Level for Goose Creek Monitoring Stations (GC1 – GC6)

SUMMARY STATISTIC [1]	MONITORING STATION					
	GC1	GC2	GC3	GC4	GC5	GC6
# TEMP Samples >20ºC [2]	7	6	6	0	7	7
# pH Samples <6.5 **or** >9.0 [2]	0	0	0	0	0	0
# DO Samples <5.0 mg/L [2]	1	0	0	0	0	0
# DO Samples <4.0 mg/L [2]	0	0	0	0	0	0
# COND Samples >3000 umhos/cm [3]	0	0	0	0	0	0
# *E. Coli* Geometric Means >126 Organisms/100mL [4]	0	1	NA	1	NA	1
# Fecal Coliform Geometric Means >200 Organisms/100mL [2]	0	2	1	4	2	2
# Fecal Coliform Samples ≥400 Organisms/100mL	0	6	1	9	4	5
# T_ALK Samples <20 mg/L [5]	0	0	0	0	0	0
# T_CL Samples >860 mg/L [2]	0	0	0	0	0	0
# T_HARD Samples <300 mg/L [6]	13	11	12	13	11	11
# Total Ammonia Samples Exceeding Standards [7]	0	0	0	0	0	0
# Total Nitrates Samples >10 mg/L [2]	0	0	0	0	0	0
# T_PHOS Samples >0.05 mg/L [8]	13	14	6	9	5	6
# T_SULF Samples >600 mg/L [9]	0	0	0	0	0	0

Notes:

1. The total number of samples taken for each parameter listed in this table are summarized in Tables Q-2 through Q-47.
2. From Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001).
3. USDA-NRCS recommendation, irrigation waters over 3000 umhos/cm may severely limit crop production (NRCS, 2000).
4. Proposed standard for full-body contact waters (WDEQ, 2001).
5. Minimum recommended level to maintain aquatic productivity in streams (EPA, 1986).
6. Water with hardness levels greater than 300 mg/L (as $CaCO_3$) are considered very hard water (EPA, 1986 after Sawyer,1960).
7. See Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001), ammonia toxicity is pH and temperature dependent.
8. EPA (1977) recommended concentrations should not exceed 0.05 mg/L in a stream entering a lake or reservoir.
9. Sulfate levels in excess of 600 mg/L may have a laxative effect when consumed by humans.

Table 8-2. Summary of Water Quality Samples Exceeding a Water Quality Standard or Recommended Consumption Level for Big Goose Creek Monitoring Stations (BG1 – BG9)

SUMMARY STATISTIC [1]	MONITORING STATION								
	BG1	BG2	BG3	BG4	BG5	BG6	BG7	BG8	BG9
# TEMP Samples >20ºC [2]	3	4	4	6	6	1	1	1	0
# pH Samples <6.5 **or** >9.0 [2]	0	0	0	0	0	0	0	0	0
# DO Samples <5.0 mg/L [2]	0	0	0	0	1	0	0	0	0
# DO Samples <4.0 mg/L [2]	0	0	0	0	0	0	0	0	0
# COND Samples >3000 umhos/cm [3]	0	0	0	0	0	0	0	0	0
# *E. Coli* Geometric Means >126 Organisms/100mL [4]	0	NA	NA	0	NA	NA	NA	NA	1
# Fecal Coliform Geometric Means >200 Organisms/100mL [2]	2	2	2	1	0	0	0	0	0
# Fecal Coliform Samples ≥400 Organisms/100mL	4	5	5	1	1	1	3	2	3
# T_ALK Samples <20 mg/L [5]	0	0	0	0	0	0	0	0	0
# T_CL Samples >860 mg/L [2]	0	0	0	0	0	0	0	0	0
# T_HARD Samples <300 mg/L [6]	9	9	10	10	8	9	8	7	13
# Total Ammonia Samples Exceeding Standards [7]	0	0	0	0	0	0	0	0	0
# Total Nitrates Samples >10 mg/L [2]	0	0	0	0	0	0	0	0	0
# T_PHOS Samples >0.05 mg/L [8]	6	7	7	4	11	4	5	9	10
# T_SULF Samples >600 mg/L [9]	0	0	0	0	0	0	0	0	0

Notes:

1. The total number of samples taken for each parameter listed in this table are summarized in Tables Q-2 through Q-47.
2. From Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001).
3. USDA-NRCS recommendation, irrigation waters over 3000 umhos/cm may severely limit crop production (NRCS, 2000).
4. Proposed standard for full-body contact waters (WDEQ, 2001).
5. Minimum recommended level to maintain aquatic productivity in streams (EPA, 1986).
6. Water with hardness levels greater than 300 mg/L (as $CaCO_3$) are considered very hard water (EPA, 1986 after Sawyer,1960).
7. See Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001), ammonia toxicity is pH and temperature dependent.
8. EPA (1977) recommended concentrations should not exceed 0.05 mg/L in a stream entering a lake or reservoir.
9. Sulfate levels in excess of 600 mg/L may have a laxative effect when consumed by humans.

Table 8-3. Summary of Water Quality Samples Exceeding a Water Quality Standard or Recommended Consumption Level for Big Goose Creek Monitoring Stations (BG10 – BG18)

SUMMARY STATISTIC [1]	MONITORING STATION								
	BG10	BG11	BG12	BG13	BG14	BG15	BG16	BG17	BG18
# TEMP Samples >20ºC [2]	3	2	3	0	3	4	1	3	0
# pH Samples <6.5 **or** >9.0 [2]	0	0	0	0	0	0	0	0	0
# DO Samples <5.0 mg/L [2]	0	0	0	1	0	0	0	0	0
# DO Samples <4.0 mg/L [2]	0	0	0	0	0	0	0	0	0
# COND Samples >3000 umhos/cm [3]	0	0	0	0	0	0	0	0	0
# *E. Coli* Geometric Means >126 Organisms/100mL [4]	NA	0	NA	NA	NA	NA	1	NA	0
# Fecal Coliform Geometric Means >200 Organisms/100mL [2]	0	0	0	2	0	0	1	0	0
# Fecal Coliform Samples ≥400 Organisms/100mL	2	4	0	8	1	3	6	1	0
# T_ALK Samples <20 mg/L [5]	0	0	0	0	0	0	0	0	1
# T_CL Samples >860 mg/L [2]	0	0	0	0	0	0	0	0	0
# T_HARD Samples <300 mg/L [6]	6	7	6	8	5	5	1	2	0
# Total Ammonia Samples Exceeding Standards [7]	0	0	0	0	0	0	0	0	0
# Total Nitrates Samples >10 mg/L [2]	0	0	0	0	0	0	0	0	0
# T_PHOS Samples >0.05 mg/L [8]	6	5	5	8	5	6	6	3	4
# T_SULF Samples >600 mg/L [9]	0	0	0	0	0	0	0	0	0

Notes:

1. The total number of samples taken for each parameter listed in this table are summarized in Tables Q-2 through Q-47.
2. From Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001).
3. USDA-NRCS recommendation, irrigation waters over 3000 umhos/cm may severely limit crop production (NRCS, 2000).
4. Proposed standard for full-body contact waters (WDEQ, 2001).
5. Minimum recommended level to maintain aquatic productivity in streams (EPA, 1986).
6. Water with hardness levels greater than 300 mg/L (as $CaCO_3$) are considered very hard water (EPA, 1986 after Sawyer,1960).
7. See Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001), ammonia toxicity is pH and temperature dependent.
8. EPA (1977) recommended concentrations should not exceed 0.05 mg/L in a stream entering a lake or reservoir.
9. Sulfate levels in excess of 600 mg/L may have a laxative effect when consumed by humans.

Table 8-4. Summary of Water Quality Samples Exceeding a Water Quality Standard or Recommended Consumption Level for Little Goose Creek Monitoring Stations (LG1 – LG11)

SUMMARY STATISTIC [1]	MONITORING STATION										
	LG1	LG2	LG3	LG4	LG5	LG6	LG7	LG8	LG9	LG10	LG11
# TEMP Samples >20ºC [2]	1	2	7	2	2	2	2	1	0	3	4
# pH Samples <6.5 **or** >9.0 [2]	0	0	0	0	0	0	0	0	0	0	0
# DO Samples <5.0 mg/L [2]	0	0	0	0	0	0	0	0	0	0	0
# DO Samples <4.0 mg/L [2]	0	0	0	0	0	0	0	0	0	0	0
# COND Samples >3000 umhos/cm [3]	0	0	1	0	0	0	0	0	0	0	0
# *E. Coli* Geometric Means >126 Organisms/100mL [4]	0	NA	NA	NA	NA	1	NA	NA	1	NA	1
# Fecal Coliform Geometric Means >200 Organisms/100mL [2]	3	1	2	1	0	2	2	2	2	1	1
# Fecal Coliform Samples ≥400 Organisms/100mL	12	1	10	3	1	7	7	5	9	3	4
# T_ALK Samples <20 mg/L [5]	0	0	0	0	0	0	0	0	0	0	0
# T_CL Samples >860 mg/L [2]	0	0	0	0	0	0	0	0	0	0	0
# T_HARD Samples <300 mg/L [6]	14	14	14	13	13	11	8	11	12	7	6
# Total Ammonia Samples Exceeding Standards [7]	0	0	0	0	0	0	0	0	0	0	0
# Total Nitrates Samples >10 mg/L [2]	0	0	0	0	0	0	0	0	0	0	0
# T_PHOS Samples >0.05 mg/L [8]	3	4	10	6	4	5	4	8	10	5	10
# T_SULF Samples >600 mg/L [9]	0	0	13	0	0	0	0	0	0	0	0

Notes:

1. The total number of samples taken for each parameter listed in this table are summarized in Tables Q-2 through Q-47.
2. From Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001).
3. USDA-NRCS recommendation, irrigation waters over 3000 umhos/cm may severely limit crop production (NRCS, 2000).
4. Proposed standard for full-body contact waters (WDEQ, 2001).
5. Minimum recommended level to maintain aquatic productivity in streams (EPA, 1986).
6. Water with hardness levels greater than 300 mg/L (as $CaCO_3$) are considered very hard water (EPA, 1986 after Sawyer,1960).
7. See Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001), ammonia toxicity is pH and temperature dependent.
8. EPA (1977) recommended concentrations should not exceed 0.05 mg/L in a stream entering a lake or reservoir.
9. Sulfate levels in excess of 600 mg/L may have a laxative effect when consumed by humans.

Table 8-5. Summary of Water Quality Samples Exceeding a Water Quality Standard or Recommended Consumption Level for Little Goose Creek Monitoring Stations (LG12 – LG22)

SUMMARY STATISTIC [1]	MONITORING STATION										
	LG12	LG13	LG14	LG15	LG16	LG17	LG18	LG19	LG20	LG21	LG22
# TEMP Samples >20ºC [2]	1	1	6	3	3	4	2	0	2	1	0
# pH Samples <6.5 **or** >9.0 [2]	0	0	0	0	0	0	0	0	0	0	0
# DO Samples <5.0 mg/L [2]	0	0	0	0	0	0	0	0	0	0	0
# DO Samples <4.0 mg/L [2]	0	0	0	0	0	0	0	0	0	0	0
# COND Samples >3000 umhos/cm [3]	0	0	0	0	0	0	0	0	0	0	0
# *E. Coli* Geometric Means >126 Organisms/100mL [4]	NA	NA	0	NA	NA	1	NA	1	NA	NA	0
# Fecal Coliform Geometric Means >200 Organisms/100mL [2]	1	0	0	0	0	3	0	2	0	0	0
# Fecal Coliform Samples ≥400 Organisms/100mL	2	1	2	2	2	8	0	3	0	0	2
# T_ALK Samples <20 mg/L [5]	0	0	0	0	0	0	0	0	0	0	1
# T_CL Samples >860 mg/L [2]	0	0	0	0	0	0	0	0	0	0	0
# T_HARD Samples <300 mg/L [6]	4	5	7	2	1	10	1	0	0	0	0
# Total Ammonia Samples Exceeding Standards [7]	0	0	0	0	0	0	0	0	0	0	0
# Total Nitrates Samples >10 mg/L [2]	0	0	0	0	0	0	0	0	0	0	0
# T_PHOS Samples >0.05 mg/L [8]	4	6	6	3	3	9	7	6	5	0	0
# T_SULF Samples >600 mg/L [9]	0	0	0	0	0	0	0	0	0	0	0

Notes:

1. The total number of samples taken for each parameter listed in this table are summarized in Tables Q-2 through Q-47.
2. From Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001).
3. USDA-NRCS recommendation, irrigation waters over 3000 umhos/cm may severely limit crop production (NRCS, 2000).
4. Proposed standard for full-body contact waters (WDEQ, 2001).
5. Minimum recommended level to maintain aquatic productivity in streams (EPA, 1986).
6. Water with hardness levels greater than 300 mg/L (as $CaCO_3$) are considered very hard water (EPA, 1986 after Sawyer,1960).
7. See Chapter 1 - Wyoming Surface Water Quality Standards (WDEQ, 2001), ammonia toxicity is pH and temperature dependent.
8. EPA (1977) recommended concentrations should not exceed 0.05 mg/L in a stream entering a lake or reservoir.
9. Sulfate levels in excess of 600 mg/L may have a laxative effect when consumed by humans.

Table 8-6. Summary of Mean Monthly Air Temperatures for the Months of April through October, 2001 and 2002.

Month	Normal Mean Monthly Air Temperature (*F)	2001 Mean Monthly Air Temperature (*F)	2001 Departure from Normal (*F)	2002 Mean Monthly Air Temperature (*F)	2002 Departure from Normal (*F)
April	43.8	45.6	1.8	40.7	-3.1
May	52.7	55.3	2.6	50.3	-2.4
June	62.1	62.9	0.8	64.3	2.2
July	69.6	74.0	4.4	75.1	5.5
August	68.4	73.1	4.7	65.2	-3.2
September	57.1	61.2	4.1	58.4	1.3
October	46.7	45.1	-1.6	38.3	-8.4
April - October Average	57.2	59.6	2.4	56.0	-1.2

Source: National Weather Service data for the Sheridan County Airport, Sheridan, Wyoming.

Table 8-7. Summary of Mean Monthly Discharge for Goose Creek During the Months of April through October, 2001 and 2002

Month	Normal Mean Monthly Discharge (cfs)	2001 Mean Monthly Discharge (cfs)	2001 Departure from Normal (cfs)	2002 Mean Monthly Discharge (cfs)	2002 Departure from Normal (cfs)
April	132.8	89.9	-42.9	71.7	-61.1
May	379.2	52.4	-326.8	70.6	-308.6
June	568.8	39.2	-529.6	125.0	-443.8
July	146.1	9.5	-136.6	15.8	-130.3
August	61.1	38.6	-22.5	22.4	-38.7
September	85.3	28.0	-57.3	39.1	-46.2
October	102.2	41.6	-60.6	NA	NA
April - October Average	210.8	42.7	-168.0	57.4	-171.4

Source: USGS data for Station No. 06305700 (Goose Creek Near Acme, Wyoming).
NA = Data not available at the time of this Final Report.

Table 8-8. Summary of 2001 and 2002 Water Temperatures Found Exceeding 20°C as Measured with Continuous Temperature Data Loggers

Sample Station	No. of days with water temperatures greater than 20°C		No. of days having the minimum water temperatures greater than 20°C		Longest period of consecutive days with water temperatures greater than 20°C		Longest period of consecutive days having the minimum water temperatures greater than 20°C	
	2001	2002	2001	2002	2001	2002	2001	2002
GC1	103	93	41	31	82	55	21	23
GC4*	NA	34	NA	6	NA	22	NA	6
BG2	92	76	29	23	78	48	17	8
BG6	100	90	22	10	82	46	13	7
BG9	NA	45	NA	1	NA	21	NA	1
BG18	0	0	0	0	0	0	0	0
LG2	110	88	15	15	82	55	4	9
LG8	90	63	6	1	71	55	3	1
LG17	NA	45	NA	6	NA	34	NA	4
LG22	2	0	0	0	1	0	0	0

NA = Not applicable, no continuous temperature logger installed at this site during 2001.
*GC4 continuous temperature logger was buried in stream sediment from 6/3/02 through 6/27/02, data from this period were not used.

Table 8-9. Comparison of April – September 2002 Mean Monthly Discharge at USGS Station No. 06305700 (Goose Creek Near Acme), USGS Station No. 06301850 (Big Goose Creek Above PK Ditch), and USGS Station No. 06303500 (Little Goose Creek In Canyon)

Month	USGS Station – Discharge (cfs)		
	06305700	06301850	06303500
April	71.7	22.4	20.7
May	70.6	66.5	83.6
June	125.4	164.8	107.6
July	15.8	58.4	71.1
August	22.4	54.4	65.6
September	39.1	50.1	22.3
Average	57.5	69.4	61.8

Table 8-10. Summary of Fecal Coliform Geometric Means for Goose Creek Monitoring Stations During the 2001 – 2002 Goose Creeks Watershed Assessment

Sample Station	Apr 2001	Apr 2002	May 2001	May 2002	Aug 2001	Aug 2002	Oct 2001	Oct 2002
GC1	28	53	64	148	115	52	40	25
GC2	48	76	112	157	436	147	373	100
GC3	10	9	58	137	261	168	53	31
GC4-Soldier Cr	12	12	287	230	2972*	536	75	76
GC5	32	5	85	90	383	210	76	44
GC6	11	10	108	110	494	361	55	50

*Soldier Creek was dry part of the month, geometric mean is based on two samples.

Table 8-11. Summary of Fecal Coliform Geometric Means for Big Goose Creek Monitoring Stations During the 2001 – 2002 Goose Creeks Watershed Assessment

Sample Station	Apr 2001	Apr 2002	May 2001	May 2002	Aug 2001	Aug 2002	Oct 2001	Oct 2002
BG1	29	4	131	64	361	275	108	70
BG2	28	2	133	59	518	230	121	72
BG3	25	6	131	71	344	259	167	50
BG4	51	4	240	46	89	74	57	21
BG5	49	5	166	12	75	84	82	27
BG6	22	3	108	28	57	68	20	14
BG7	10	2	55	11	151	161	40	15
BG8	5	3	73	16	99	94	110	22
BG9-Beaver Cr	25	5	193	52	195	169	196	30
BG10	3	2	44	7	93	62	79	7
BG11	4	1	38	8	174	110	75	93
BG12	3	1	48	3	82	108	11	27
BG13-Park Cr	974	3	162	546*	**	**	143*	106
BG14	4	1	24	3	80	129	14	9
BG15	3	1	39	2	17	169	42	45
BG16-Rapid Cr	12	4	78	42	76	216	152	152
BG17	4	1	17	9	26	64	24	8
BG18	1	1	2	1	23	3	4	2

*Park Creek was dry part of the month, geometric mean is based on two samples.
**Park Creek was dry during the entire month, no samples were taken.

Table 8-12. Summary of Fecal Coliform Geometric Means for Little Goose Creek Monitoring Stations During the 2001 – 2002 Goose Creeks Watershed Assessment

Sample Station	Apr 2001	Apr 2002	May 2001	May 2002	Aug 2001	Aug 2002	Oct 2001	Oct 2002
LG1	180	12	264	107	1069	509	72	17
LG2	49	14	50	119	155	214	59	21
LG3-Storm Drain	8	2	37	19	1131	1281	6	8
LG4	23	3	50	80	292	184	32	16
LG5	33	5	62	78	87	150	28	24
LG6	48	4	195	108	465	438	47	31
LG7	12	4	240	76	183	3505	47	35
LG8	10	3	63	85	256	380	42	41
LG9-McCormick Cr	4	4	167	138	353	586	30	71
LG10	4	2	58	58	101	352	27	66
LG11-Kruse Cr	19	6	137	93	181	427	39	97
LG12	3	3	23	50	88	274	27	38
LG13	3	2	23	21	51	85	15	42
LG14	2	2	24	40	105	70	15	9
LG15	7	1	27	10	104	90	24	18
LG16	13	1	34	10	119	97	35	17
LG17-Jackson Cr	1	4	287	16	230	610	97	168
LG18	2	1	21	5	91	54	31	8
LG19-Sackett Cr	2	1	38	8	276	280	22	12
LG20	1	1	4	7	47	86	18	7
LG21	5	1	12	4	48	61	9	8
LG22	1	1	1	2	8	13	10	22

Table 8-13. Summary of 2001 – 2002 Goose Creek Watershed Assessment Fecal Coliform Geometric Means Exceeding 200 CFU/100 mL – Organized by Sample Station

Sample Station	Number of Geometric Means Exceeding 200 CFU/100 mL	Sample Station	Number of Geometric Means Exceeding 200 CFU/100 mL
GC1	0	LG1	3
GC2	2	LG2	1
GC3	1	LG3	2
GC4	4	LG4	1
GC5	2	LG5	0
GC6	2	LG6	2
BG1	2	LG7	2
BG2	2	LG8	2
BG3	2	LG9	2
BG4	1	LG10	1
BG5	0	LG11	1
BG6	0	LG12	1
BG7	0	LG13	0
BG8	0	LG14	0
BG9	0	LG15	0
BG10	0	LG16	0
BG11	0	LG17	3
BG12	0	LG18	0
BG13	2	LG19	2
BG14	0	LG20	0
BG15	0	LG21	0
BG16	1	LG22	0
BG17	0		
BG18	0	**Grand Total**	**44**

Table 8-14. Summary of 2001 – 2002 Goose Creek Watershed Assessment Fecal Coliform Geometric Means Exceeding 200 CFU/100 mL – Organized by Month

Month	Number of Geometric Means Exceeding 200 CFU/100 mL	Month	Number of Geometric Means Exceeding 200 CFU/100 mL
April 2001	1	April 2002	0
May 2001	5	May 2002	2
August 2001	16	August 2002	19
October 2001	1	October 2002	0
2001 Total	**23**	**2002 Total**	**21**

Table 8-15. Data Table of *E. coli* and Fecal Coliform Geometric Means for Samples Collected at the Same Site on the Same Days During August 2002

Sample Site	*E. Coli* Geometric Mean (CFU/100 mL)	Fecal Coliform Geometric Mean (CFU/100 mL)
GC1	38	52
GC2	156	147
GC4-Soldier Creek	420	536
GC6	225*	361
BG1	122	275
BG4	78	74
BG9-Beaver Creek	157	169
BG11	117	110
BG13-Park Creek	**	**
BG16-Rapid Creek	129	216
BG18	4	3
LG1	104	509
LG6	138	438
LG9-McCormick Creek	219	586
LG11-Kruse Creek	150	427
LG14	18	70
LG17-Jackson Creek	206	610
LG19-Sackett Creek	179	280
LG22	7	13

*Geometric mean is based on four samples.
**Park Creek was dry during August 2002.

Table 8-16. Biological condition score and rating for all comparable historic and current Goose Creek Watershed benthic macroinvertebrate sample stations based on the Wyoming Stream Integrity Index (WSII; from Jessup and Stribling, 2002).

		WSII			
		Middle Rockies		Northwestern Great Plains	
Sampling Station and Year	**Sampling Group**	**Score**	**Rating**	**Score**	**Rating**
Goose Creek GC1 (2001)	SCCD	NA[A]	NA[A]	43.6	Fair
Goose Creek GC1 (2002)	SCCD	NA	NA	50.1	Fair
Goose Creek GC1A (2001)	SCCD	NA	NA	35.1	Poor
Goose Creek GC1A (2002)	SCCD	NA	NA	30.7	Poor
Goose Creek GC1B (2001)	SCCD	NA	NA	27.6	Poor
Goose Creek GC1B (2002)	SCCD	NA	NA	24.6	Poor
Goose Creek GC2 (2001)	SCCD	NA	NA	24.4	Poor
Goose Creek GC2 (2002)	SCCD	NA	NA	32.4	Poor
Goose Creek GC3 (2001)	SCCD	NA	NA	36.0	Poor
Goose Creek GC3 (2002)	SCCD	NA	NA	39.0	Fair
Goose Creek NGPI51 (1998)	WDEQ	NA	NA	38.4	Fair
Goose Creek NGPI50 (1998)	WDEQ	NA	NA	41.7	Fair
Goose Creek NGP21 (1998)	WDEQ	NA	NA	40.5	Fair
Goose Creek NGP22 (1998)	WDEQ	NA	NA	49.3	Fair
Goose Creek NGPI19 (1994)	WDEQ	NA	NA	35.8	Poor
Goose Creek NGPI19 (1998)	WDEQ	NA	NA	42.6	Fair
Big Goose Creek BG2 (2001)	SCCD	NA	NA	52.9	Fair
Big Goose Creek BG2 (2002)	SCCD	NA	NA	45.8	Fair
Big Goose Creek BG4 (2001)	SCCD	NA	NA	58.5	Good
Big Goose Creek BG4 (2002)	SCCD	NA	NA	62.8	Good
Big Goose Creek BG8 (2001)	SCCD	NA	NA	61.9	Good

Table 8-16. (con't) Biological condition score and rating for all comparable historic and current Goose Creek Watershed benthic macroinvertebrate sample stations based on the Wyoming Stream Integrity Index (WSII; from Jessup and Stribling, 2002).

		WSII			
		Middle Rockies		Northwestern Great Plains	
Sampling Station and Year	**Sampling Group**	**Score**	**Rating**	**Score**	**Rating**
Big Goose Creek BG8 (2002)	SCCD	NA	NA	52.3	Fair
Big Goose Creek BG10 (2001)	SCCD	NA	NA	79.7	Very Good
Big Goose Creek BG10 (2002)	SCCD	NA	NA	62.8	Good
Big Goose Creek BG14 (2001)	SCCD	NA	NA	61.4	Good
Big Goose Creek BG14 (2002)	SCCD	NA	NA	59.6	Good
Big Goose Creek BG15 (2001)	SCCD	NA	NA	56.6	Good
Big Goose Creek BG15 (2002)	SCCD	NA	NA	62.2	Good
Big Goose Creek BG18 (2001)	SCCD	55.7	Fair	71.9	Good
Big Goose Creek BG18 (2002)	SCCD	51.4	Fair	62.2	Good
Big Goose Creek NGPI21 (1994)	WDEQ	NA	NA	51.4	Fair
Big Goose Creek NGPI21 (1998)	WDEQ	NA	NA	64.5	Good
Big Goose Creek NGPI47 (1998)	WDEQ	NA	NA	79.6	Very Good
Big Goose Creek NGPI48 (1998)	WDEQ	70.4	Good	86.7	Very Good
Big Goose Creek NGPI49 (1998)	WDEQ	NA	NA	67.3	Good
Little Goose Creek LG2A (2001)	SCCD	NA	NA	39.2	Fair
Little Goose Creek LG2A (2002)	SCCD	NA	NA	42.0	Fair
Little Goose Creek LG5 (2001)	SCCD	NA	NA	39.6	Fair
Little Goose Creek LG5 (2002)	SCCD	NA	NA	46.3	Fair
Little Goose Creek LG7 (2001)	SCCD	NA	NA	49.9	Fair
Little Goose Creek LG7 (2002)	SCCD	NA	NA	49.6	Fair

Table 8-16. (con't) Biological condition score and rating for all comparable historic and current Goose Creek Watershed benthic macroinvertebrate sample stations based on the Wyoming Stream Integrity Index (WSII; from Jessup and Stribling, 2002).

		WSII			
		Middle Rockies		Northwestern Great Plains	
Sampling Station and Year	**Sampling Group**	**Score**	**Rating**	**Score**	**Rating**
Little Goose Creek LG10 (2001)	SCCD	NA	NA	55.1	Good
Little Goose Creek LG10 (2002)	SCCD	NA	NA	53.9	Fair
Little Goose Creek LG18 (2001)	SCCD	NA	NA	62.0	Good
Little Goose Creek LG18 (2002)	SCCD	NA	NA	58.3	Good
Little Goose Creek LG21 (2001)	SCCD	NA	NA	73.7	Good
Little Goose Creek LG21 (2002)	SCCD	NA	NA	63.1	Good
Little Goose Creek LG22 (2001)	SCCD	71.0	Good	88.1	Very Good
Little Goose Creek LG22 (2002)	SCCD	67.6	Good	82.4	Very Good
Little Goose Creek NGPI20 (1994)	WDEQ	NA	NA	30.5	Poor
Little Goose Creek NGPI20 (1998)	WDEQ	NA	NA	46.7	Fair
Little Goose Creek NGPI26 (1994)	WDEQ	NA	NA	35.2	Poor
Little Goose Creek NGPI26 (1997)	WEST, Inc.	NA	NA	39.4	Fair
Little Goose Creek NGPI26 (1998)	WDEQ	NA	NA	44.1	Fair
Little Goose Creek NGPI36 (1997)	WEST, Inc.	NA	NA	40.5	Fair
Little Goose Creek NGPI36 (1998)	WDEQ	NA	NA	45.7	Fair
Little Goose Creek NGPI52 (1998)	WDEQ	NA	NA	53.9	Fair
Little Goose Creek MRC38 (1996)	WDEQ	69.4	Good	70.7	Very Good
Little Goose Creek MRC38 (1998)	WDEQ	66.8	Good	85.3	Very Good
Soldier Creek NGP64 (1999)	WDEQ	NA	NA	32.5	Poor
Soldier Creek NGP63 (1999)	WDEQ	NA	NA	40.1	Fair
Soldier Creek NGP-- (1999)	WDEQ	NA	NA	70.3	Good
Soldier Creek MRC78 (1999)	WDEQ	71.7	Good	82.7	Very Good

NA[A] = Score and rating not applicable to this sample station.

Table 8-17. Aquatic Life Use support, Narrative Water Quality Standards (from WDEQ, 2002b).

	FULL SUPPORT				
Biological Data	**Full Support**	**Full Support**	**Threatened**	**PARTIAL SUPPORT**	**NON-SUPPORT**
	Biological data do not deviate from the natural range of reference condition. Historical data do no show a decrease in biological condition that could lead to a condition of non-support.	Biological data deviate from the natural range of reference condition. Deviation can be explained by soils, geology, hydrology, climate, geomorphology, or stream succession and not the influence of man upon the system.	Biological data deviates slightly from the natural range of reference condition. Any deviation observed is not explained by soils, geology, hydrology, climate, geomorphology, or stream succession. Data show a downward trend in biological condition that will lead to a condition of non-support in near future.	Biological data deviate slightly from the natural range of reference condition. Deviation can not be explained by soils, geology, hydrology, climate, geomorphology, or stream succession. Biological condition of partial support verified by chemical, physical, or historical data.	Biological data deviate dramatically from the natural range of reference condition. Deviation can not be explained by soils, geology, hydrology, climate, geomorphology, or stream succession.
	And	**And**	**And/Or**	**And/Or**	**And/Or**
Chemical Data	Narrative water quality standards are achieved. Historical water quality data do not show seasonal or flow related trends that may not have been detected at the time of sampling.	Narrative water quality standards are not achieved. Failure to achieve standard is explained by soils, geology, hydrology, climate, geomorphology, or stream succession and not the influence of man upon the system.	Narrative water quality standards may be only marginally achieved. Condition observed is not explained by soils, geology, hydrology, climate, geomorphology, or stream succession. Data show a downward trend in water quality condition that will lead to a condition of non-support in near future.	Narrative water quality standards not achieved. Condition observed is not explained by soils, geology, hydrology, climate, geomorphology, or stream succession. Water chemistry condition of partial support verified by biological, physical, or historical data.	Narrative water quality standards not achieved. Condition observed is not explained by soils, geology, hydrology, climate, geomorphology, or stream succession.
	And	**And**	**And/Or**	**And/Or**	**And/Or**
Physical (Habitat) Data	Narrative water quality standards are achieved.	Narrative water quality standards are not achieved. Failure to achieve standard is explained by soils, geology, hydrology, climate, geomorphology, or stream succession and not the influence of man upon the system.	Narrative water quality standards may be marginally achieved. Condition observed is not explained by soils, geology, hydrology, climate, geomorphology, or stream succession. Data show a downward trend in water quality condition that will lead to a condition of non-support in near future.	Narrative water quality standards not achieved. Condition observed is not explained by soils, geology, hydrology, climate, geomorphology, or stream succession. Physical (habitat) condition of partial support verified by biological, physical, or historical data.	Narrative water quality standards not achieved. Condition observed is not explained by soils, geology, hydrology, climate, geomorphology, or stream succession.

Table 8-18. Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den), Percent Composition (%), Pollution Tolerance Value (HBI) and Functional Feeding Group (FFG) designation for macroinvertebrate taxa collected from all stations in the Goose Creeks Watershed, 2001 and 2002.

Taxon	Occ	Den	%	HBI	FFG
Acari (water mites)					
Acari	100	145	0.57	5	CG
Amphipoda (freshwater shrimp)					
Hyalella azteca	58	69	0.27	8	CG
Bivalvia (clams)					
Pisidium	89	137	0.53	8	CG
Sphaerium	47	29	0.11	8	CG
Sphaerium striatinum	37	45	0.18	8	CG
Coleoptera: Elmidae (riffle beetles)					
Cleptelmis addenda	10	22	0.09	4	CG
Dubiraphia	74	498	1.94	8	CG
Lara avara	5	5	0.02	3	SH
Microcylloepus	84	2517	9.81	7	SC
Narpus	5	24	0.09	4	SC
Optioservus	74	570	2.22	5	SC
Stenelmis	63	390	1.52	7	SC
Zaitzevia	95	459	1.79	6	SC
Coleoptera: Other Taxa					
Haliplus	21	19	0.07	8	MH
Helichus	10	4	0.02	5	SH
Postelichus	10	9	0.04	5	SH
Decapoda (crayfish)					
Orconectes	5	13	0.05	6	OM
Diptera: Chironomidae (midge flies)					
Apedilum	5	9	0.04	NA	CG
Brillia	5	3	0.01	5	SH
Cardiocladius	16	17	0.07	5	PR
Chironomidae-pupae	100	138	0.54	6	UN
Chironomus	10	7	0.03	10	CG
Cladotanytarsus	21	154	0.60	7	CG
Cricotopus	79	924	3.60	7	CG
Cricotopus (Nostococladius)	16	9	0.04	3	MH
Cricotopus Bicinctus group	63	186	0.72	7	CG
Cricotopus Trifascia Group	84	494	1.93	6	CG

Table 8-18. (con't) Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den), Percent Composition (%), Pollution Tolerance Value (HBI) and Functional Feeding Group (FFG) designation for macroinvertebrate taxa collected from all stations in the Goose Creeks Watershed, 2001 and 2002.

Taxon	Occ	Den	%	HBI	FFG
Cryptochironomus	16	12	0.05	8	PR
Dicrotendipes	32	513	2.00	8	CG
Epoicocladius	5	3	0.01	4	CG
Eukiefferiella	63	42	0.16	8	OM
Eukiefferiella Devonica group	5	3	0.01	4	OM
Lopescladius	16	25	0.10	6	CG
Macropelopia	5	7	0.03	6	PR
Micropsectra	37	178	0.69	7	CG
Microtendipes	42	189	0.74	6	CG
Odontomesa	5	13	0.05	4	CG
Orthocladius	5	5	0.02	6	CG
Orthocladius Complex	74	72	0.28	6	CG
Pagastia	16	17	0.07	1	CG
Parakiefferiella	32	48	0.19	4	CG
Parametriocnemus	10	3	0.01	5	CG
Paratendipes	10	14	0.05	8	CG
Pentaneura	63	99	0.39	6	PR
Polypedilum	42	62	0.24	6	OM
Pseudochironomus	63	110	0.43	5	CG
Pseudosmittia	16	24	0.09	6	UN
Rheocricotopus	89	58	0.23	6	OM
Rheotanytarsus	95	1228	4.79	6	CF
Stempellinella	26	21	0.08	4	UN
Stictochironomus	16	15	0.06	9	CG
Tanytarsus	10	8	0.03	6	CF
Thienemanniella	63	50	0.19	6	CG
Thienemannimyia Complex	58	29	0.11	6	PR
Tvetenia Bavarica group	5	1	<0.01	5	CG
Tvetenia Discoloripes group	16	48	0.19	5	CG
Diptera: Empididae (dance flies)					
Chelifera	16	9	0.04	6	PR
Hemerodromia	37	19	0.07	6	PR

Table 8-18. (con't) Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den), Percent Composition (%), Pollution Tolerance Value (HBI) and Functional Feeding Group (FFG) designation for macroinvertebrate taxa collected from all stations in the Goose Creeks Watershed, 2001 and 2002.

Taxon	Occ	Den	%	HBI	FFG
Diptera: Muscidae (muscid and stable flies)					
Limnophora	16	9	0.04	8	PR
Diptera: Psychodidae (moth and sand flies)					
Pericoma	32	28	0.11	5	CG
Diptera: Simuliidae (black flies)					
Simulium	89	588	2.29	6	CF
Diptera: Stratiomyidae (soldier flies)					
Caloparyphus	16	30	0.12	8	CG
Odontomyia	10	7	0.03	8	CG
Stratiomyiidae	5	7	0.03	8	CG
Diptera: Tipulidae (craneflies)					
Antocha	5	74	0.29	6	CG
Cryptolabis	32	60	0.23	4	UN
Dicranota	26	20	0.08	6	PR
Erioptera	5	7	0.03	4	CG
Hesperoconopa	5	5	0.02	1	UN
Hexatoma	53	14	0.05	5	PR
Limonia	10	5	0.02	7	MH
Pseudolimnophila	5	4	0.02	4	UN
Tipula	37	34	0.13	6	OM
Diptera: Other Taxa					
Atherix	5	27	0.11	7	PR
Ceratopogoninae	68	53	0.21	7	PR
Dasyhelea	32	14	0.05	7	CG
Dolichopodidae	10	7	0.03	6	PR
Ephydridae	16	7	0.03	9	CG
Tabanidae	5	13	0.05	7	PR
Enopla (proboscis and ribbon worms)					
Prostoma	16	47	0.18	8	CG
Ephemeroptera (mayflies)					
Acentrella insignificans	74	147	0.57	6	CG
Ameletus	11	34	0.13	3	CG

Table 8-18. (con't) **Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den), Percent Composition (%), Pollution Tolerance Value (HBI) and Functional Feeding Group (FFG) designation for macroinvertebrate taxa collected from all stations in the Goose Creeks Watershed, 2001 and 2002.**

Taxon	Occ	Den	%	HBI	FFG
Asioplax	10	18	0.07	7	CG
Baetidae	21	14	0.05	4	CG
Baetis tricaudatus	74	229	0.89	6	CG
Caenis	5	32	0.12	7	CG
Camelobaetidius	5	4	0.02	4	CG
Centroptilum	5	7	0.03	6	CG
Choroterpes	5	11	0.04	7	CG
Cinygmula	10	80	0.31	4	SC
Drunella doddsi	5	6	0.02	1	CG
Drunella grandis/spinifera	16	65	0.25	2	CG
Epeorus	21	119	0.46	1	SC
Epeorus grandis	5	6	0.02	0	SC
Ephemera	26	18	0.07	4	CG
Ephemerella inermis/infrequens	21	205	0.80	3	CG
Fallceon quilleri	89	909	3.54	4	CG
Heptagenia	5	7	0.03	4	SC
Heptagenia/Nixe	10	4	0.02	4	SC
Neochoroterpes	53	364	1.42	7	CG
Paraleptophlebia	42	31	0.12	4	CG
Paraleptophlebia bicornuta	10	14	0.05	5	CG
Rhithrogena	16	129	0.50	2	SC
Stenonema	10	13	0.05	6	SC
Timpanoga hecuba	5	7	0.03	5	CG
Tricorythodes minutus	95	2535	9.88	7	CG
Gastropoda (snails)					
Ferrissia	16	144	0.56	6	SC
Fossaria	32	1064	4.15	8	CG
Lymnaeidae	21	32	0.12	8	CG
Physella	79	423	1.65	8	CG
Heteroptera (true bugs)					
Ambrysus	58	43	0.17	7	PR

Table 8-18. (con't) **Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den), Percent Composition (%), Pollution Tolerance Value (HBI) and Functional Feeding Group (FFG) designation of macroinvertebrate taxa collected from all stations in the Goose Creeks Watershed, 2001 and 2002.**

Taxon	Occ	Den	%	HBI	FFG
Hirudinea (leeches)					
Hirudinea	68	56	0.22	10	PR
Helobdella stagnalis	5	8	0.03	9	PR
Hydroida (hydranths)					
Hydra	10	27	0.11	5	PR
Lepidoptera (butterflies and moths)					
Petrophila	79	356	1.39	6	SC
Megaloptera (alderflies)					
Sialis	37	22	0.09	7	PR
Nemata (nematode worms)					
Nematoda	79	76	0.30	5	UN
Odonata (dragonflies and damselflies)					
Argia	53	39	0.15	7	PR
Coenagrionidae	10	11	0.04	9	PR
Hetaerina	5	9	0.04	6	PR
Ophiogomphus	26	10	0.04	4	PR
Oligochaeta (worms)					
Oligochaeta	100	491	1.91	5	CG
Plecoptera (stoneflies)					
Acroneuria	5	4	0.02	4	PR
Capniidae	10	4	0.02	3	SH
Chloroperlidae	26	13	0.05	3	PR
Claassenia sabulosa	5	5	0.02	4	PR
Doroneuria	5	37	0.14	2	PR
Hesperoperla pacifica	5	8	0.03	4	PR
Isoperla	5	14	0.05	4	PR
Malenka	10	11	0.04	4	SH
Perlodidae-early instar	5	15	0.06	2	PR
Pteronarcella	5	5	0.02	4	OM
Skwala	16	9	0.04	4	PR
Sweltsa	21	92	0.36	3	PR
Zapada cinctipes	10	10	0.04	4	SH

Table 8-18. (con't) **Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den), Percent Composition (%), Pollution Tolerance Value (HBI) and Functional Feeding Group (FFG) designation for macroinvertebrate taxa collected from all stations in the Goose Creeks Watershed, 2001 and 2002.**

Taxon	Occ	Den	%	HBI	FFG
Trichoptera (caddis flies)					
Arctopsyche grandis	5	6	0.02	3	PR
Brachycentrus americanus	5	11	0.04	4	SC
Brachycentrus occidentalis	5	20	0.08	4	SC
Cheumatopsyche	64	234	0.91	8	CF
Chimarra	63	1086	4.23	5	CF
Culoptila	16	67	0.26	6	SC
Dolophilodes	5	33	0.13	2	CF
Glossosoma	5	11	0.04	4	SC
Helicopsyche borealis	100	1189	4.63	7	SC
Hydropsyche	89	1022	3.98	7	CF
Hydroptila	53	122	0.48	7	PH
Lepidostoma Pluviale group	26	916	3.57	5	SH
Leucotrichia	16	16	0.06	7	SC
Micrasema	16	42	0.16	4	MH
Nectopsyche	58	240	0.94	7	OM
Neotrichia	10	19	0.07	7	SC
Neureclipsis	5	4	0.02	7	PR
Oecetis	89	247	0.96	8	OM
Oligophlebodes	10	195	0.76	1	SC
Oxyethira	5	3	0.01	8	PH
Polycentropus	16	32	0.12	6	PR
Protoptila	16	395	1.54	6	SC
Psychomyia	16	7	0.03	4	SC
Rhyacophila Angelita group	5	5	0.02	4	PR
Rhyacophila Brunnea group	5	69	0.27	4	PR
Rhyacophila Coloradensis group	5	12	0.05	5	PR
Rhyacophila Hyalinata group	5	27	0.11	4	PR
Rhyacophila pellisa	5	16	0.06	3	PR
Rhyacophila-early instar	5	6	0.02	2	PR
Turbellaria (flatworms)					
Turbellaria	95	683	2.66	4	UN

Table 8-19. Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den) and Percent Composition (%) for benthic macroinvertebrate taxa collected at Big Goose Creek, Little Goose Creek and Goose Creek, 2001 and 2002.

	Big Goose			Little Goose			Goose		
Taxon	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**
Acari (water mites)									
Acari	100	102	0.54	100	96	0.39	100	275	1.03
Amphipoda (freshwater shrimp)									
Hyalella azteca	71	40	0.21	43	115	0.46	60	69	0.26
Bivalvia (clams)									
Pisidium	86	82	0.44	100	185	0.75	80	134	0.50
Sphaerium	43	20	0.11	57	34	0.14	40	31	0.12
Sphaerium striatinum	29	66	0.35	43	26	0.10	40	52	0.20
Coleoptera: Elmidae (riffle beetles)									
Cleptelmis addenda	14	3	0.02	14	40	0.16	--	--	--
Dubiraphia	71	309	1.65	57	426	1.72	100	746	2.80
Lara avara	--	--	--	14	5	0.02	--	--	--
Microcylloepus	86	2403	12.82	71	2339	9.44	100	2831	10.63
Narpus	--	--	--	14	24	0.10	--	--	--
Optioservus	71	528	2.82	100	761	3.07	40	9	0.03
Stenelmis	43	327	1.75	57	127	0.51	100	638	2.40
Zaitzevia	100	301	1.61	100	844	3.40	80	61	0.23
Coleoptera: Other Taxa									
Haliplus	14	27	0.14	14	7	0.03	--	--	--
Helichus	29	4	0.02	--	--	--	--	--	--
Postelichus	29	9	0.05	--	--	--	--	--	--
Decapoda (crayfish)									
Orconectes	--	--	--	14	13	0.05	--	--	--
Diptera: Chironomidae (midge flies)									
Apedilum	--	--	--	--	--	--	20	9	0.03
Brillia	--	--	--	14	3	0.01	--	--	--
Cardiocladius	14	4	0.02	29	24	0.10	--	--	--
Chironomidae-pupae	100	87	0.46	100	124	0.50	100	229	0.86
Chironomus	--	--	--	--	--	--	40	7	0.03
Cladotanytarsus	14	51	0.27	43	188	0.76	--	--	--
Cricotopus	100	99	0.53	57	402	1.62	80	2893	10.86
Cricotopus (Nostococladius)	14	4	0.02	29	11	0.04	--	--	--
Cricotopus Bicinctus group	43	24	0.13	57	132	0.53	100	327	1.23
Cricotopus Trifascia group	86	89	0.47	71	206	0.83	100	1269	4.76

Table 8-19. (con't) **Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den) and Percent Composition (%) for benthic macroinvertebrate taxa collected at Big Goose Creek, Little Goose Creek and Goose Creek, 2001 and 2002.**

	Big Goose			**Little Goose**			**Goose**		
Taxon	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**
Cryptochironomus	14	5	0.03	14	27	0.11	20	4	0.02
Dicrotendipes	14	22	0.12	14	7	0.03	80	762	2.86
Epoicocladius	14	3	0.02	--	--	--	--	--	--
Eukiefferiella	43	25	0.13	100	55	0.22	40	20	0.08
Eukiefferiella Devonica group	14	3	0.02	--	--	--	--	--	--
Lopescladius	29	8	0.04	14	60	0.24	--	--	--
Macropelopia	14	7	0.04	--	--	--	--	--	--
Micropsectra	29	120	0.64	43	275	1.11	40	91	0.34
Microtendipes	43	57	0.30	57	333	1.34	20	9	0.03
Odontomesa	14	13	0.07	--	--	--	--	--	--
Orthocladius	--	--	--	14	5	0.02	--	--	--
Orthocladius Complex	57	21	0.11	86	63	0.25	80	137	0.51
Pagastia	14	11	0.06	29	20	0.08	--	--	--
Parakiefferiella	--	--	--	43	78	0.31	60	18	0.07
Parametriocnemus	--	--	--	10	3	0.01	--	--	--
Paratendipes	14	22	0.12	14	7	0.03	--	--	--
Pentaneura	71	137	0.73	57	86	0.35	60	53	0.20
Polypedilum	14	34	0.18	71	82	0.33	40	26	0.10
Pseudochironomus	57	107	0.57	43	172	0.69	100	76	0.29
Pseudosmittia	14	43	0.23	--	--	--	40	14	0.05
Rheocricotopus	86	49	0.26	86	30	0.12	100	103	0.39
Rheotanytarsus	100	900	4.80	86	610	2.46	100	2430	9.12
Stempellinella	43	29	0.15	14	3	0.01	20	13	0.05
Stictochironomus	43	15	0.08	--	--	--	--	--	--
Tanytarsus	14	3	0.02	14	13	0.05	--	--	--
Thienemanniella	71	64	0.34	57	15	0.06	60	74	0.28
Thienemannimyia Complex	100	35	0.19	57	19	0.08	--	--	--
Tvetenia Bavarica group	--	--	--	--	--	--	20	1	<0.01
Tvetenia Discoloripes group	29	59	0.31	--	--	--	20	27	0.10
Diptera: Empididae (dance flies)									
Chelifera	14	4	0.02	29	12	0.05	--	--	--
Hemerodromia	29	11	0.06	57	18	0.07	20	40	0.15

Table 8-19. (con't) Frequency of Occurrence (Occ), Mean Density in Number per Meter² (Den) and Percent Composition (%) for benthic macroinvertebrate taxa collected at Big Goose Creek, Little Goose Creek and Goose Creek, 2001 and 2002.

	Big Goose			Little Goose			Goose		
Taxon	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**
Diptera: Muscidae (muscid flies)									
Limnophora	43	9	0.05	--	--	--	--	--	--
Diptera: Psychodidae (moth flies)									
Pericoma	14	4	0.02	29	51	0.21	60	20	0.08
Diptera: Simuliidae (black flies)									
Simulium	71	187	1.00	100	845	3.41	100	630	2.37
Diptera: Stratiomyidae (soldier flies)									
Caloparyphus	29	30	0.16	14	32	0.13	--	--	--
Odontomyia	29	7	0.04	--	--	--	--	--	--
Stratiomyiidae	--	--	--	14	7	0.03	--	--	--
Diptera: Tipulidae (craneflies)									
Antocha	--	--	--	14	74	0.30	--	--	--
Cryptolabis	57	15	0.08	29	150	0.61	--	--	--
Dicranota	14	20	0.11	57	20	0.08	--	--	--
Erioptera	--	--	--	14	7	0.03	--	--	--
Hesperoconopa	--	--	--	14	5	0.02	--	--	--
Hexatoma	71	14	0.07	71	14	0.06	--	--	--
Limonia	--	--	--	14	7	0.03	20	3	0.01
Pseudolimnophila	14	4	0.02	--	--	--	--	--	--
Tipula	43	8	0.04	57	53	0.21	--	--	--
Diptera: Other Taxa									
Atherix	14	27	0.14	--	--	--	--	--	--
Ceratopogoninae	71	35	0.19	57	96	0.39	80	33	0.12
Dasyhelea	29	14	0.07	29	10	0.04	40	18	0.07
Dolichopodidae	14	11	0.06	14	3	0.01	--	--	--
Ephydridae	--	--	--	14	3	0.01	40	9	0.03
Tabanidae	--	--	--	14	13	0.05	--	--	--
Enopla (ribbon worms)									
Prostoma	14	3	0.02	14	135	0.54	20	4	0.02
Ephemeroptera (mayflies)									
Acentrella insignificans	86	201	1.07	71	112	0.45	60	99	0.37
Ameletus	14	43	0.23	14	26	0.10	--	--	--

Table 8-19. (con't) Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den) and Percent Composition (%) for benthic macroinvertebrate taxa collected at Big Goose Creek, Little Goose Creek and Goose Creek, 2001 and 2002.

	Big Goose			Little Goose			Goose		
Taxon	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**
Asioplax	--	--	--	--	--	--	40	18	0.07
Baetidae	29	15	0.08	14	7	0.03	20	20	0.08
Baetis tricaudatus	86	92	0.49	86	425	1.71	40	51	0.19
Caenis	--	--	--	14	32	0.13	--	--	--
Camelobaetidius	14	4	0.02	--	--	--	--	--	--
Centroptilum	14	7	0.04	--	--	--	--	--	--
Choroterpes	14	11	0.06	--	--	--	--	--	--
Cinygmula	14	31	0.17	14	128	0.52	--	--	--
Drunella doddsi	--	--	--	14	6	0.02	--	--	--
Drunella grandis/spinifera	14	130	0.69	29	33	0.13	--	--	--
Epeorus	14	4	0.02	43	157	0.63	--	--	--
Epeorus grandis	--	--	--	14	6	0.02	--	--	--
Ephemera	57	18	0.10	--	--	--	20	20	0.08
Ephemerella inermis/infrequens	14	246	1.31	43	191	0.77	--	--	--
Fallceon quilleri	86	833	4.45	86	704	2.84	100	1245	4.67
Heptagenia	14	7	0.04	--	--	--	--	--	--
Heptagenia/Nixe	29	4	0.02	--	--	--	--	--	--
Neochoroterpes	86	584	3.12	43	33	0.13	20	40	0.15
Paraleptophlebia	57	15	0.08	57	46	0.19	--	--	--
Paraleptophlebia bicornuta	14	4	0.02	14	24	0.10	--	--	--
Rhithrogena	29	19	0.10	14	349	1.41	--	--	--
Stenonema	29	13	0.07	--	--	--	--	--	--
Timpanoga hecuba	14	7	0.04	--	--	--	--	--	--
Tricorythodes minutus	100	1364	7.28	86	1559	6.29	100	5346	20.07
Gastropoda (snails)									
Ferrissia	--	--	--	--	--	--	40	213	0.80
Fossaria	29	606	3.23	29	888	3.58	40	1700	6.38
Lymnaeidae	29	41	0.22	14	27	0.11	20	20	0.08
Physella	57	544	2.90	86	198	0.80	100	598	2.25
Heteroptera (true bugs)									
Ambrysus	86	44	0.23	29	67	0.27	20	10	0.04

Table 8-19. (con't) **Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den) and Percent Composition (%) for benthic macroinvertebrate taxa collected at Big Goose Creek, Little Goose Creek and Goose Creek, 2001 and 2002.**

	Big Goose			Little Goose			Goose		
Taxon	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**
Hirudinea (leeches)									
Hirudinea	57	35	0.19	57	38	0.15	100	87	0.33
Helobdella stagnalis	--	--	--	--	--	--	20	8	0.03
Hydroida (hydranths)									
Hydra	14	27	0.14	14	27	0.11	--	--	--
Lepidoptera (butterflies and moths)									
Petrophila	86	491	2.62	86	373	1.50	60	56	0.21
Megaloptera (alderflies)									
Sialis	43	16	0.09	57	27	0.11	--	--	--
Nemata (nematode worms)									
Nematoda	57	15	0.08	86	93	0.38	100	106	0.40
Odonata (dragonflies& damselflies)									
Argia	43	33	0.18	43	26	0.10	80	53	0.20
Coenagrionidae	14	18	0.10	--	--	--	20	3	0.01
Hetaerina	--	--	--	--	--	--	20	9	0.03
Ophiogomphus	43	12	0.06	--	--	--	40	7	0.03
Oligochaeta (worms)									
Oligochaeta	100	413	2.20	100	557	2.25	100	509	1.91
Plecoptera (stoneflies)									
Acroneuria	14	4	0.02	--	--	--	--	--	--
Capniidae	14	4	0.02	14	3	0.01	--	--	--
Chloroperlidae	57	15	0.08	14	5	0.02	--	--	--
Claassenia sabulosa	--	--	--	14	5	0.02	--	--	--
Doroneuria	--	--	--	14	37	0.15	--	--	--
Hesperoperla pacifica	--	--	--	14	8	0.03	--	--	--
Isoperla	--	--	--	14	14	0.06	--	--	--
Malenka	--	--	--	29	11	0.04	--	--	--
Perlodidae-early instar	--	--	--	14	15	0.06	--	--	--
Pteronarcella	--	--	--	14	5	0.02	--	--	--
Skwala	14	11	0.06	29	8	0.03	--	--	--
Sweltsa	29	43	0.23	29	142	0.57	--	--	--
Zapada cinctipes	--	--	--	29	10	0.04	--	--	--

Table 8-19. (con't) **Frequency of Occurrence (Occ), Mean Density in Number per Meter^2 (Den) and Percent Composition (%) for benthic macroinvertebrate taxa collected at Big Goose Creek, Little Goose Creek and Goose Creek, 2001 and 2002.**

	Big Goose			Little Goose			Goose		
Taxon	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**	**Occ**	**Den**	**%**
Trichoptera (caddis flies)									
Arctopsyche grandis	--	--	--	14	6	0.02	--	--	--
Brachycentrus americanus	--	--	--	14	11	0.04	--	--	--
Brachycentrus occidentalis	14	20	0.11	--	--	--	--	--	--
Cheumatopsyche	86	69	0.37	57	623	2.51	60	44	0.17
Chimarra	86	616	3.29	71	1830	7.38	20	182	0.68
Culoptila	29	15	0.08	14	171	0.69	--	--	--
Dolophilodes	--	--	--	14	33	0.13	--	--	--
Glossosoma	--	--	--	14	11	0.04	--	--	--
Helicopsyche borealis	100	2248	12.00	100	582	2.35	100	558	2.09
Hydropsyche	100	474	2.53	100	1989	8.02	60	42	0.16
Hydroptila	71	133	0.71	57	117	0.47	20	90	0.34
Lepidostoma Pluviale group	29	974	5.20	43	878	3.54	--	--	--
Leucotrichia	14	12	0.06	14	5	0.02	--	--	--
Micrasema	14	17	0.09	29	54	0.22	--	--	--
Nectopsyche	86	150	0.80	14	619	2.50	80	279	1.05
Neotrichia	29	19	0.10	--	--	--	--	--	--
Neureclipsis	14	4	0.02	--	--	--	--	--	--
Oecetis	100	336	1.79	100	184	0.74	60	188	0.71
Oligophlebodes	14	161	0.86	14	229	0.92	--	--	--
Oxyethira	14	3	0.02	--	--	--	--	--	--
Polycentropus	29	48	0.26	--	--	--	20	1	<0.01
Protoptila	14	54	0.29	29	566	2.28	--	--	--
Psychomyia	43	7	0.04	--	--	--	--	--	--
Rhyacophila Angelita group	--	--	--	14	5	0.02	--	--	--
Rhyacophila Brunnea group	--	--	--	14	69	0.28	--	--	--
Rhyacophila Coloradensis group	--	--	--	14	12	0.05	--	--	--
Rhyacophila Hyalinata group	--	--	--	14	27	0.11	--	--	--
Rhyacophila pellisa	--	--	--	14	16	0.06	--	--	--
Rhyacophila-early instar	--	--	--	14	6	0.02	--	--	--
Turbellaria (flatworms)									
Turbellaria	100	579	3.09	86	675	2.72	100	839	3.15

Table 8-20. Ten most dominant macroinvertebrate taxa based on mean abundance (no./meter^2), rank (in parenthesis) for each taxon by water body, Tolerance Value (TV) and Functional Feeding Group (FFG) designation in the Goose Creek Watershed Assessment Project area, 2001 and 2002

Taxon (group)	All Stations	Goose Creek	Big Goose Creek	Little Goose Creek	TV	FFG*
Tricorythodes minutus (mayfly)	2535 (1)	5346 (1)	1364 (3)	1559 (4)	7	CG
Microcylloepus (riffle beetle)	2517 (2)	2831 (3)	2403 (1)	2339 (1)	7	SC
Rheotanytarsus (midge fly)	1228 (3)	2430 (4)	900 (5)	610 (14)	6	CF
Helicopsyche borealis (caddisfly)	1189 (4)	558 (14)	2248 (2)	582 (15)	7	SC
Chimarra (caddisfly)	1086 (5)	182 (22)	616 (7)	1830 (3)	5	CF
Fossaria (snail)	1064 (6)	1700 (5)	606 (8)	888 (5)	8	CG
Hydropsyche (caddisfly)	1022 (7)	42 (41)	474 (15)	1989 (2)	7	CF
Cricotopus (midge fly)	924 (8)	2893 (2)	99 (32)	402 (20)	7	CG
Lepidostoma Pluviale Grp. (caddisfly)	916 (9)	0 (–)	974 (4)	878 (6)	5	SH
Fallceon quilleri (mayfly)	909 (10)	1245 (7)	833 (6)	704 (10)	4	CG

FFG* = CG = Collector Gatherer; SC = Scraper; CF = Collector Filterer; SH = Shredder.

Table 8-21. Mean habitat assessment score, weighted embeddedness value and current velocity for Goose Creek stations, 2001 and 2002.

	GC1	GC1A	GC1B	GC2	GC3
Habitat Parameter					
Substrate / Percent Fines	9.5	16.0	9.5	12.5	10.0
Instream Cover	7.5	12.0	4.0	5.5	7.5
Embeddedness	6.0	8.0	7.5	9.0	4.0
Velocity / Depth	13.5	8.5	13.5	12.0	7.0
Channel Flow Status	18.5	18.5	16.5	18.0	17.5
Channel Shape	9.5	10.0	10.0	10.0	6.0
Pool Riffle Ratio	11.5	2.0	7.5	9.0	2.0
Channelization	10.0	9.5	9.0	6.5	3.5
Width Depth Ratio	3.0	7.0	3.5	4.0	1.5
Bank Vegetation Protection	9.0	8.3	8.8	9.0	9.3
Bank Stability	9.0	7.5	9.0	8.3	9.3
Disruptive Pressures	8.5	8.8	8.8	9.0	7.5
Riparian Zone Width	7.3	6.5	6.0	7.3	3.3
TOTAL SCORE	122.8	122.5	113.5	120.0	88.3
Weighted Embeddedness	45.8	64.5	34.9	40.5	47.9
Current Velocity	1.5	1.6	1.3	1.2	1.9

Table 8-22. Mean habitat assessment score, weighted embeddedness value and current velocity for Big Goose Creek and Little Goose Creek stations, 2001 and 2002.

	BG2	BG4	BG8	BG10	BG14	BG15	BG18	LG2A	LG5	LG7	LG10	LG18A	LG21	LG22
Habitat Parameter														
Substrate / Percent Fines	12.5	13.5	17.0	15.5	16.0	13.5	10.0	11.0	13.0	10.5	14.0	15.0	16.0	17.5
Instream Cover	6.0	8.5	8.0	13.0	18.0	14.0	17.5	3.5	4.5	6.5	15.5	17.0	19.5	20.0
Embeddedness	6.5	8.0	7.5	12.0	15.0	16.0	18.5	8.0	10.0	10.5	12.0	12.5	11.0	15.0
Velocity / Depth	12.5	17.0	16.0	17.5	10.0	16.0	17.5	11.0	17.0	13.5	12.5	13.0	13.5	16.0
Channel Flow Status	13.5	15.5	15.0	16.5	16.5	15.0	15.5	18.5	18.5	18.5	15.5	16.5	16.5	14.5
Channel Shape	6.5	10.0	7.5	8.5	8.5	8.5	6.0	9.0	11.0	9.5	9.5	8.0	8.5	7.0
Pool Riffle Ratio	8.0	14.0	7.5	12.0	8.0	7.5	14.5	12.0	11.5	6.0	9.5	6.0	8.0	13.0
Channelization	9.0	11.0	6.5	11.5	14.5	15.0	14.0	3.0	14.0	11.0	9.5	9.5	12.0	13.5
Width Depth Ratio	3.0	4.5	5.5	7.0	2.0	2.5	3.5	2.5	6.0	7.5	5.5	2.5	3.5	4.5
Bank Vegetation Protection	7.3	8.5	7.3	8.3	8.3	10.0	10.0	8.5	9.5	9.3	9.5	6.5	9.0	9.3
Bank Stability	8.8	8.0	6.5	7.8	7.3	9.5	10.0	9.0	9.3	9.5	8.0	7.8	8.8	10.0
Disruptive Pressures	8.0	7.3	9.5	9.3	7.8	8.5	9.5	8.5	10.0	9.3	9.3	6.5	8.0	8.3
Riparian Zone Width	6.5	6.8	7.5	8.3	8.0	9.5	9.5	4.0	10.0	6.8	9.3	5.0	9.0	9.3
TOTAL SCORE	108.0	132.5	121.3	147.0	139.8	145.5	156.0	108.5	144.3	128.3	139.5	125.8	143.3	157.8
Weighted Embeddedness	42.8	53.5	57.4	71.4	90.0	75.0	87.0	32.6	37.4	44.0	82.1	87.6	97.4	98.7
Current Velocity	1.2	1.0	1.3	1.5	0.9	0.8	0.8	1.5	1.2	1.5	1.3	0.9	0.8	1.1

Table 8-23. Mean percent substrate composition for Goose Creek, Big Goose Creek and Little Goose Creek stations, 2001 and 2002.

Station	% Cobble	% Coarse Gravel	% Fine Gravel	% Silt	% Sand
Goose Creek GC1	40	21	12	6	21
Goose Creek GC1A	32	39	21	0	8
Goose Creek GC1B	58	5	7	17	13
Goose Creek GC2	39	24	17	5	15
Goose Creek GC3	41	25	10	13	11
Big Goose Creek BG2	64	11	9	4	12
Big Goose Creek BG4	71	11	4	9	5
Big Goose Creek BG8	73	16	4	3	5
Big Goose Creek BG10	83	5	3	3	7
Big Goose Creek BG14	82	6	4	1	8
Big Goose Creek BG15	63	17	7	4	10
Big Goose Creek BG18	55	11	9	14	10
Little Goose Creek LG2A	41	30	10	2	19
Little Goose Creek LG5	20	47	19	5	10
Little Goose Creek LG7	30	36	14	5	15
Little Goose Creek LG10	65	15	7	1	11
Little Goose Creek LG18A	54	19	16	4	7
Little Goose Creek LG21	75	10	6	3	6
Little Goose Creek LG22	59	13	22	1	6

Table 8-24. Mean total habitat scores and weighted embeddedness values for stations in the Project area compared to habitat scores and embeddedness values presented in 10th percentile intervals for 129 plains stream stations in the Northwestern Great Plains (NGP) ecoregion of Wyoming.

Goose Creek			Big Goose Creek			Little Goose Creek		
Station	**Habitat Score**	**Embed-dedness**	**Station**	**Habitat Score**	**Embed-dedness**	**Station**	**Habitat Score**	**Embed-dedness**
GC1	122.8	45.8	BG2	108.0	42.8	LG2A	108.5	32.6
GC1A	122.5	64.5	BG4	132.5	53.5	LG5	144.3	37.4
GC1B	113.5	34.9	BG8	121.3	57.4	LG7	128.3	44.0
GC2	120.0	40.5	BG10	147.0	71.4	LG10	139.5	82.1
GC3	88.3	47.9	BG14	139.8	90.0	LG18A	125.8	87.6
			BG15	145.5	75.0	LG21	143.3	97.4
			BG18	156.0	87.0	LG22	157.8	98.7

Range in Habitat Score and Embeddedness Value by 10th Percentile Intervals for NGP Streams			
Percentile	**Range in Habitat Scores by 10th Percentile Interval**	**Percentile**	**Range in Embeddedness Values by 10th Percentile Interval**
0.10 - 9.99%	<91.0	0.10 - 9.99%	20.0 - 21.0
10.00 - 19.99%	91.0 - 101.9	10.00 - 19.99%	21.1 - 24.6
20.00 - 29.99%	102.0 - 117.9	20.00 - 29.99%	24.7 - 30.0
30.00 - 39.99%	118.0 -126.4	30.00 - 39.99%	30.1 - 36.4
40.00 - 49.99%	126.6 - 132.4	40.00 - 49.99%	36.5 - 40.8
50.00 - 59.99%	132.5 -134.4	50.00 - 59.99%	40.9 - 49.0
60.00 - 69.99%	134.5 - 137.9	60.00 - 69.99%	49.1 - 58.0
70.00 - 79.99%	138.0 - 142.9	70.00 - 79.99%	58.1 - 68.0
80.00 - 89.99%	143.0 -151.4	80.00 - 89.99%	68.1 - 90.0
90.00 - 100.00%	151.5 - 169.0	90.00 - 99.99%	90.1 - 100.0

Table 8-25. Frequency of Occurrence for fish species reported from Goose Creek, Big Goose Creek and Little Goose Creek.

Common Name / (N = native; I = introduced)	Scientific Name	WDEQ Class	Goose Creek	Big Goose Creek	Little Goose Creek
Minnows	**Family Cyprinidae**				
Carp (I)	*Cyprinus carpio*	NG[1]	88	--	4
Creek chub (N)	*Semotilus atromaculatus*	NG	12	--	12
Fathead minnow (N)	*Pimephales promelas*	NG	38	--	16
Flathead chub (N)	*Platygobio gracilis*	NG	25	--	--
Golden shiner (I)	*Notemigonus crysoleucas*	NG	12	--	--
Lake chub (N)	*Couesius plumbeus*	NG	12	--	4
Longnose dace (N)	*Rhinichthys cataractae*	NG	38	64	36
Suckers	**Family Catostomidae**				
Longnose sucker (N)	*Catostomus catostomus*	NG	100	64	24
Mountain sucker (N)	*Catostomus platyrhynchus*	NG	62	64	28
Northern redhorse (N)	*Moxostoma macrolepidotum*	NG	100	7	--
White sucker (N)	*Catostomus commersoni*	NG	100	50	48
Catfishes	**Family Ictaluridae**				
Black bullhead (N)	*Ameiurus melas*	WWGF[2]	38	--	--
Stonecat (N)	*Noturus flavus*	WWGF	75	21	--
Sunfishes	**Family Centrarchidae**				
Bluegill (I)	*Lepomis macrochirus*	WWGF	–	--	4
Green sunfish (I)	*Lepomis cyanellus*	WWGF	50	--	8
Rock bass (I)	*Ambloplites rupestris*	WWGF	88	14	12
Smallmouth bass (I)	*Micropterus dolomieui*	WWGF	38	--	--
White crappie (I)	*Pomoxis annularis*	WWGF	12	--	--
Perches	**Family Percidae**				
Sauger (N)	*Stizostedion canadense*	WWGF2	12	--	--
Yellow perch (I)	*Perca flavescens*	WWGF2	12	--	--
Trouts and Whitefish	**Family Salmonidae**				
Brook trout (I)	*Salvelinus fontinalis*	CWGF[3]	--	--	40
Brown trout (I)	*Salmo trutta*	CWGF	62	93	84
Cutthroat trout (N)	*Onchorhynchus clarki*	CWGF	–	14	--
Rainbow trout (I)	*Oncorhynchus mykiss*	CWGF	12	57	72
Mountain whitefish (N)	*Prosopium williamsoni*	CWGF	–	57	8

NG[1] = non-game species; WWGF[2] = warm water game species; CWGF[3] = cold water game species (WDEQ, 2001a).

Figure 8-1. Mean Annual Instantaneous Temperature Values for Goose Creek and Big Goose Creek Monitoring Stations

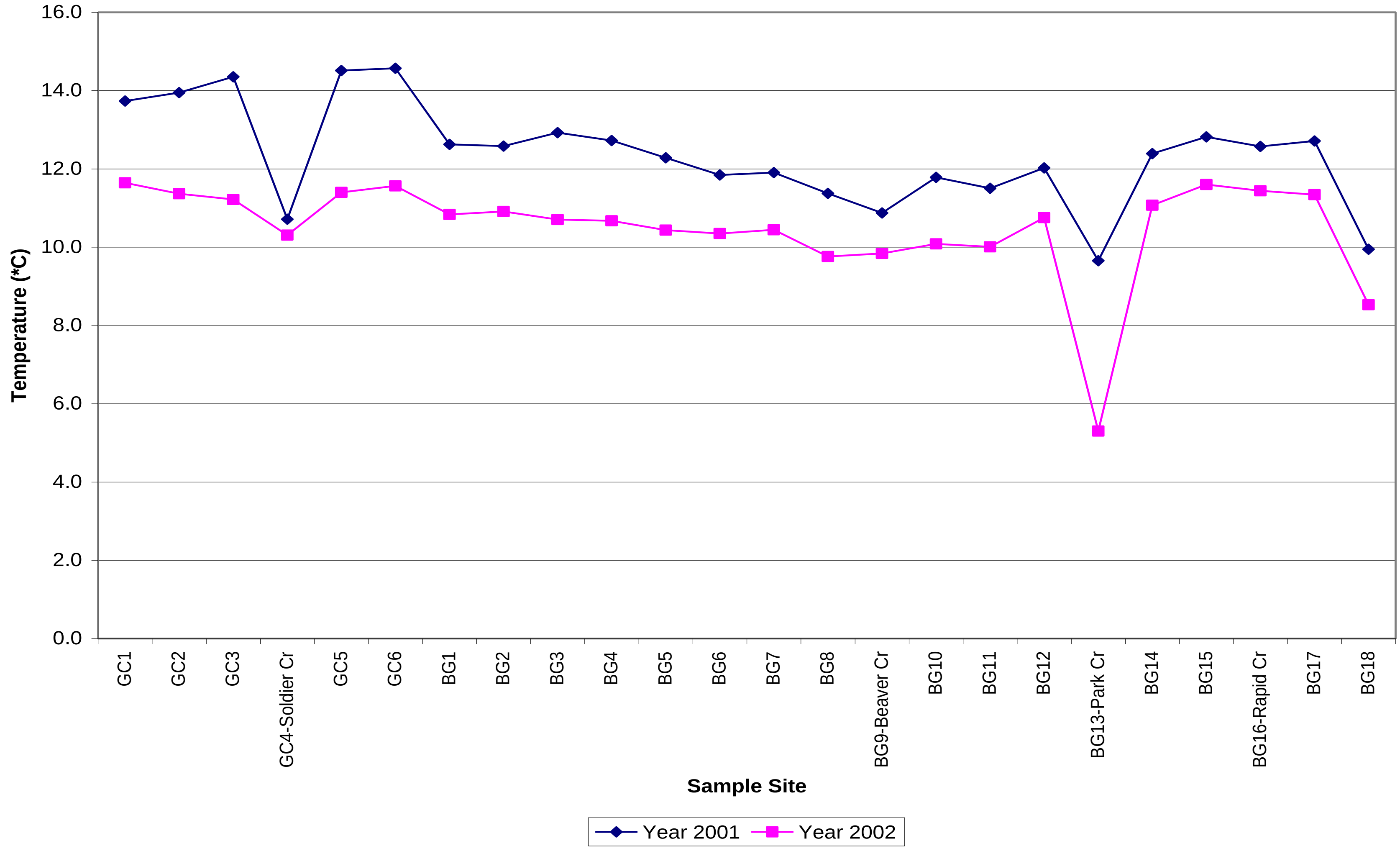


Figure 8-2. Mean Annual Instantaneous Temperature Values for Little Goose Creek Monitoring Stations

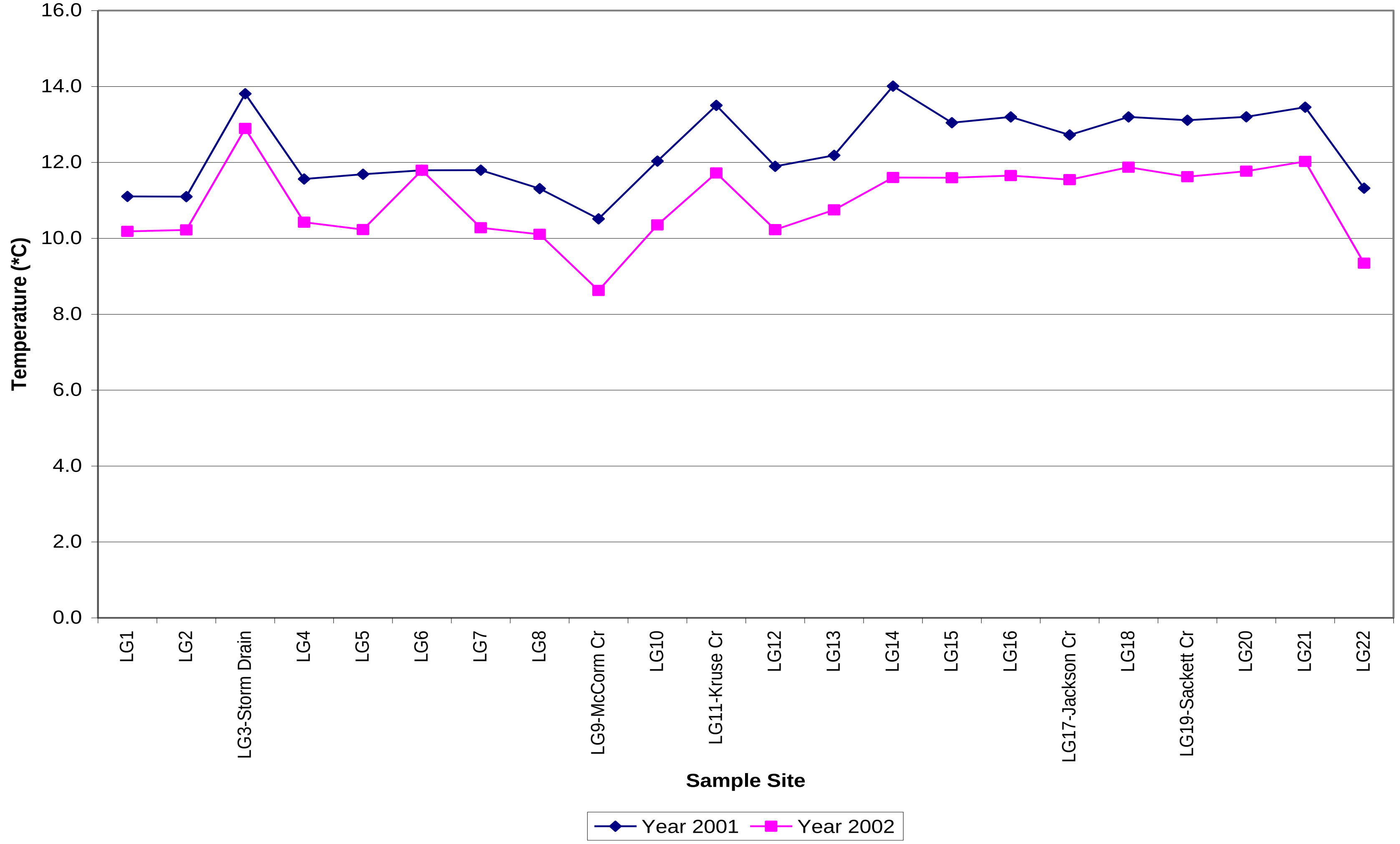


Figure 8-3. Daily Average Temperature for Goose Creek at Sample Station GC1—As Measured with a Continuous Temperature Data Logger

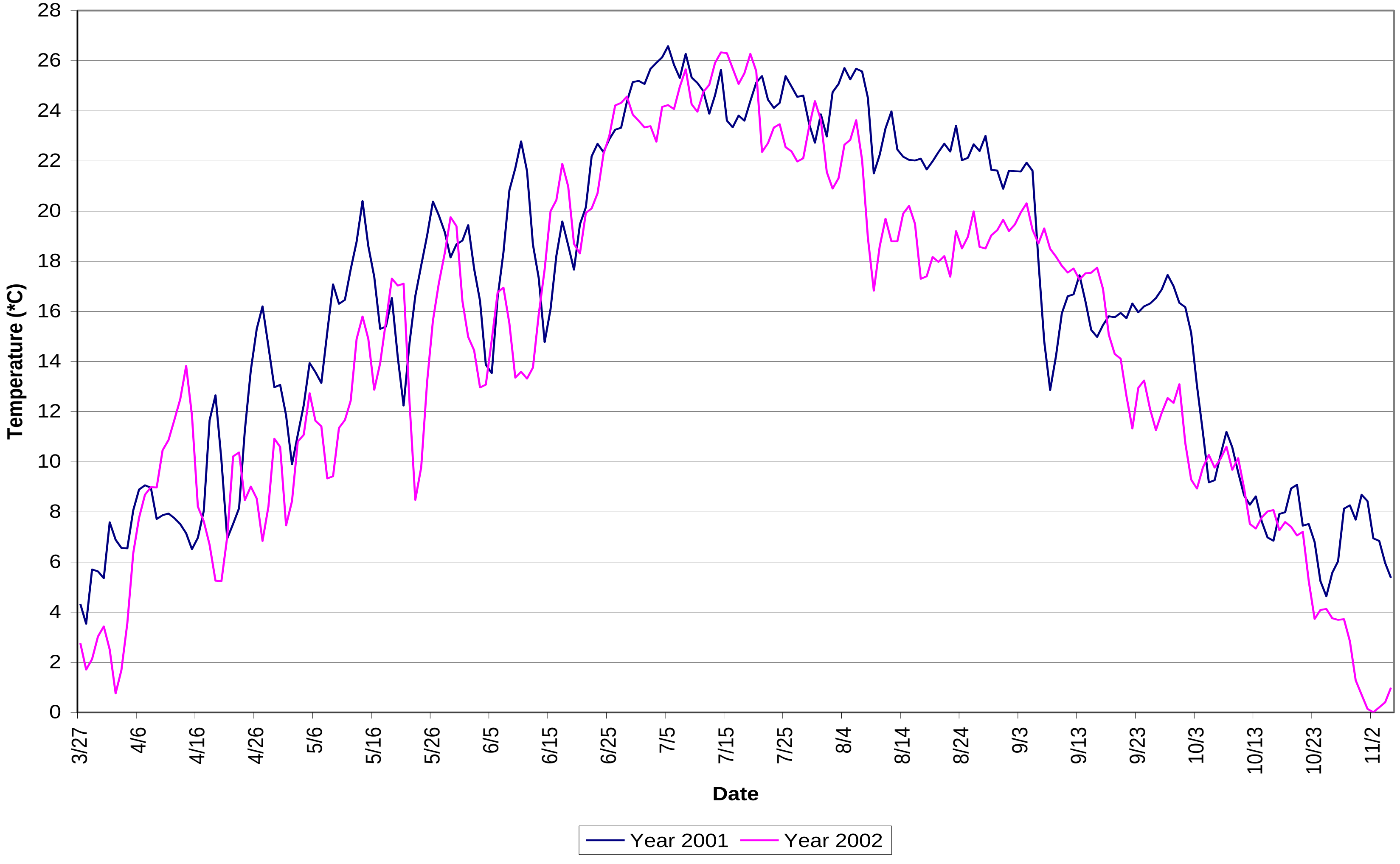


Figure 8-4. Daily Average Temperature for Big Goose Creek at Sample Station BG2—As Measured with a Continuous Temperature Data Logger

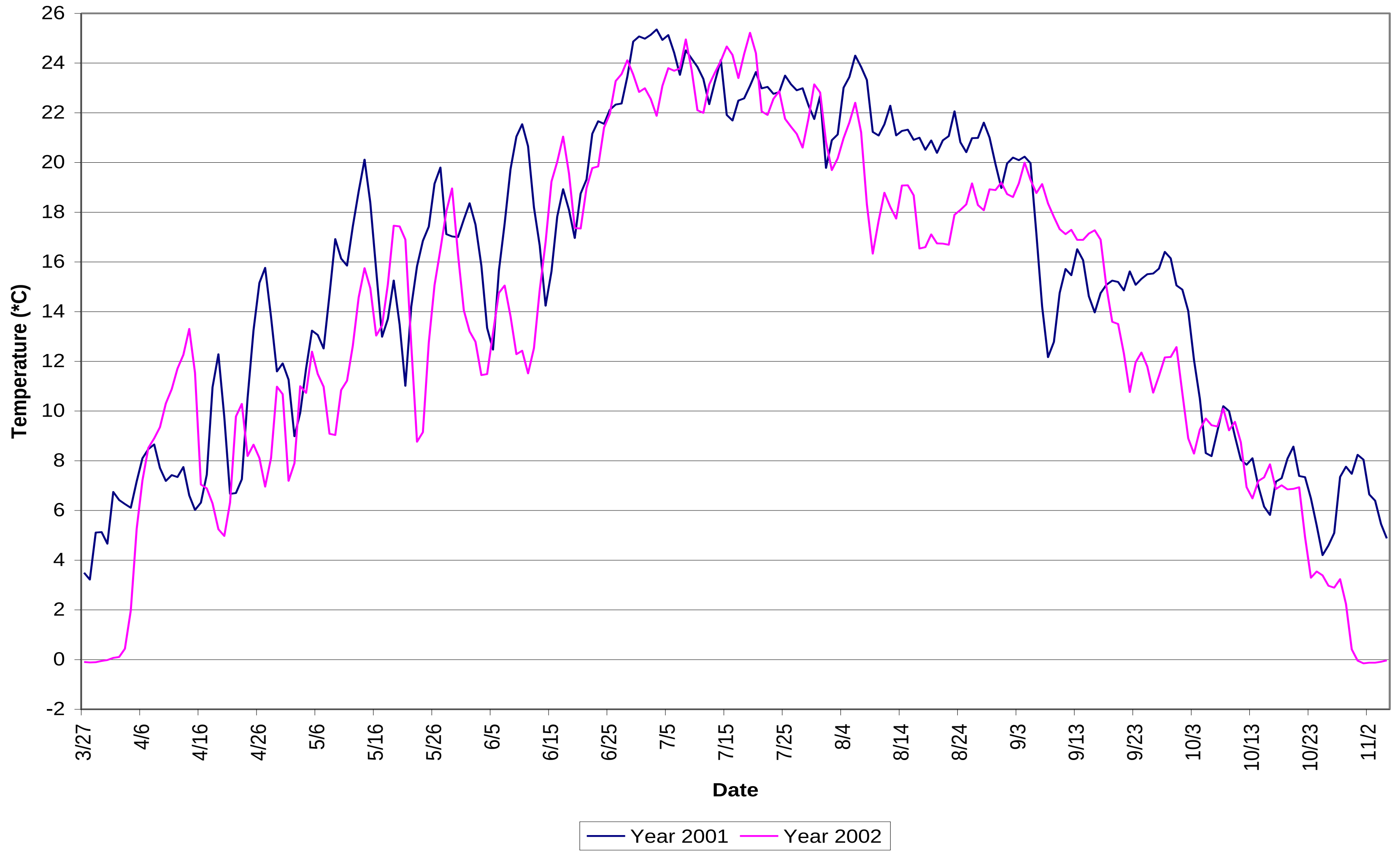


Figure 8-5. Daily Average Temperature for Big Goose Creek at Sample Station BG6—As Measured with a Continuous Temperature Data Logger

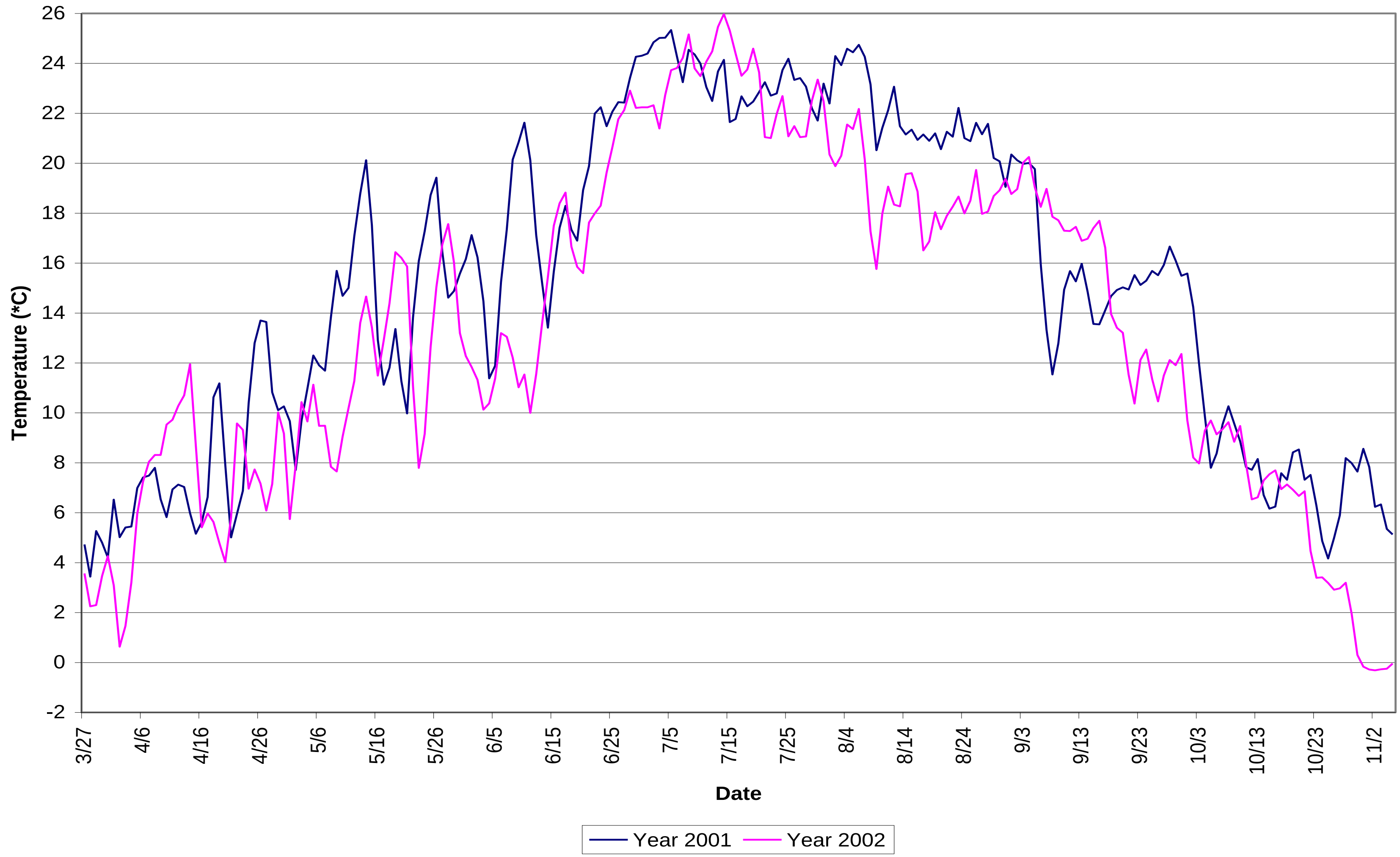


Figure 8-6. Daily Average Temperature for Big Goose Creek at Sample Station BG18—As Measured with a Continuous Temperature Data Logger

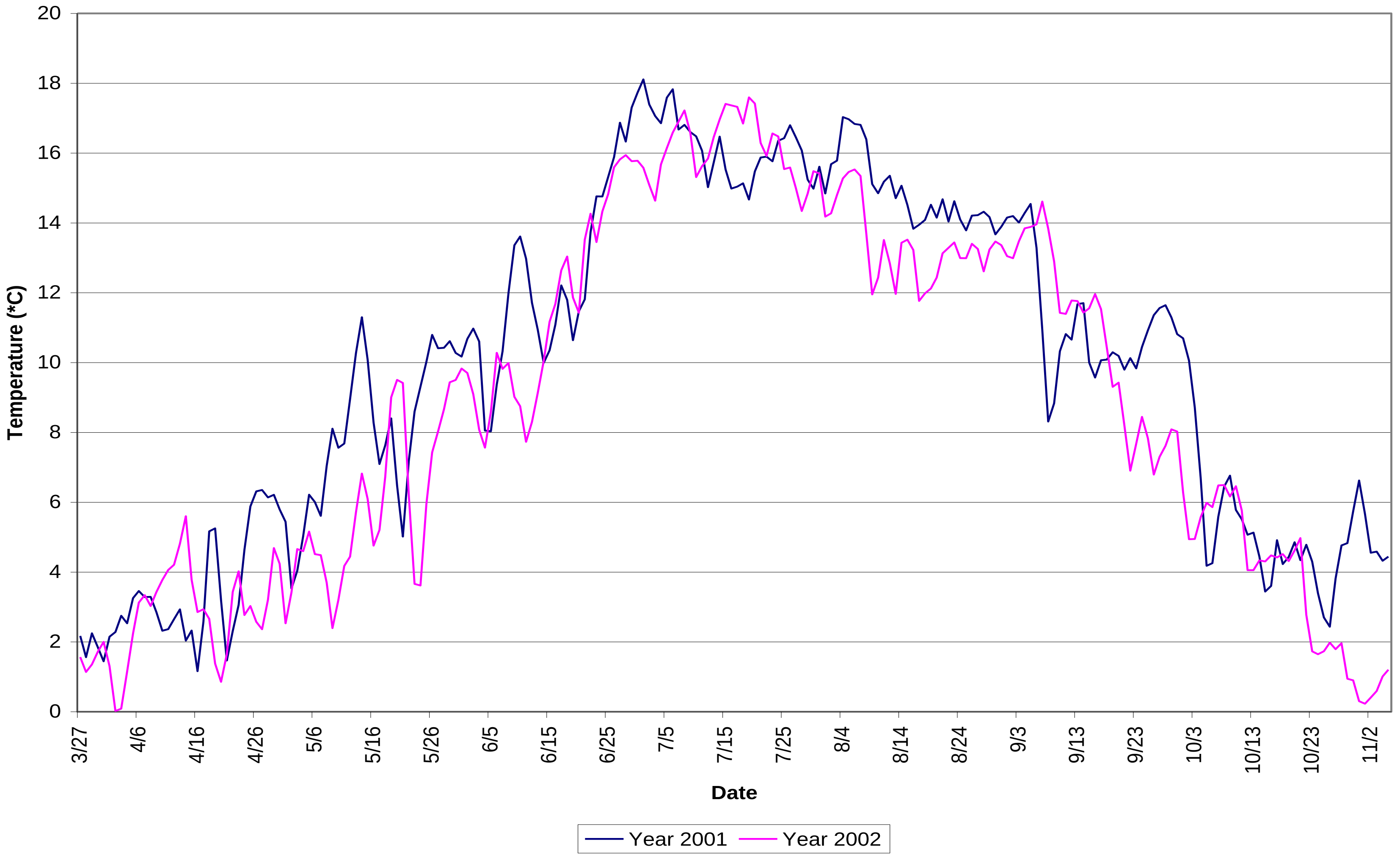


Figure 8-7. Daily Average Temperature for Little Goose Creek at Sample Station LG2—As Measured with a Continuous Temperature Data Logger

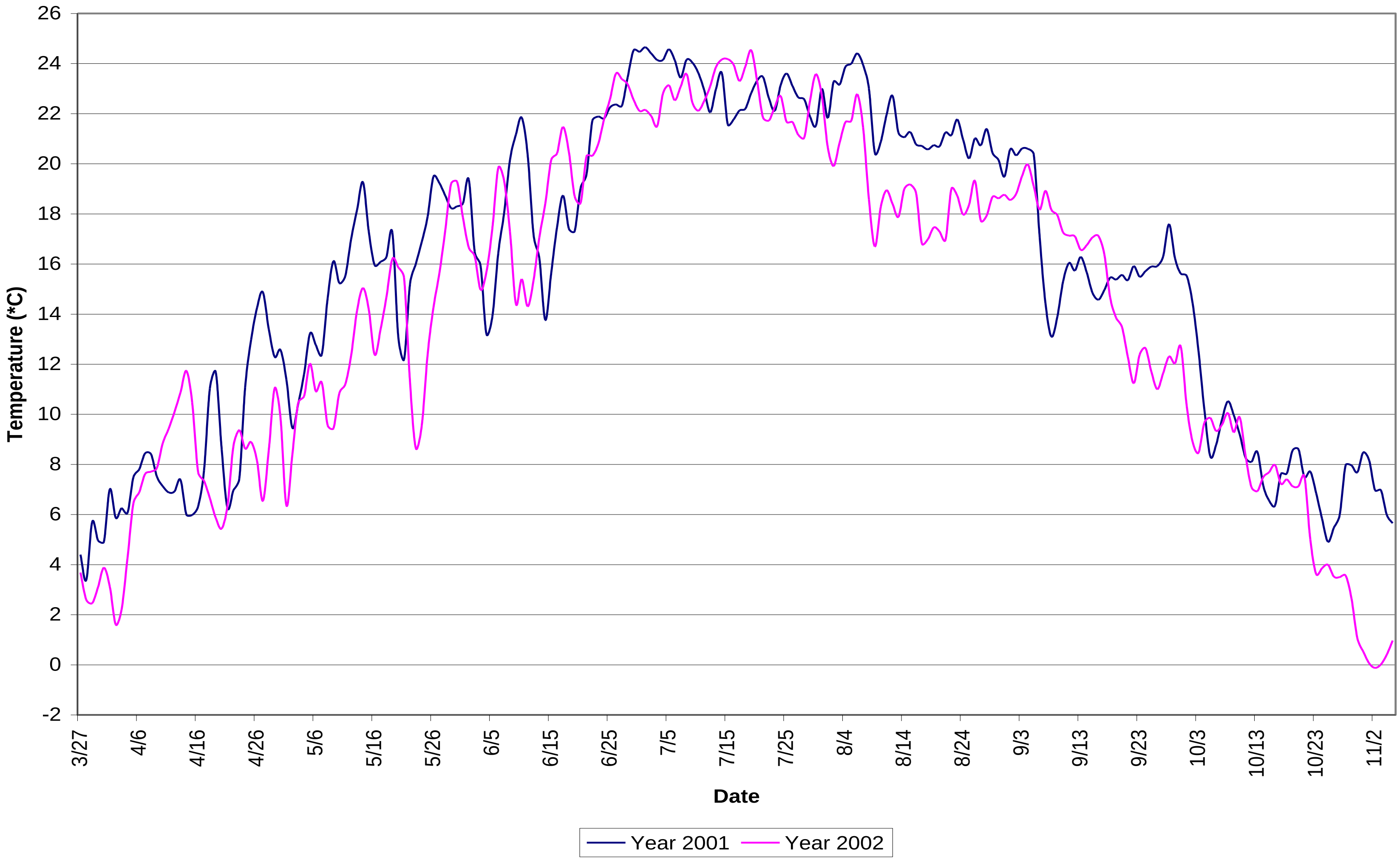


Figure 8-8. Daily Average Temperature for Little Goose Creek at Sample Station LG8—As Measured with a Continuous Temperature Data Logger

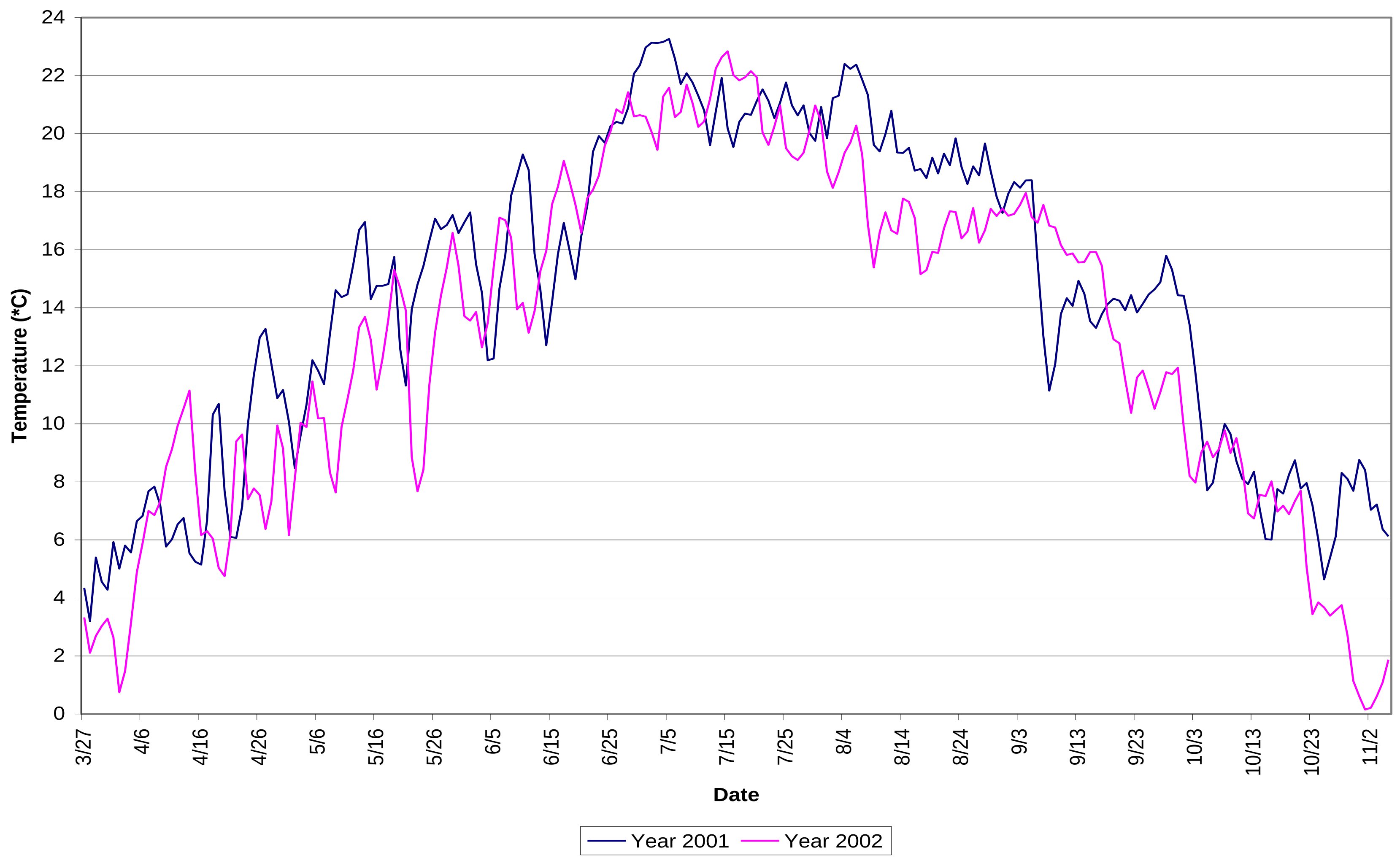


Figure 8-9. Daily Average Temperature for Little Goose Creek at Sample Station LG22—As Measured with a Continuous Temperature Data Logger

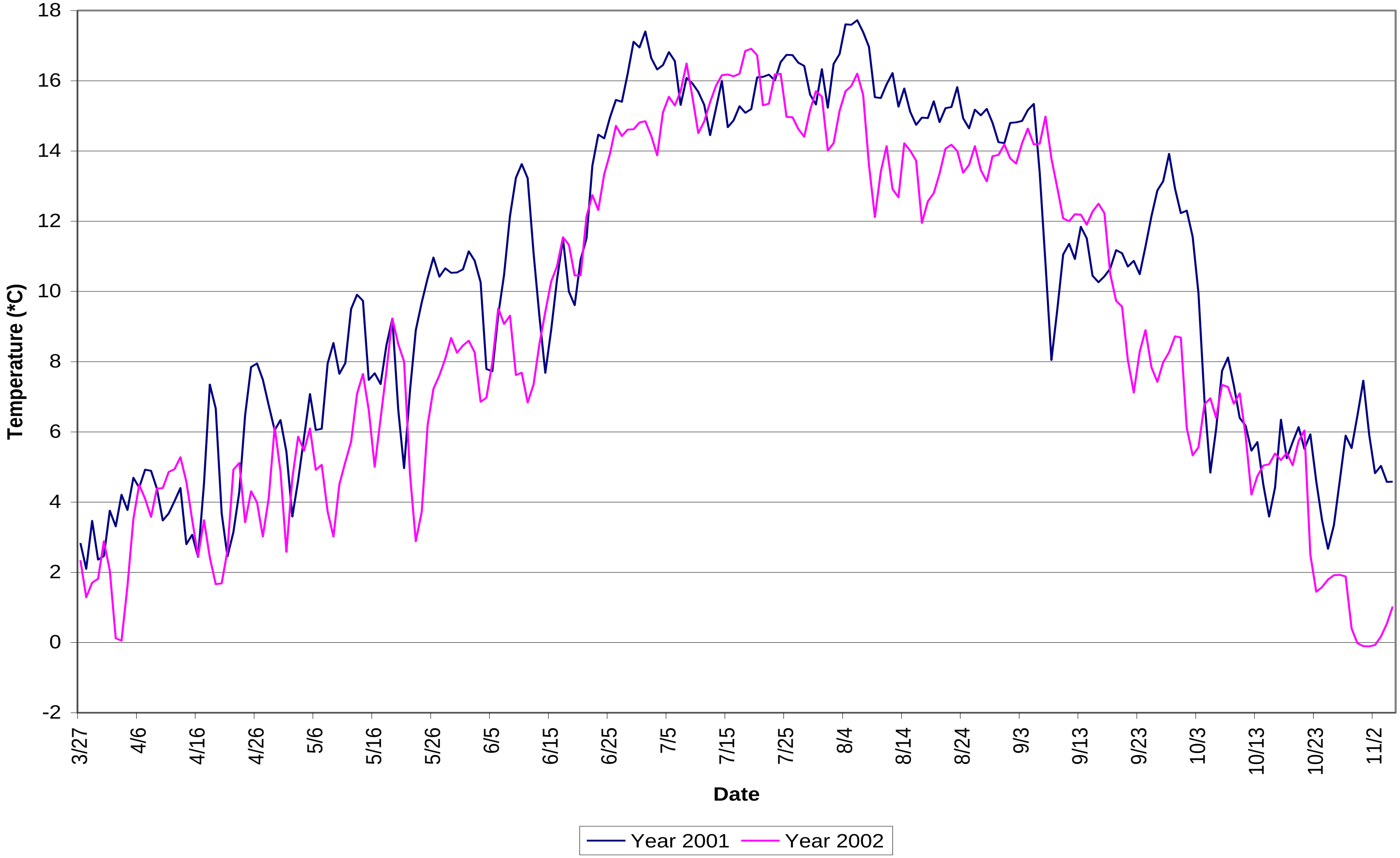


Figure 8-10. Year 2002 Daily Average Temperature for Soldier Creek (GC4), Beaver Creek (BG9), and Jackson Creek (LG17)—As Measured with Continuous Temperature Data Loggers

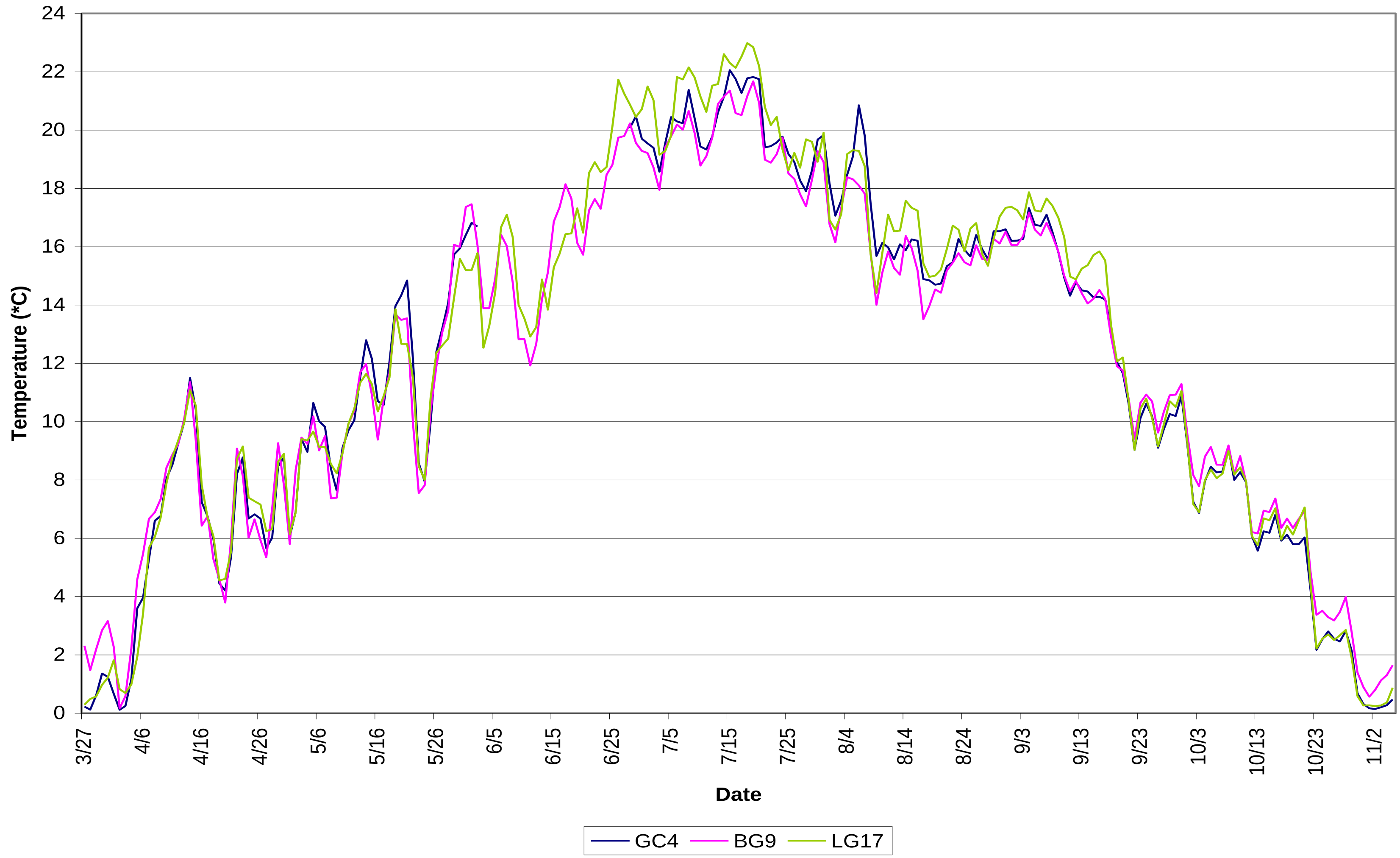


Figure 8-11. Comparison of Daily Average Water Temperatures (measured by site GC1 Continuous Temperature Data Logger) and Discharge Rates (from USGS Station No. 06305700)—Years 2001 and 2002

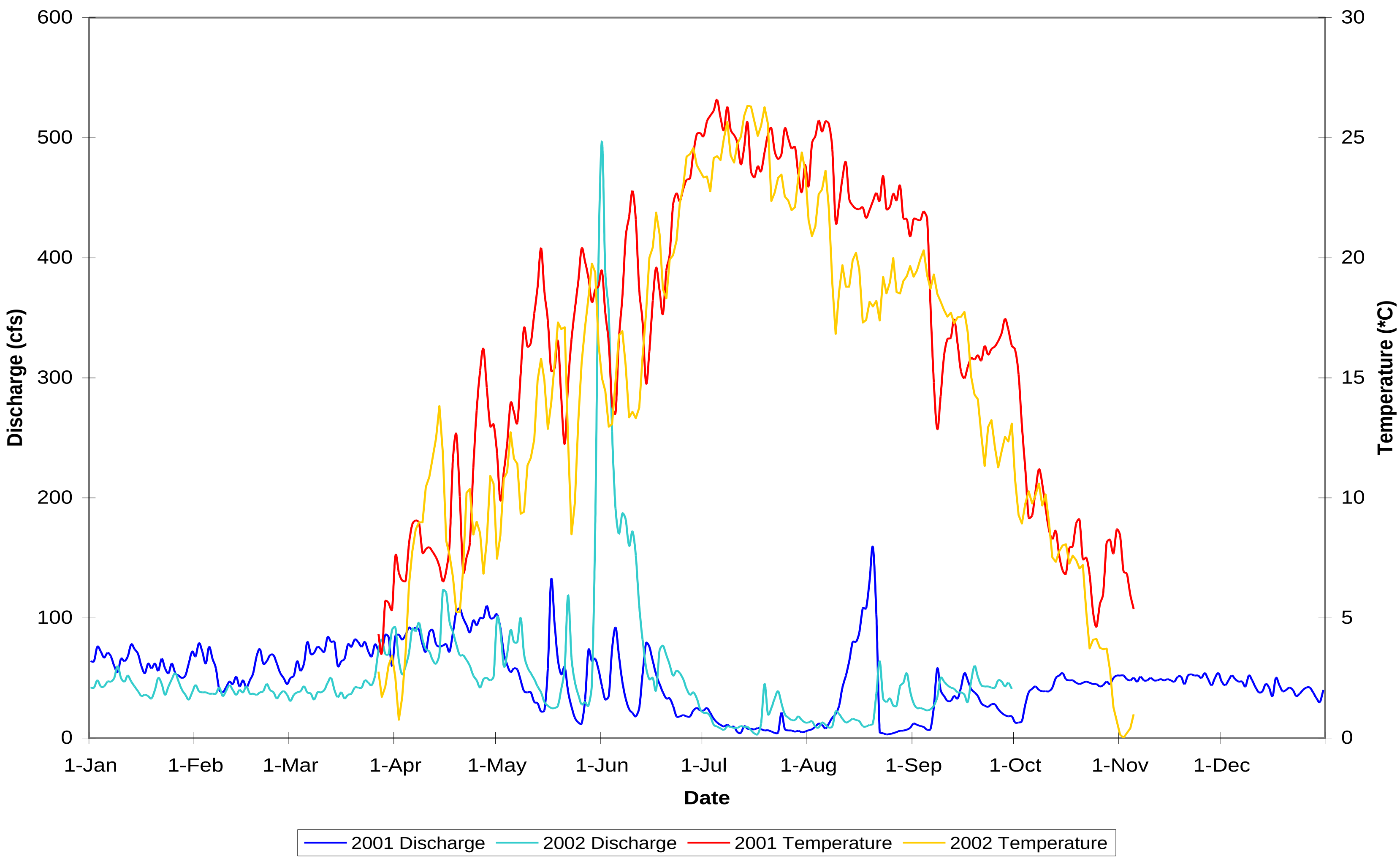


Figure 8-12. Comparison of 2001 Daily Average Air Temperature (National Weather Service Data for the Sheridan County Airport) and 2001 Daily Average Water Temperature (Goose Creek site GC1 Continuous Temperature Logger)

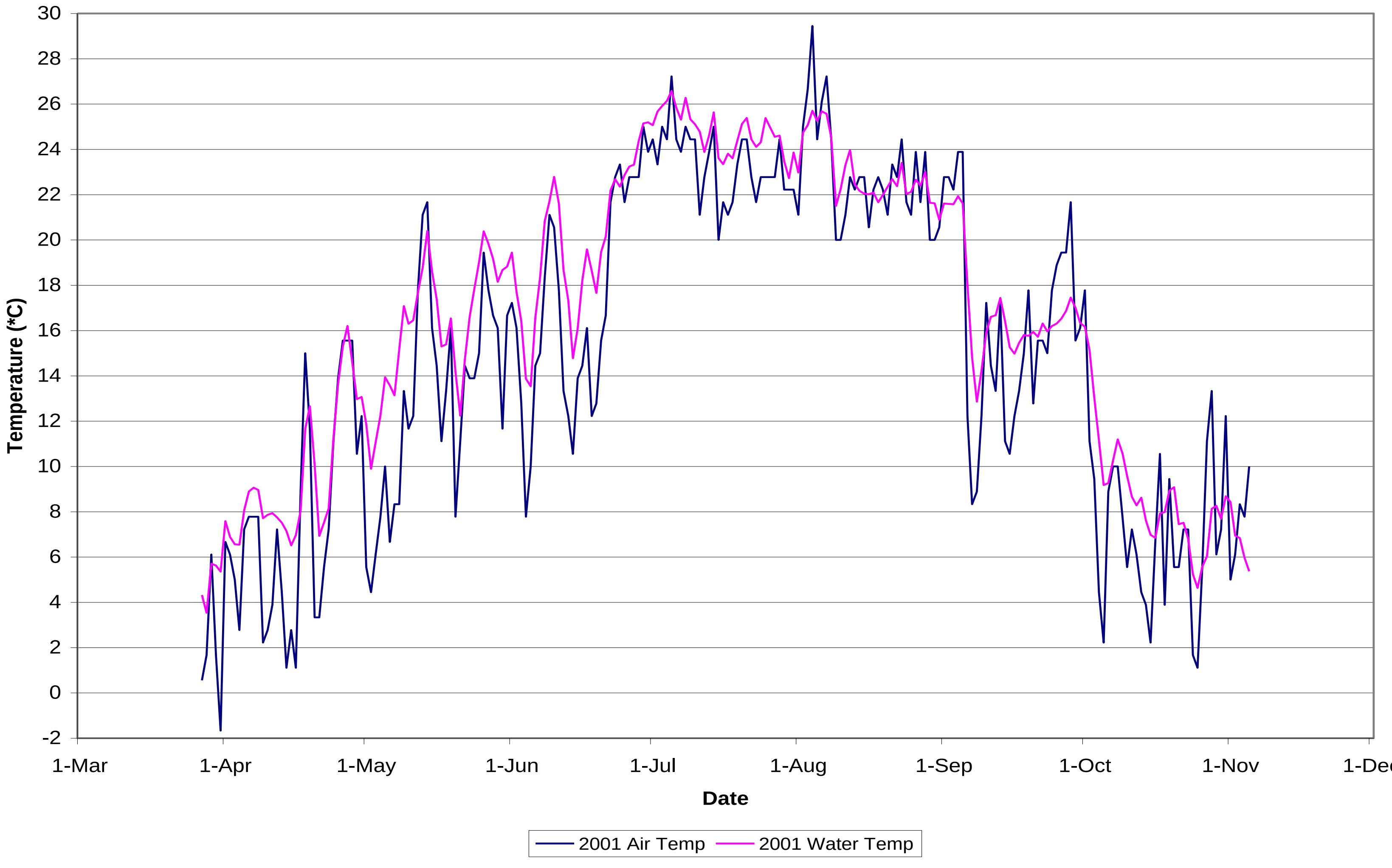


Figure 8-13. Comparison of 2002 Daily Average Air Temperature (National Weather Service Data for the Sheridan County Airport) and 2002 Daily Average Water Temperature (Goose Creek site GC1 Continuous Temperature Logger)

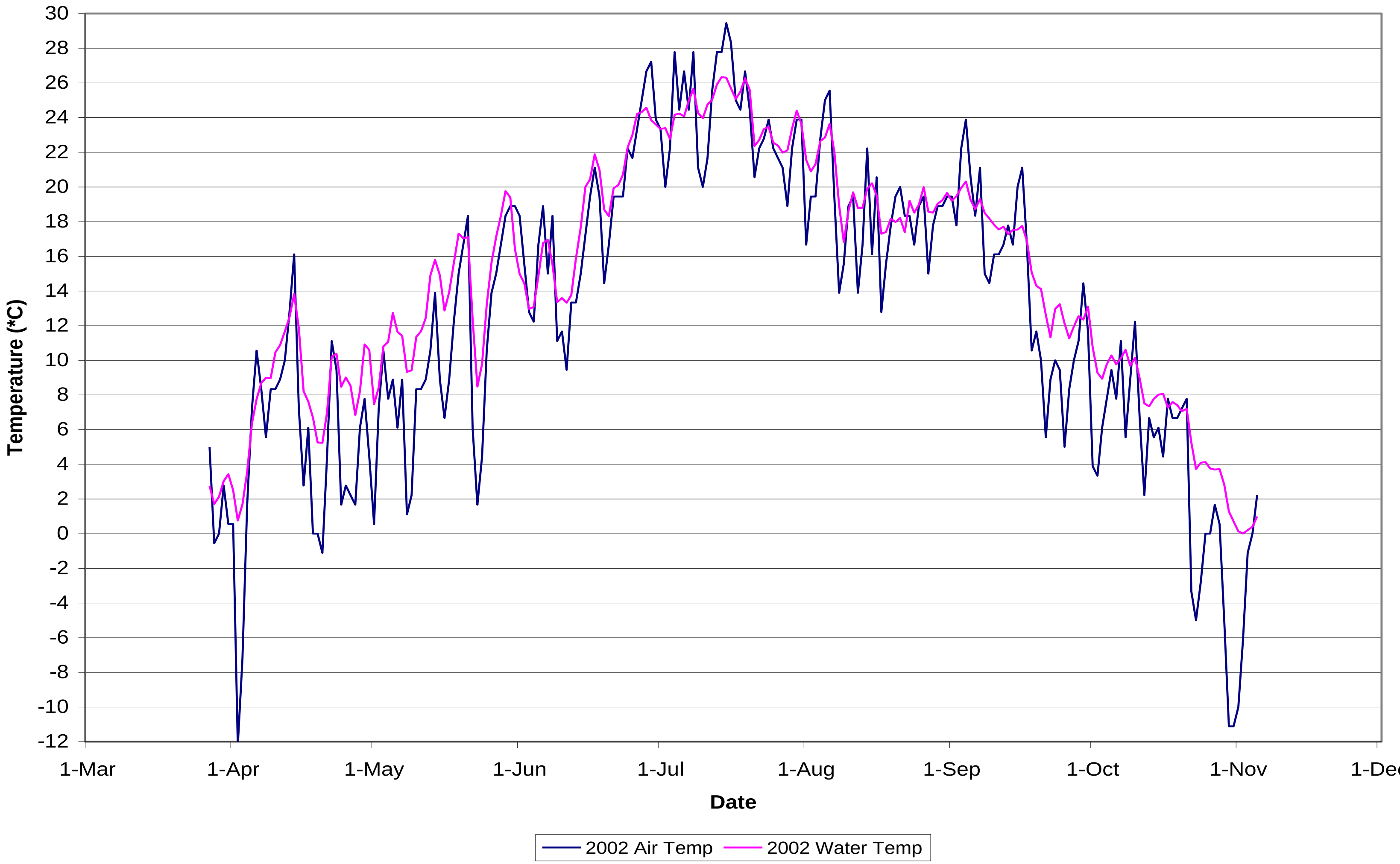


Figure 8-14. Mean Annual pH Values for Goose Creek and Big Goose Creek Monitoring Stations

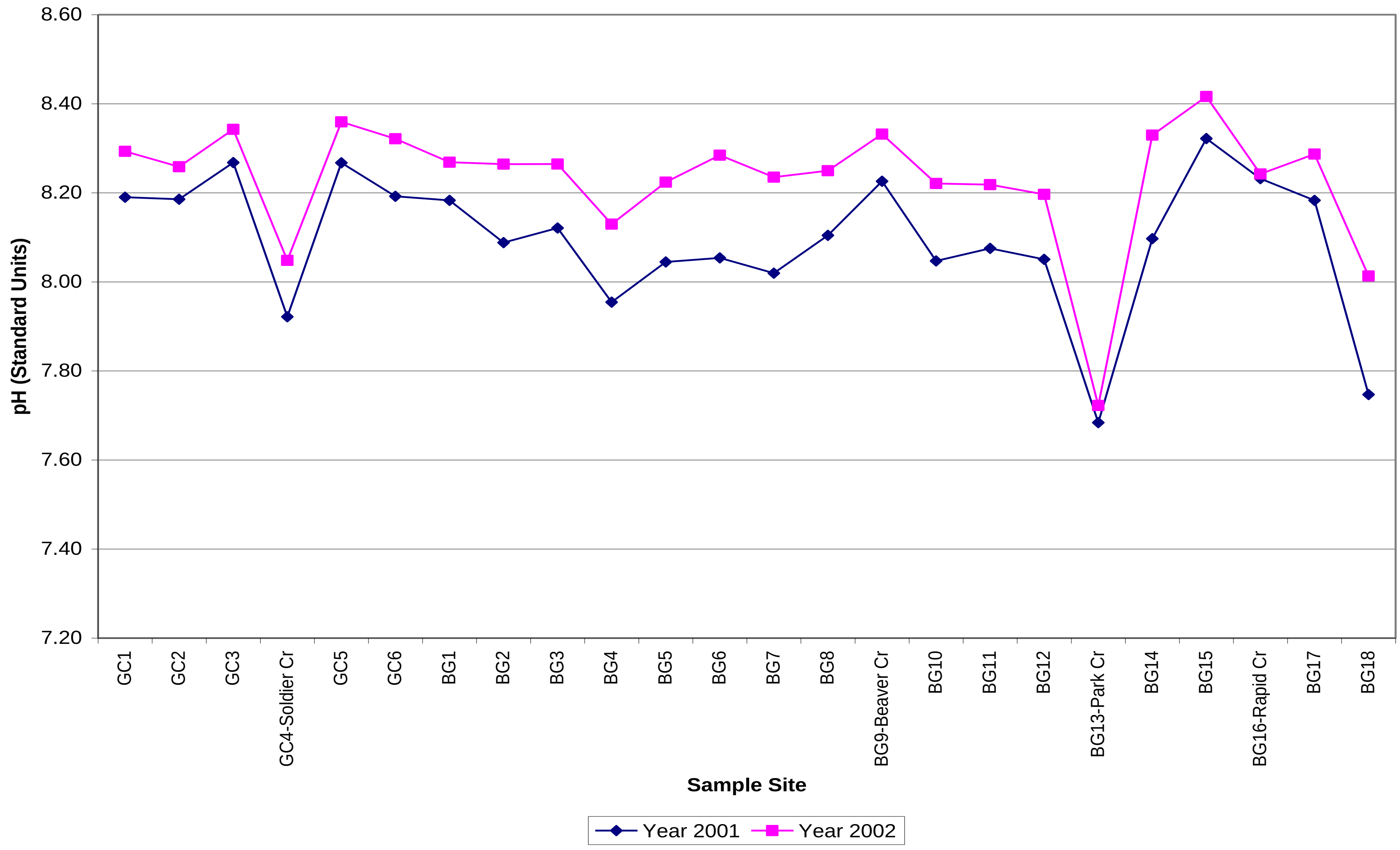


Figure 8-15. Mean Annual pH Values for Little Goose Creek Monitoring Stations

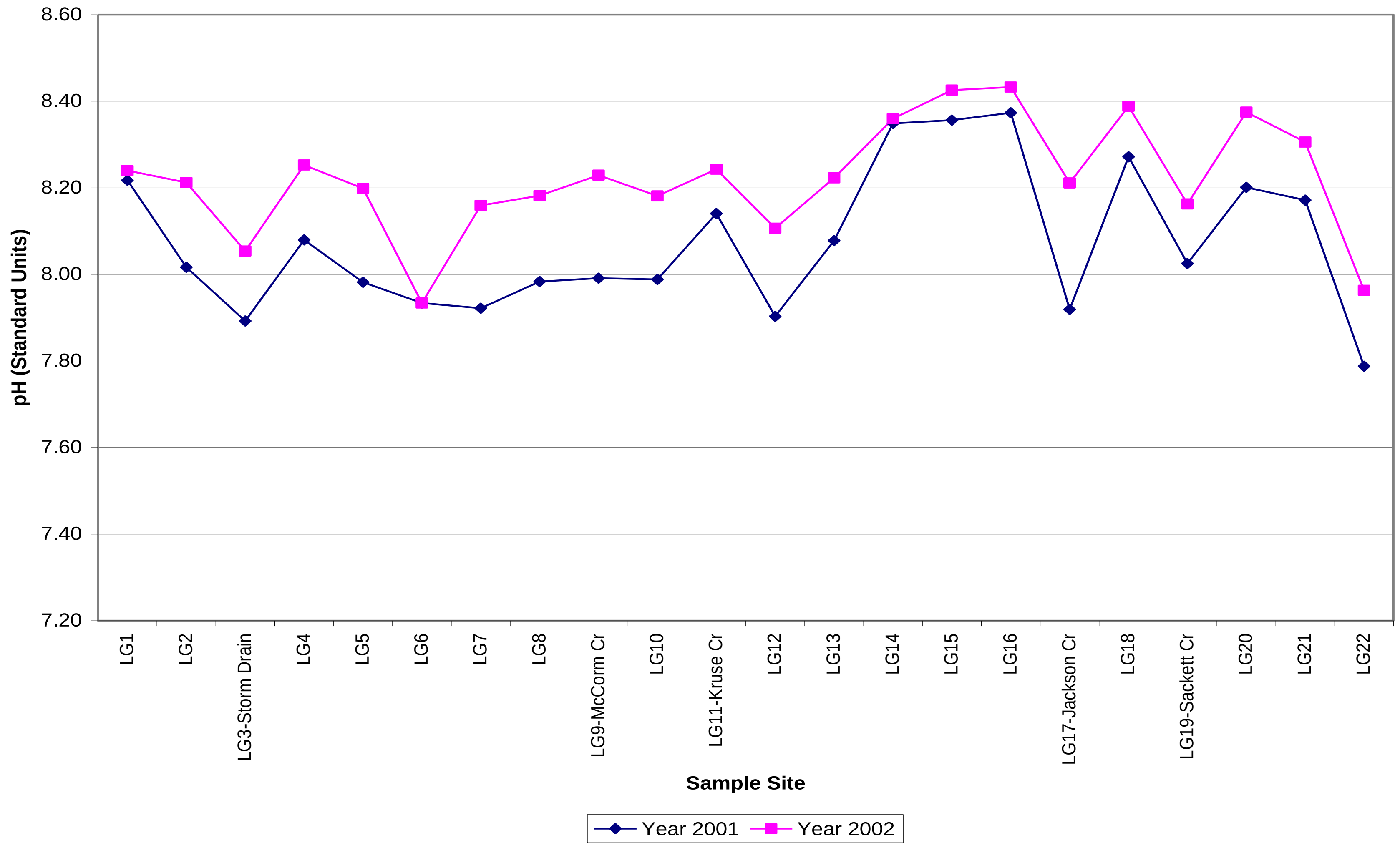


Figure 8-16. Mean Annual Conductivity Values for Goose Creek and Big Goose Creek Monitoring Stations

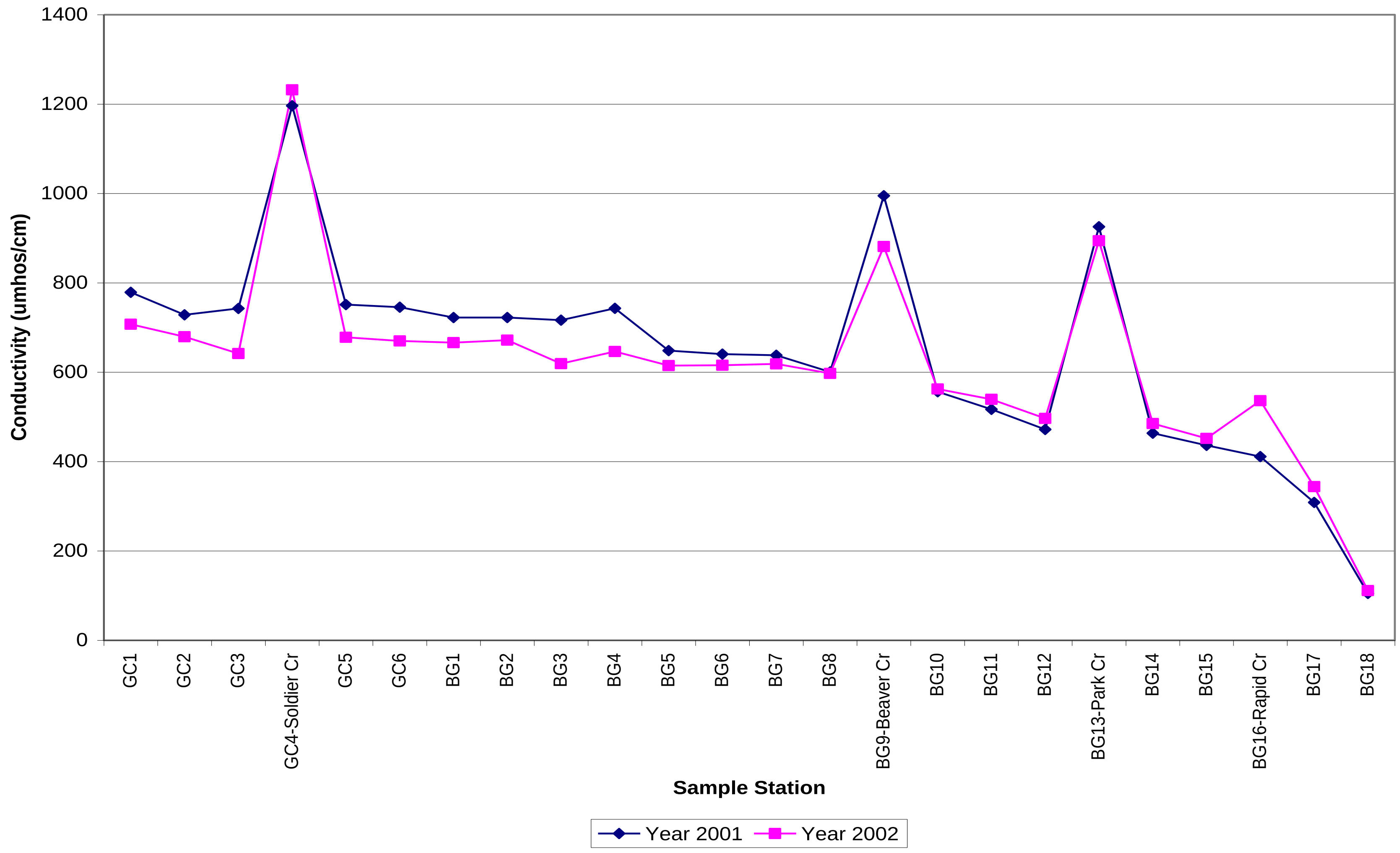


Figure 8-17. Mean Annual Conductivity Values for Little Goose Creek Monitoring Stations

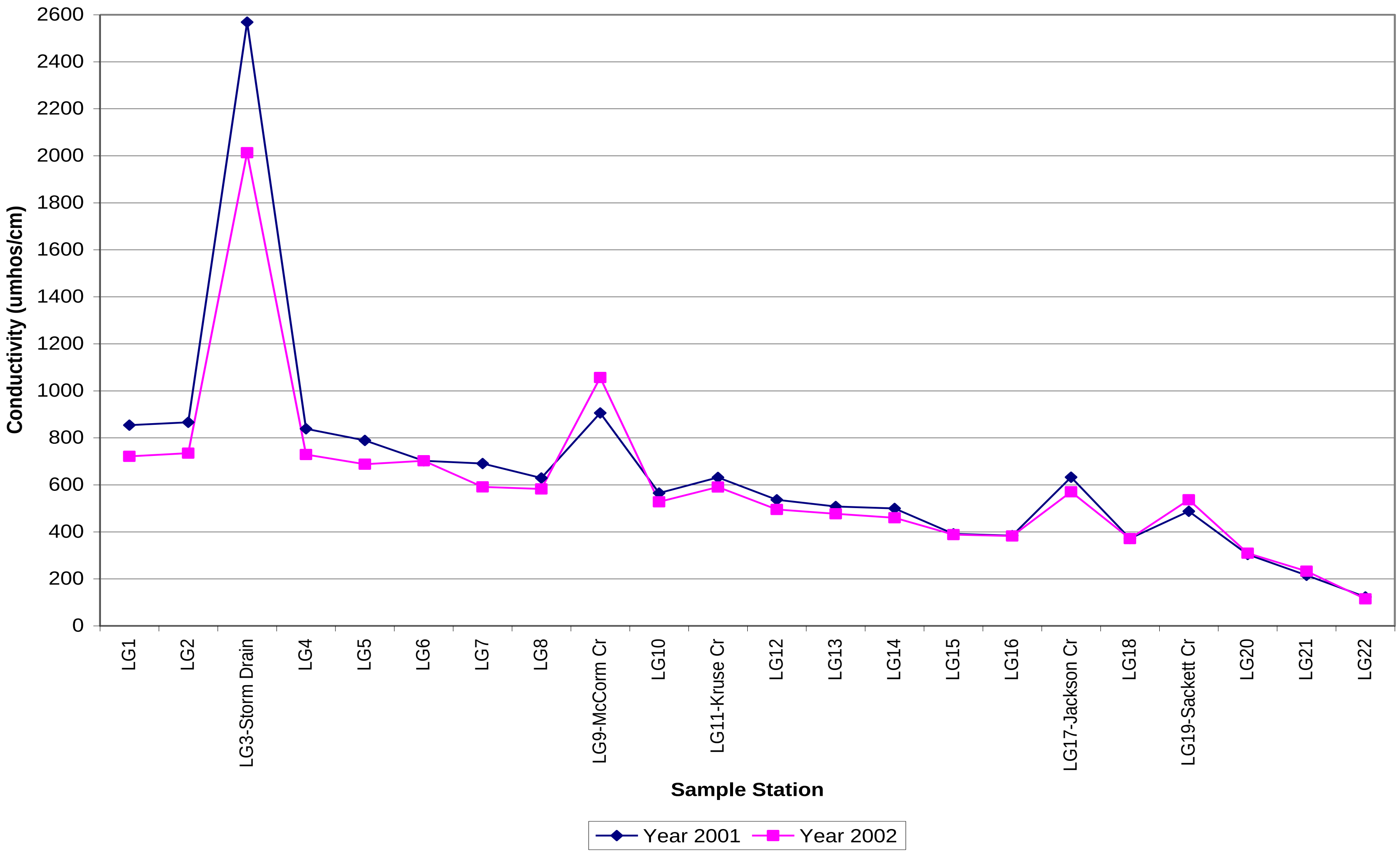


Figure 8-18. Scatterplot with Linear Regression that Shows the Relationship Between Conductivity and Discharge at Little Goose Creek site LG6

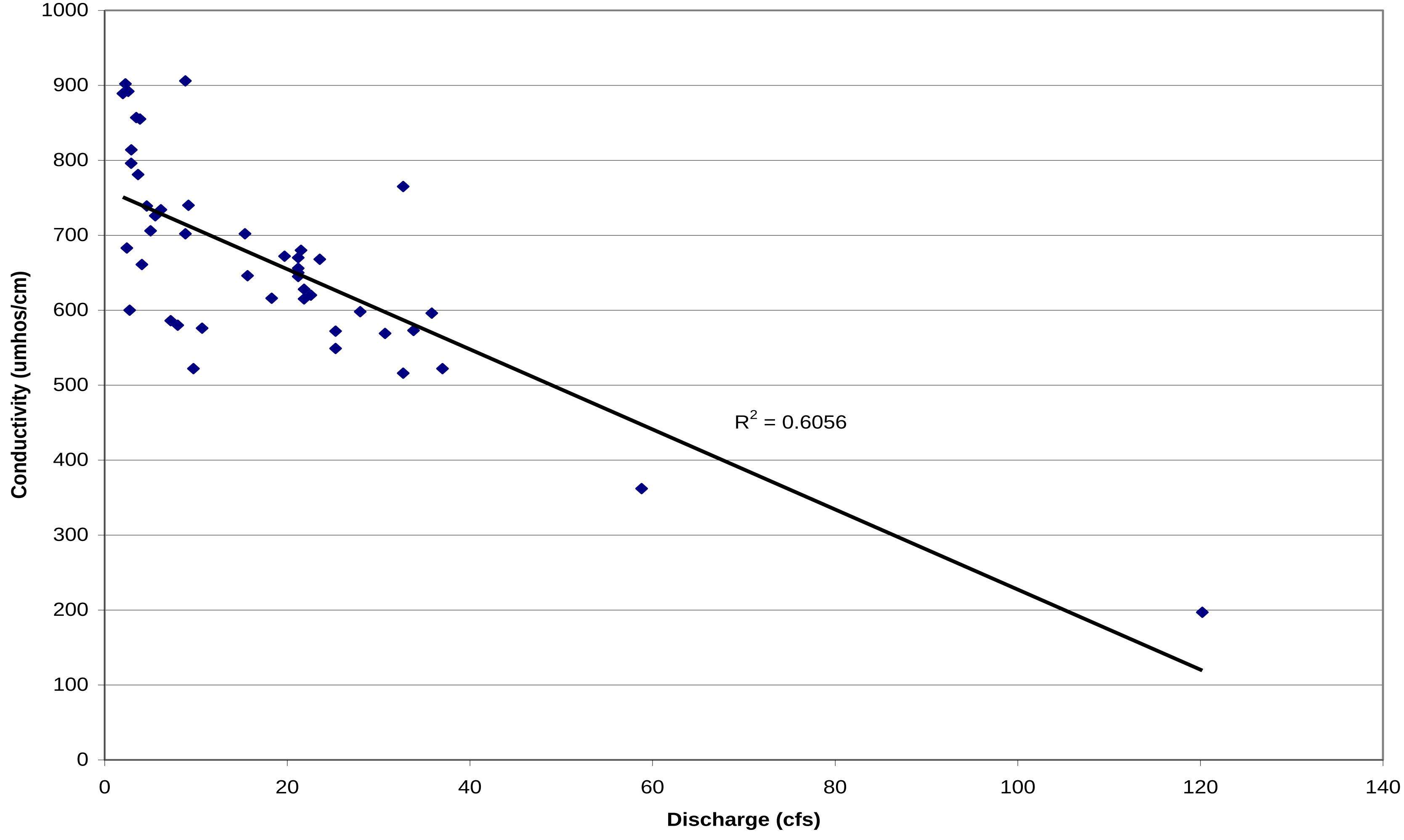


Figure 8-19. Mean Annual Dissolved Oxygen Values for Goose Creek and Big Goose Creek Monitoring Stations

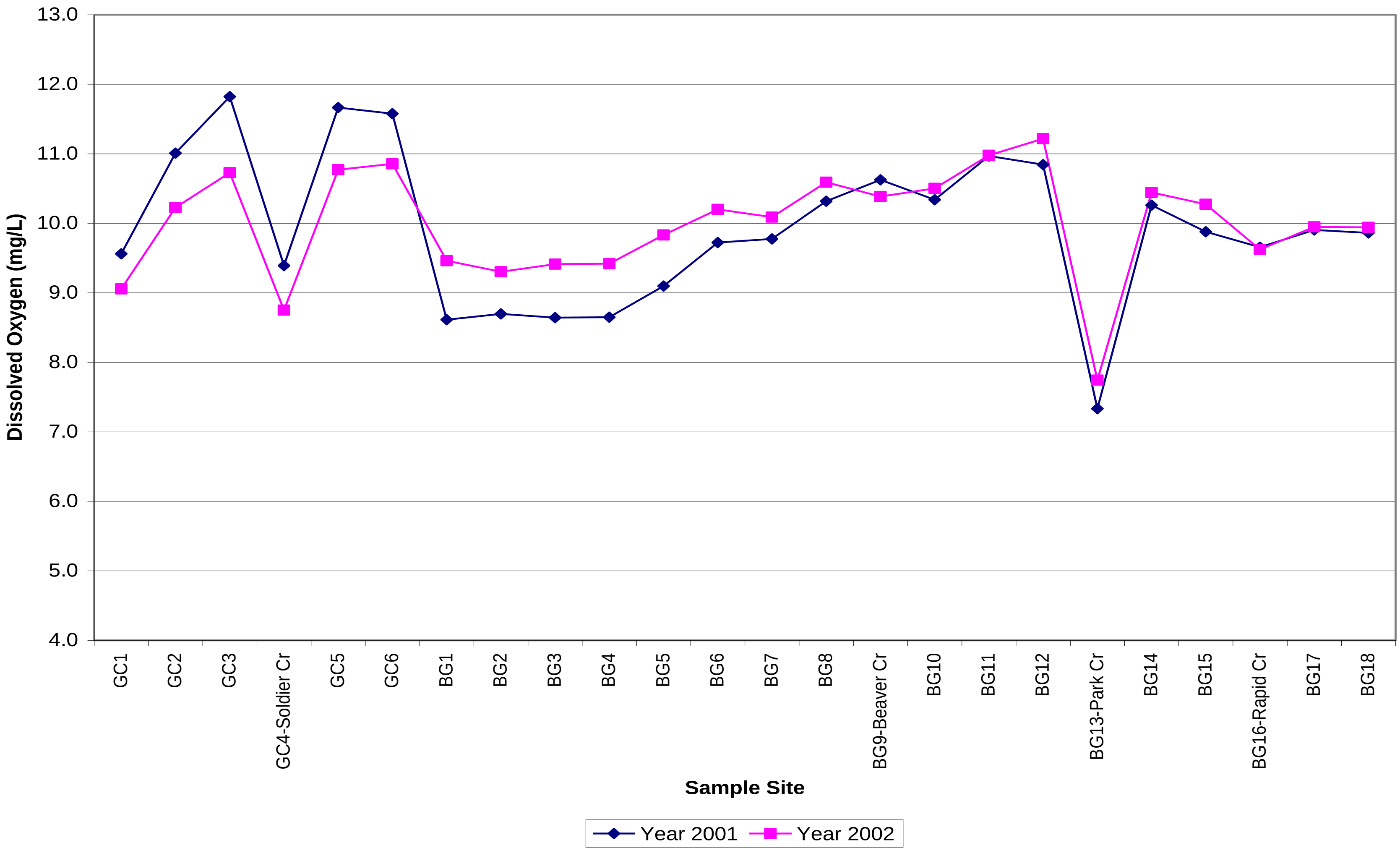


Figure 8-20. Mean Annual Dissolved Oxygen Values for Little Goose Creek Monitoring Stations

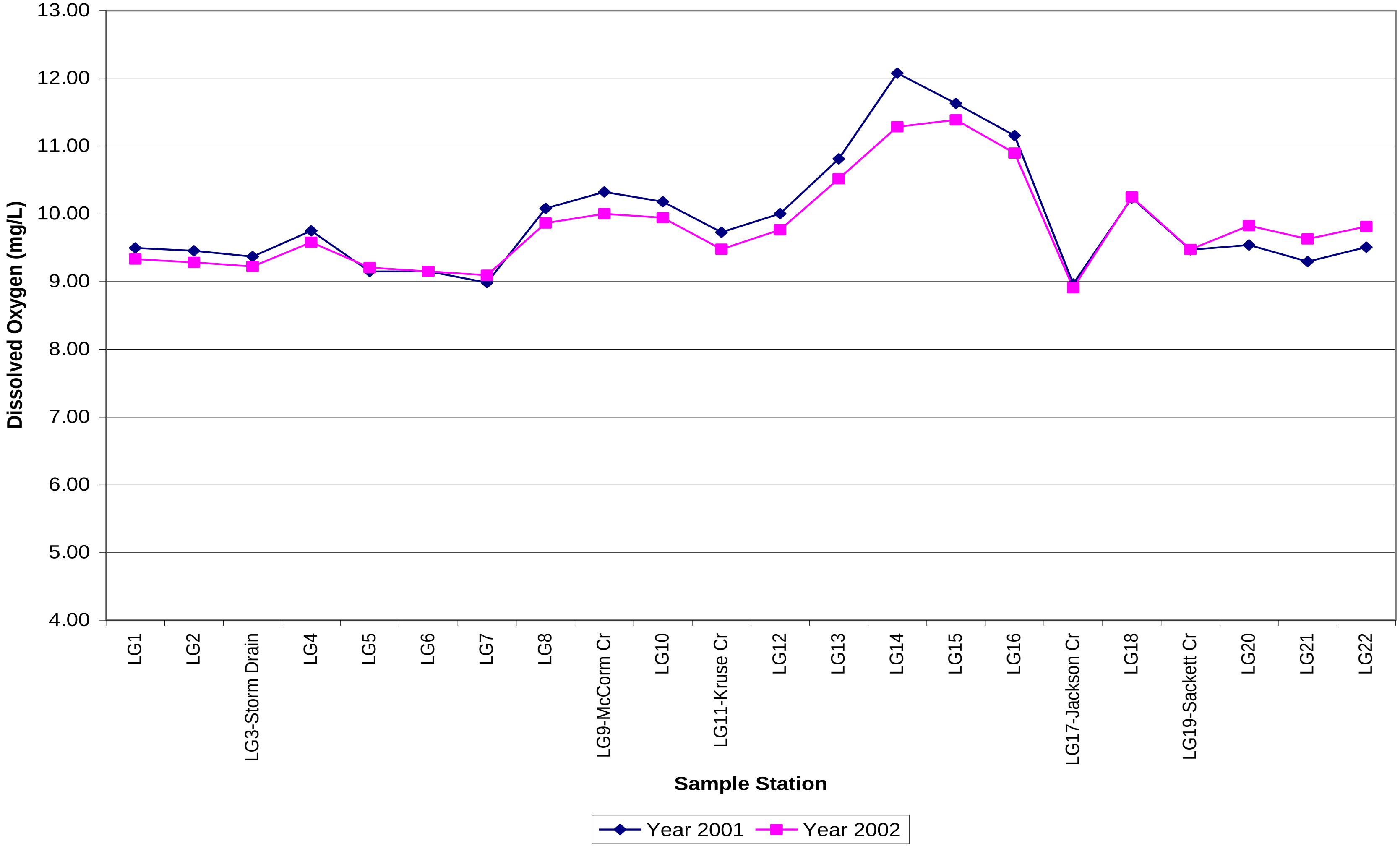


Figure 8-21. Scatterplot with Linear Regression that Shows the Relationship Between Dissolved Oxygen and Temperature at Big Goose Creek site BG1

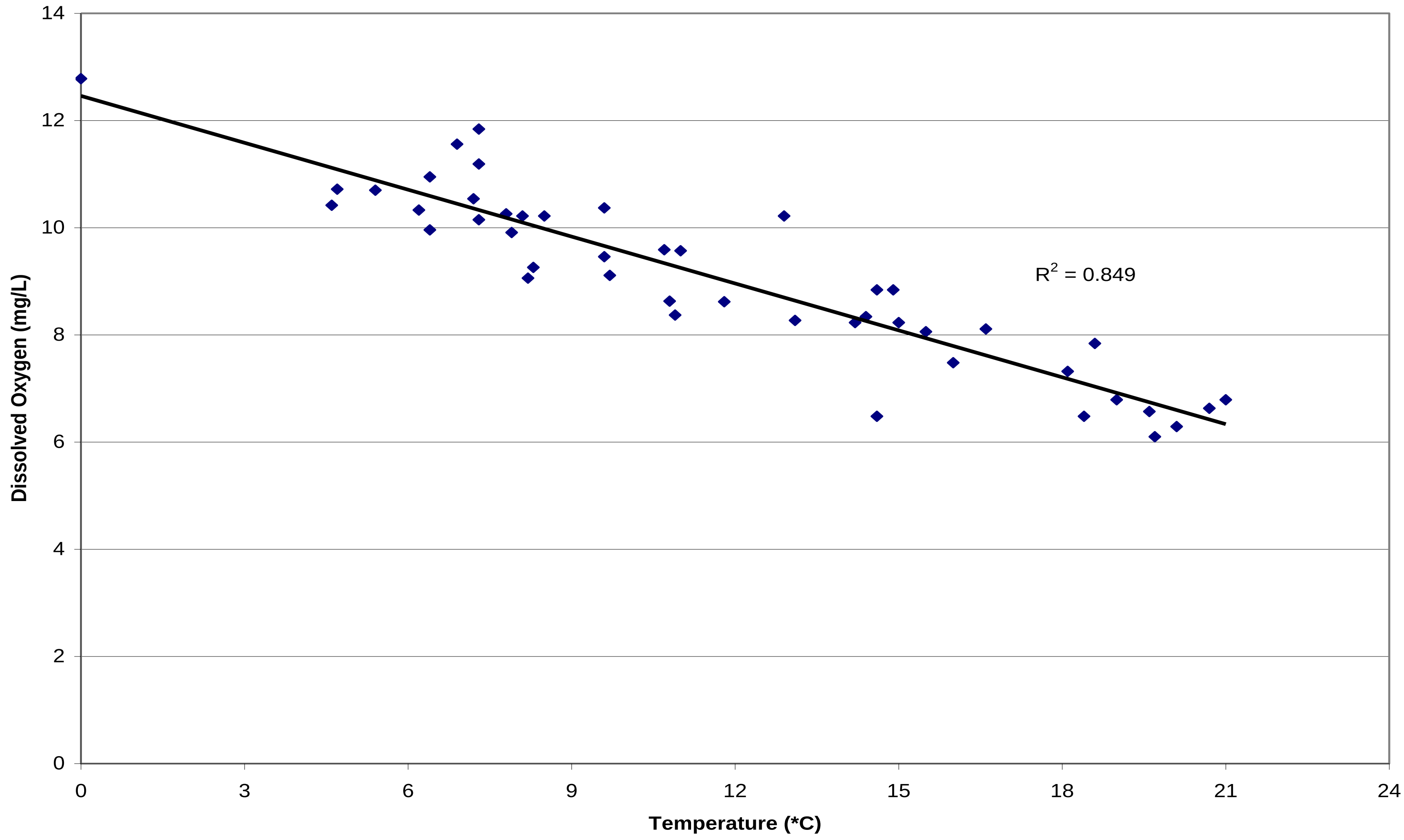


Figure 8-22. Comparison of 2001 and 2002 Actual Daily Discharge Rates to the 1984 – 2002 Average Daily Discharge Rates at USGS Station No. 06305700 (Goose Creek Near Acme, Wyoming)

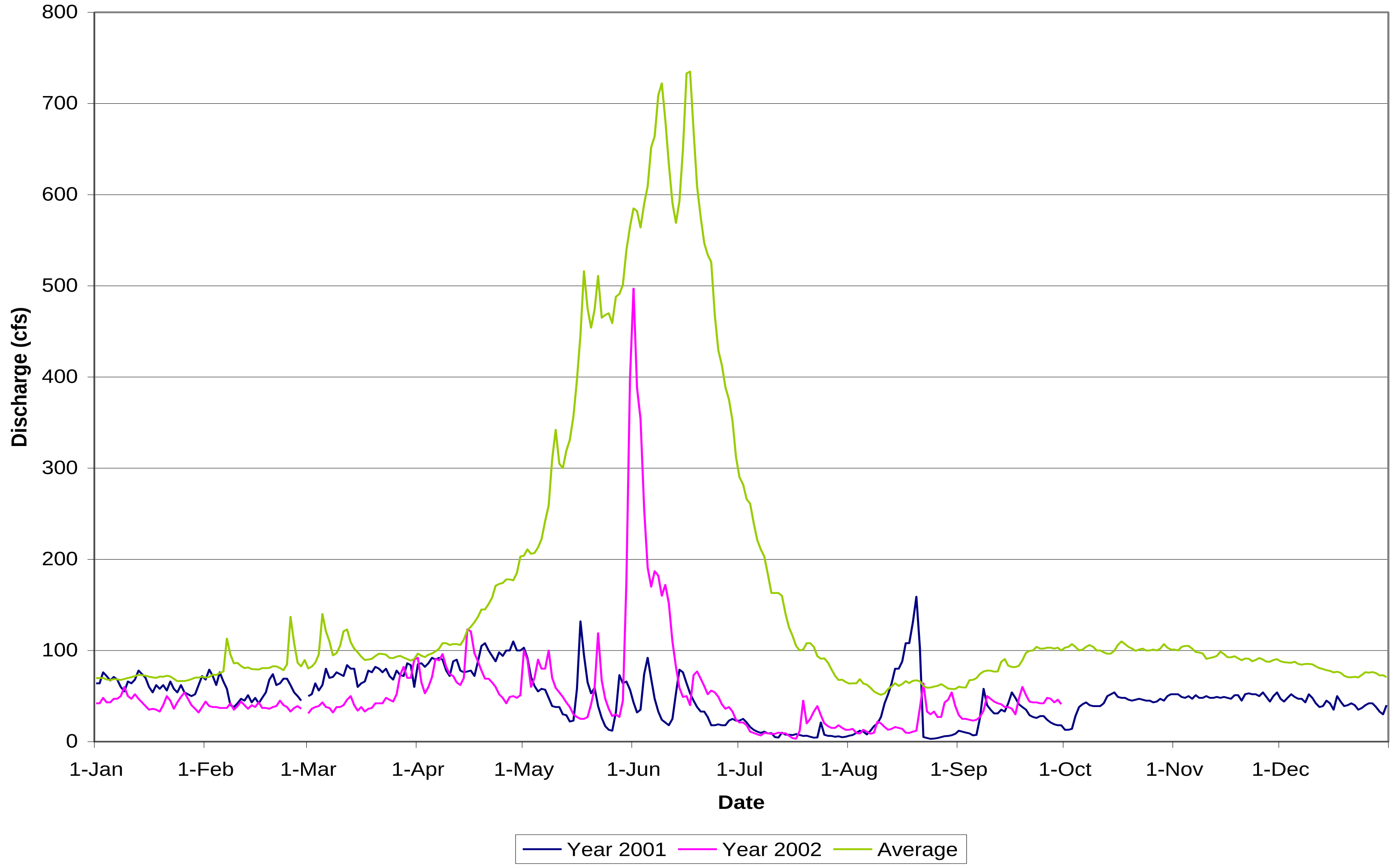


Figure 8-23. Comparison of 2002 Discharge at USGS Station No. 06301850 (Big Goose Creek Above PK Ditch) to 1930 – 2000 Average Daily Discharge at USGS Station No. 06302000 (Big Goose Creek Near Sheridan)

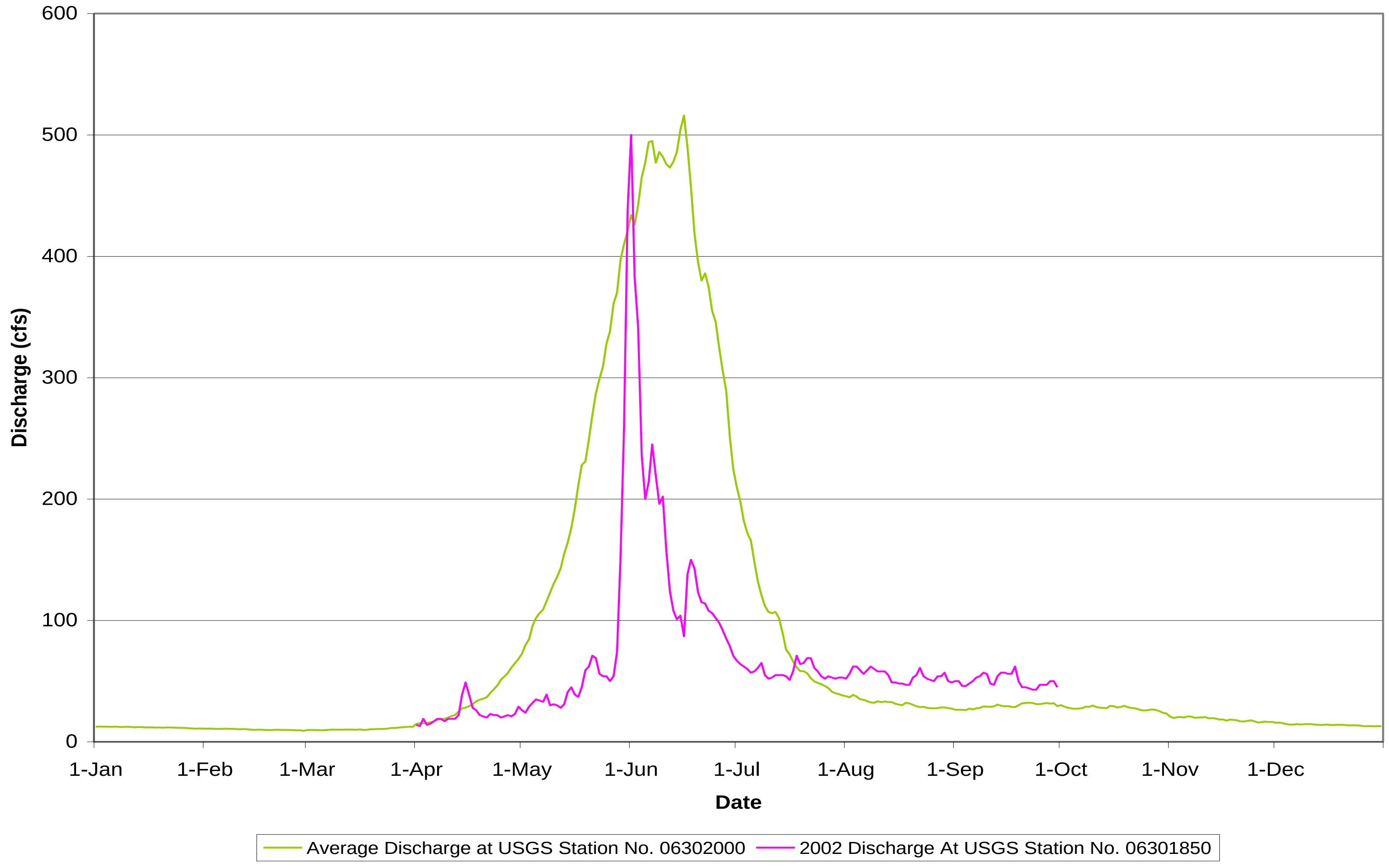


Figure 8-24. Comparison of 2001 and 2001 Actual Daily Discharge to the 1953 – 2002 Average Daily Discharge Rates at USGS Station No. 06301500 (West Fork Big Goose Creek Near Big Horn, Wyoming)

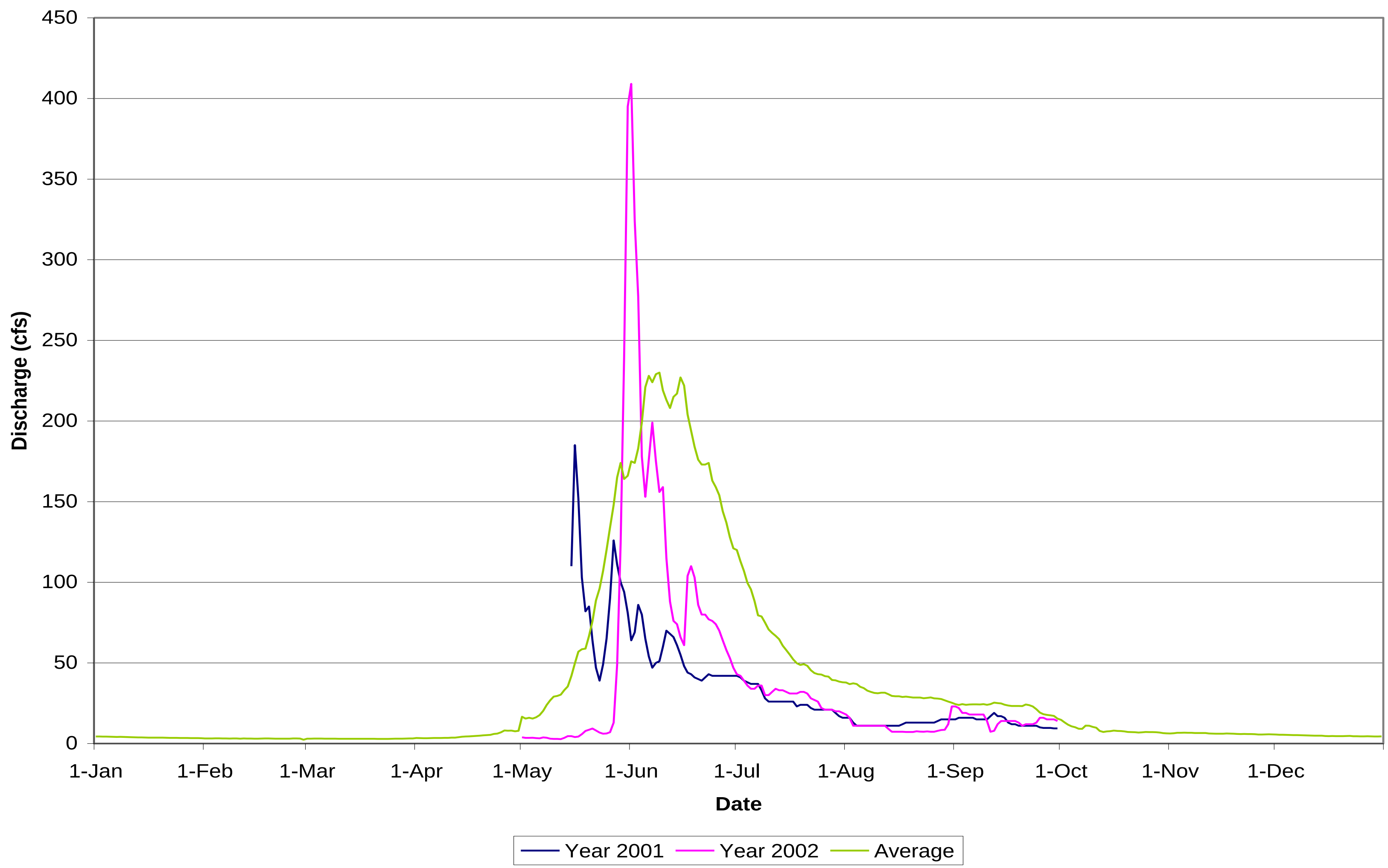


Figure 8-25. Comparison of 2001 and 2002 Actual Daily Discharge to the 1941 – 2002 Average Daily Discharge at USGS Station No. 06303500 (Little Goose Creek in Canyon, Near Big Horn, Wyoming)

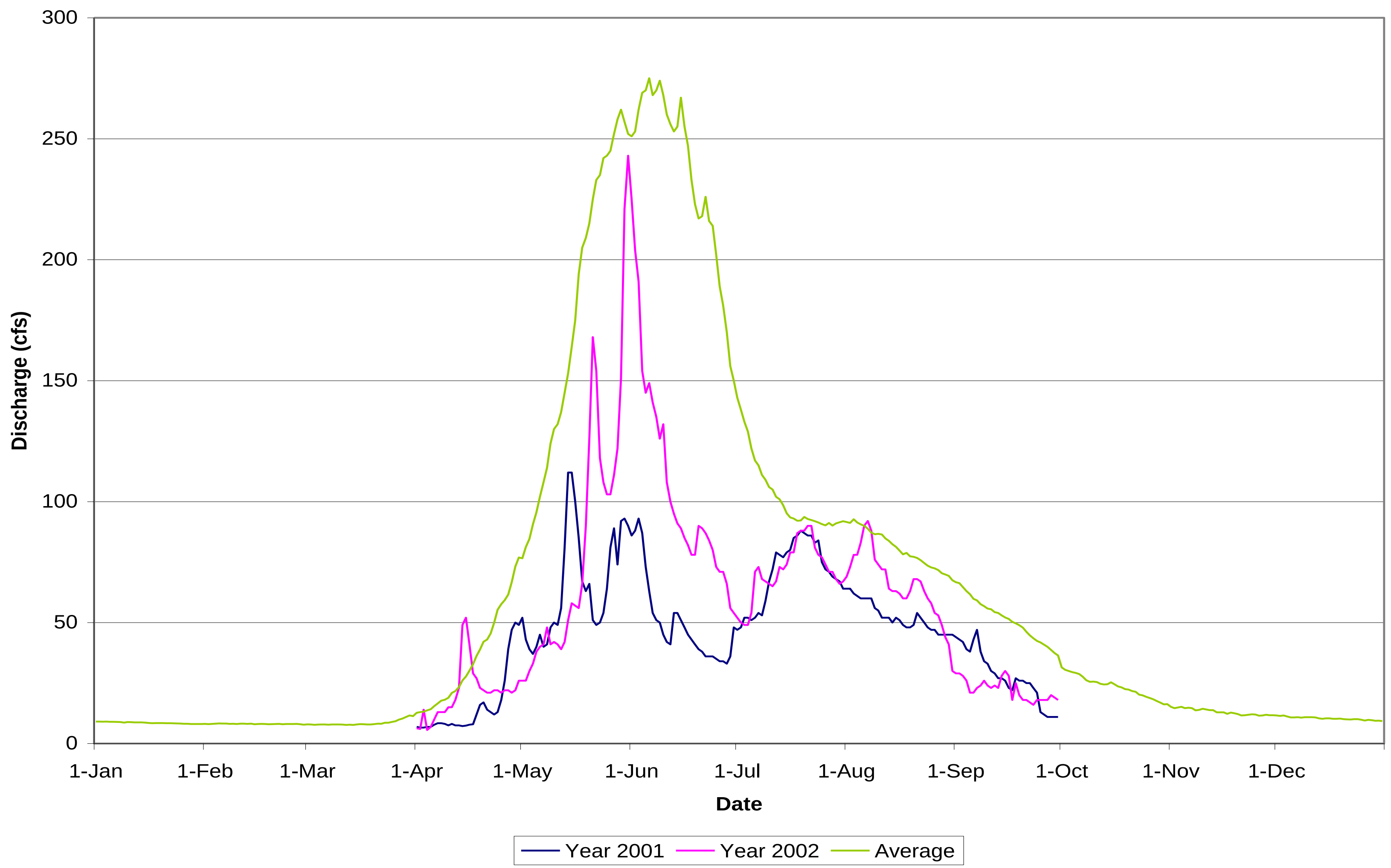


Figure 8-26. Comparison of 2002 Discharge at USGS Station No. 06305700 (Goose Creek Near Acme), USGS Station No. 06301850 (Big Goose Creek Above PK Ditch), and USGS Station No. 06303500 (Little Goose Creek in Canyon)

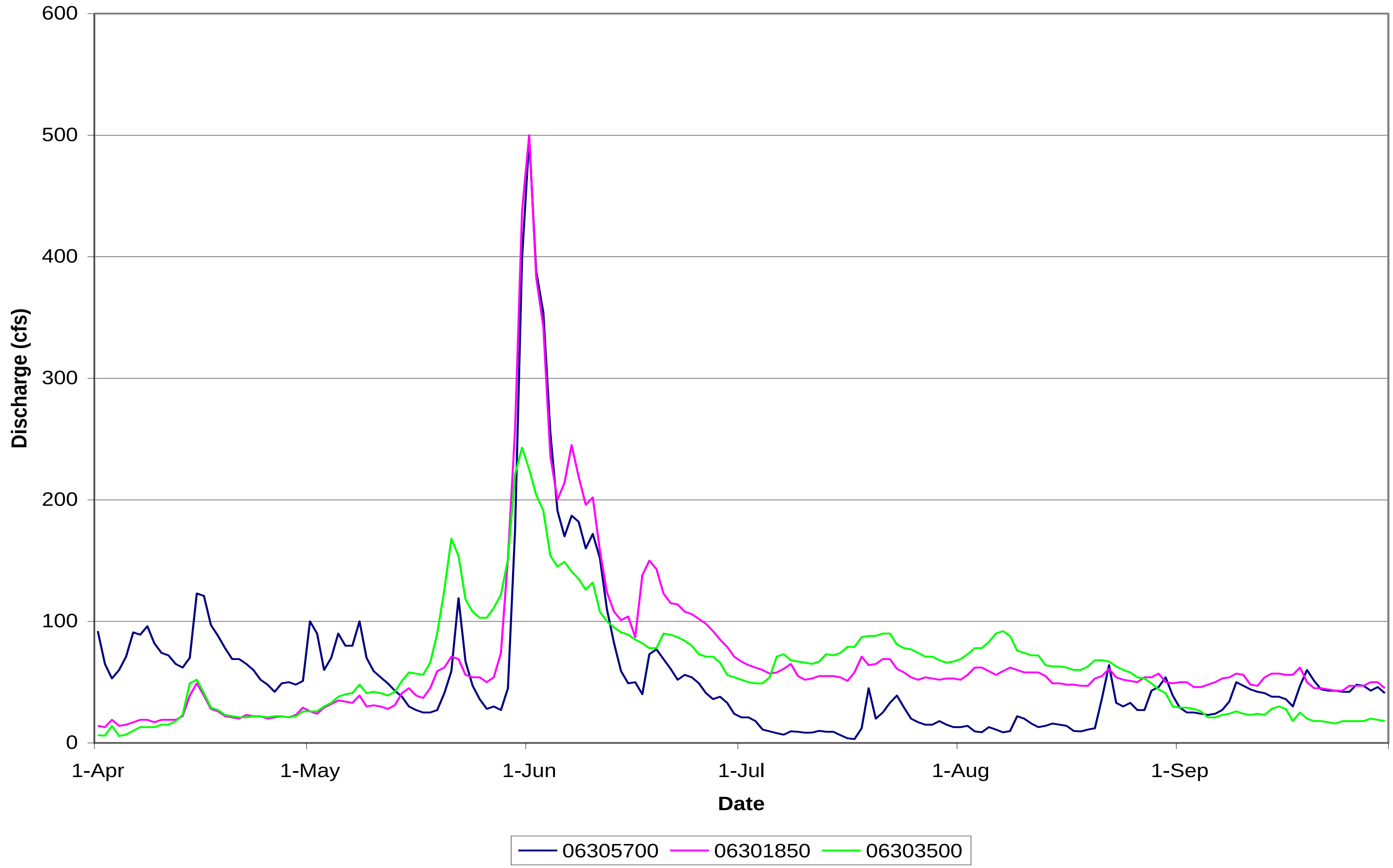


Figure 8-27. Comparison of Instantaneous Discharge Measurements Recorded on the Same Day for Upper (site GC6) and Lower (site GC1) Goose Creek

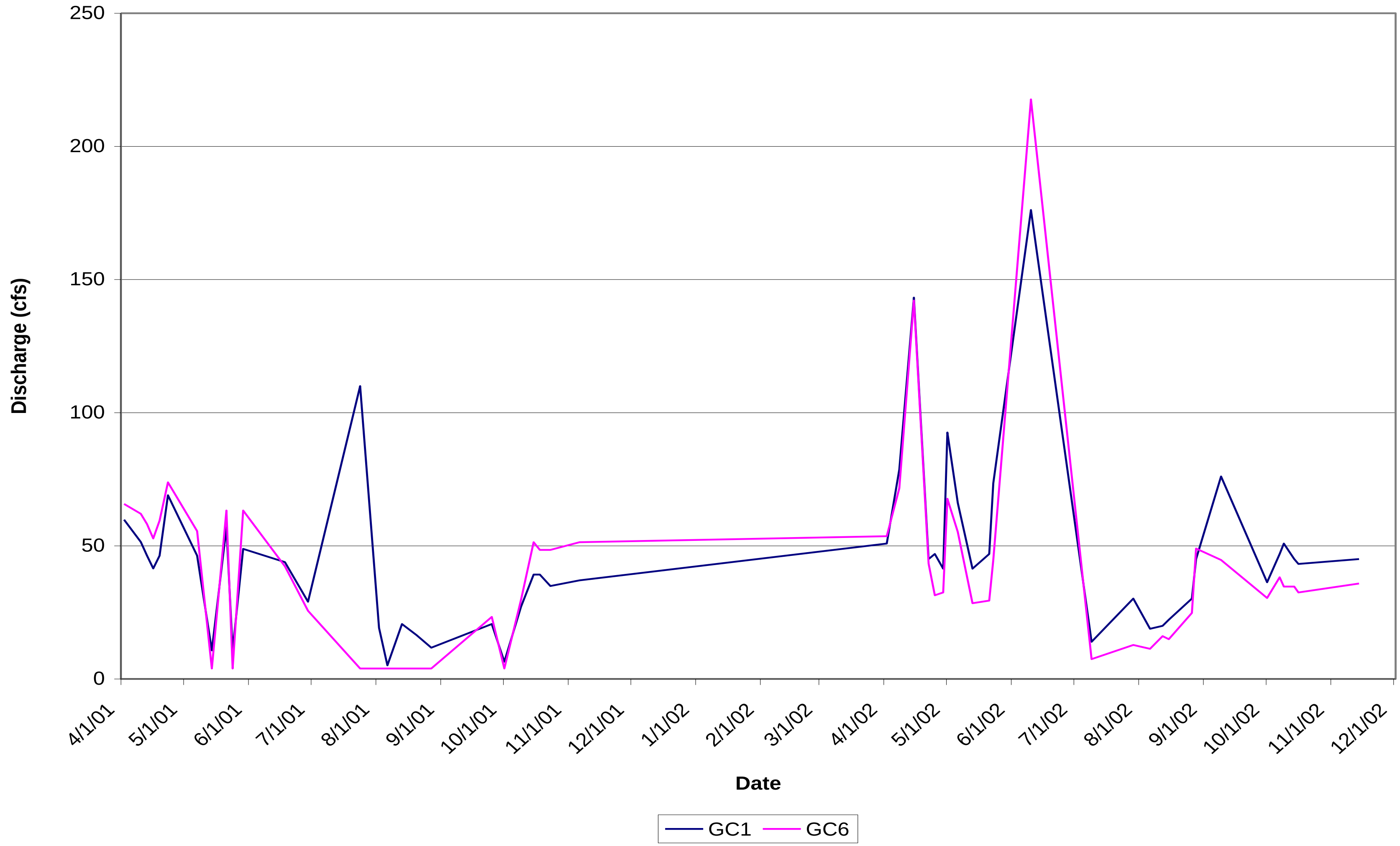


Figure 8-28. Comparison of Instantaneous Discharge Measurements Recorded on the Same Day for Upper (site BG18), Middle (sites BG6 & BG14), and Lower (site BG1) Big Goose Creek

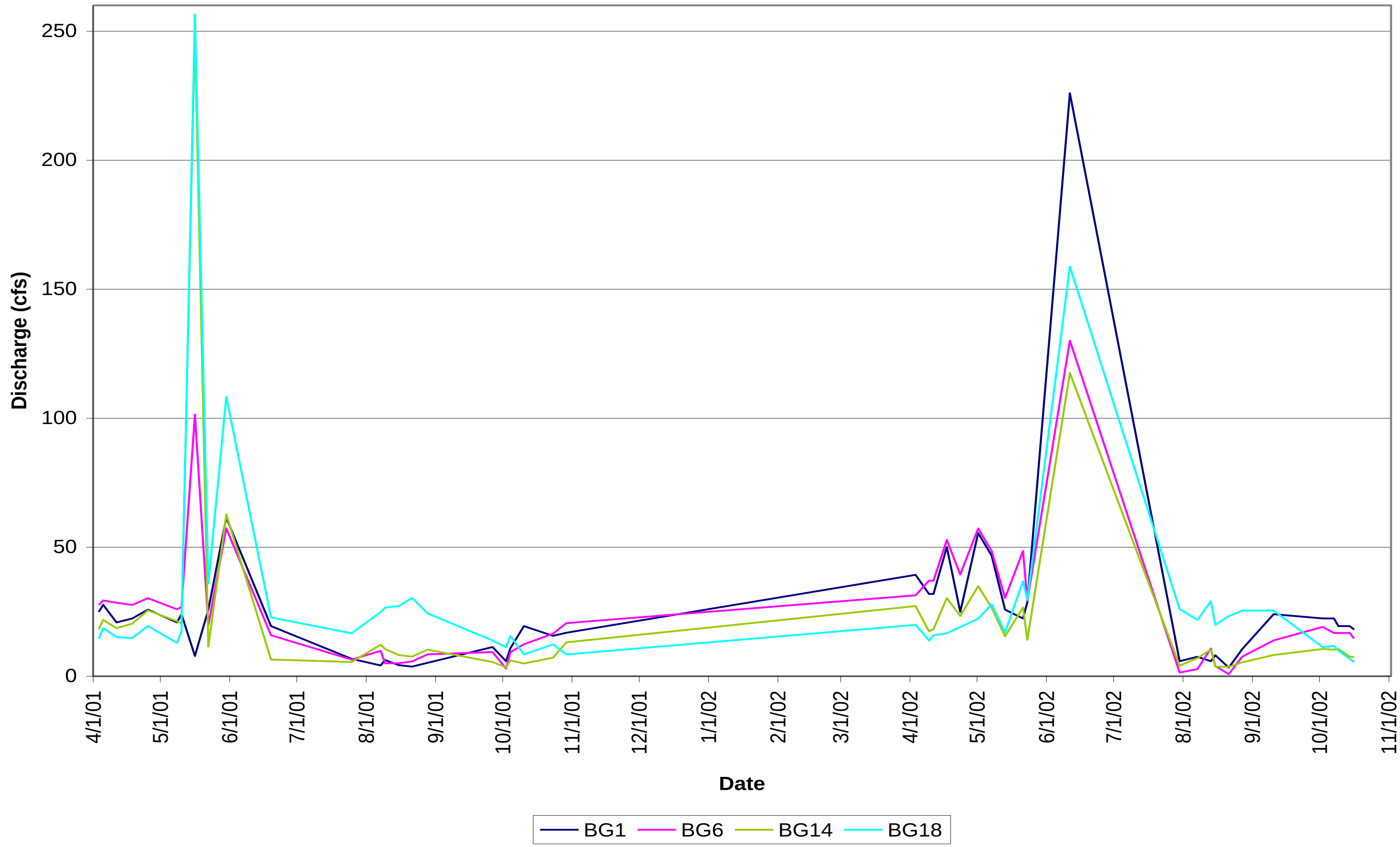


Figure 8-29. Comparison of Instantaneous Discharge Measurements Recorded on the Same Day for Upper (site LG22), Middle (sites LG6 and LG13), and Lower (site LG1) Little Goose Creek

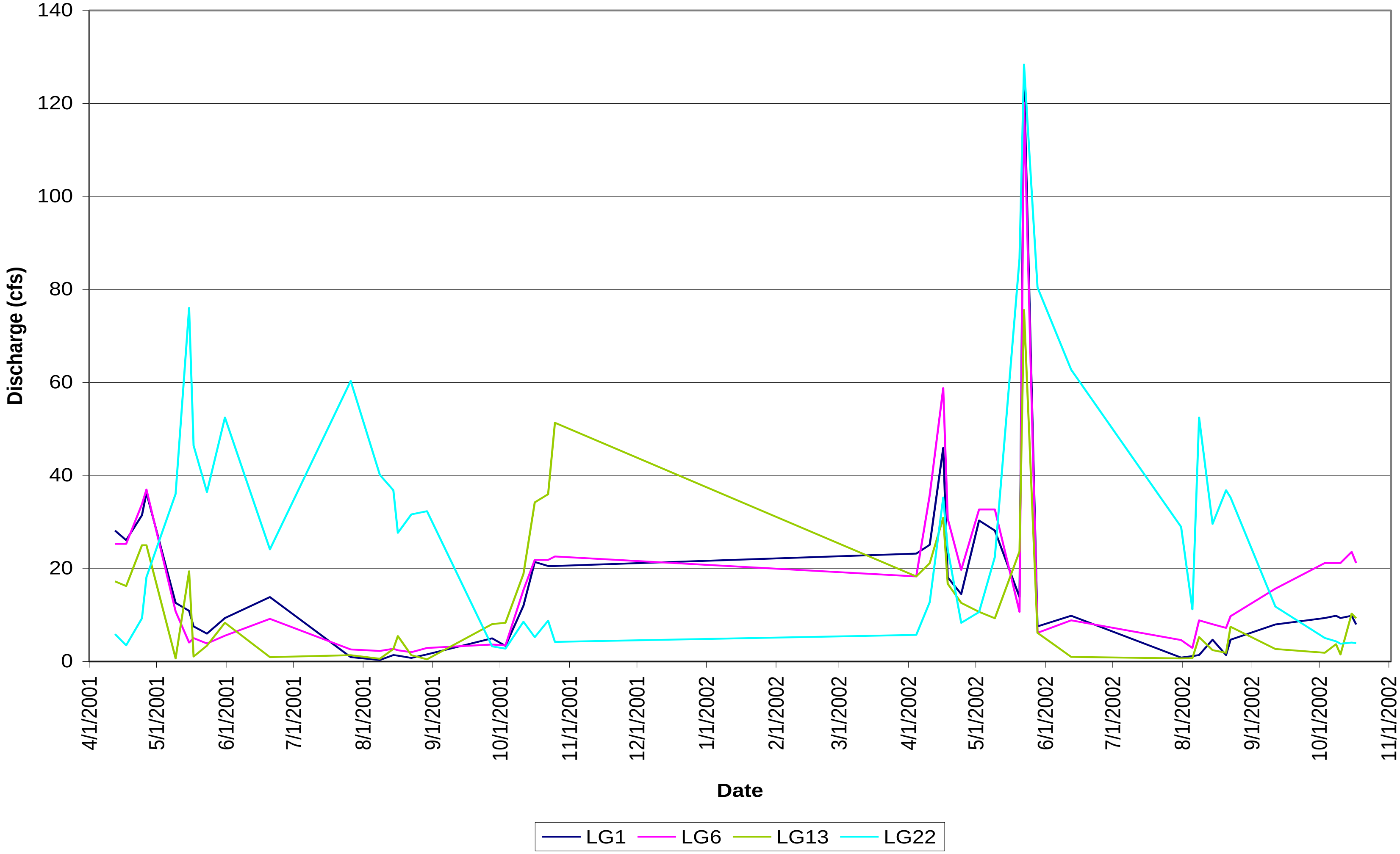


Figure 8-30. Mean Annual Turbidity Values for Goose Creek and Big Goose Creek Monitoring Stations

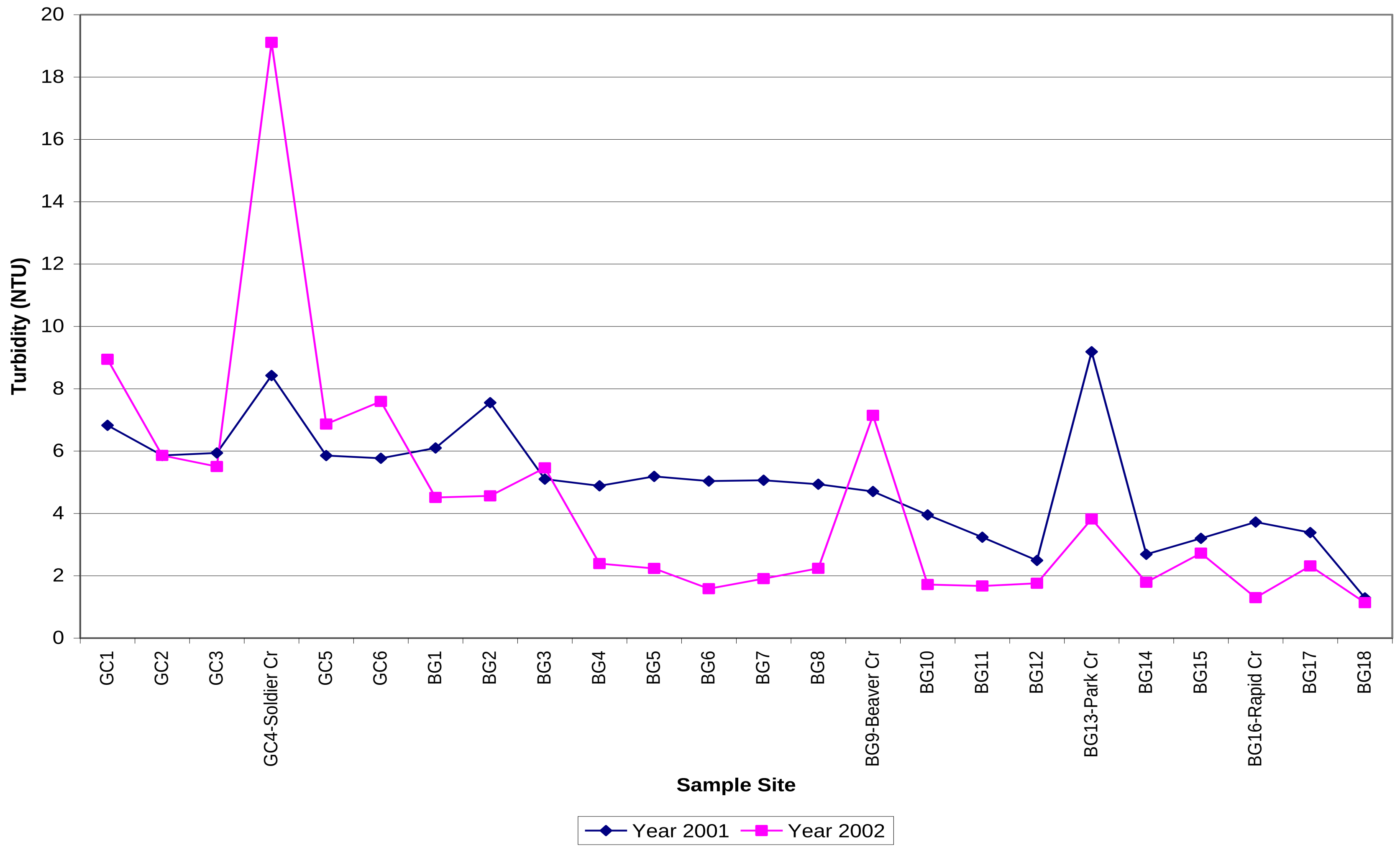


Figure 8-31. Mean Annual Turbidity Values for Little Goose Creek Monitoring Stations

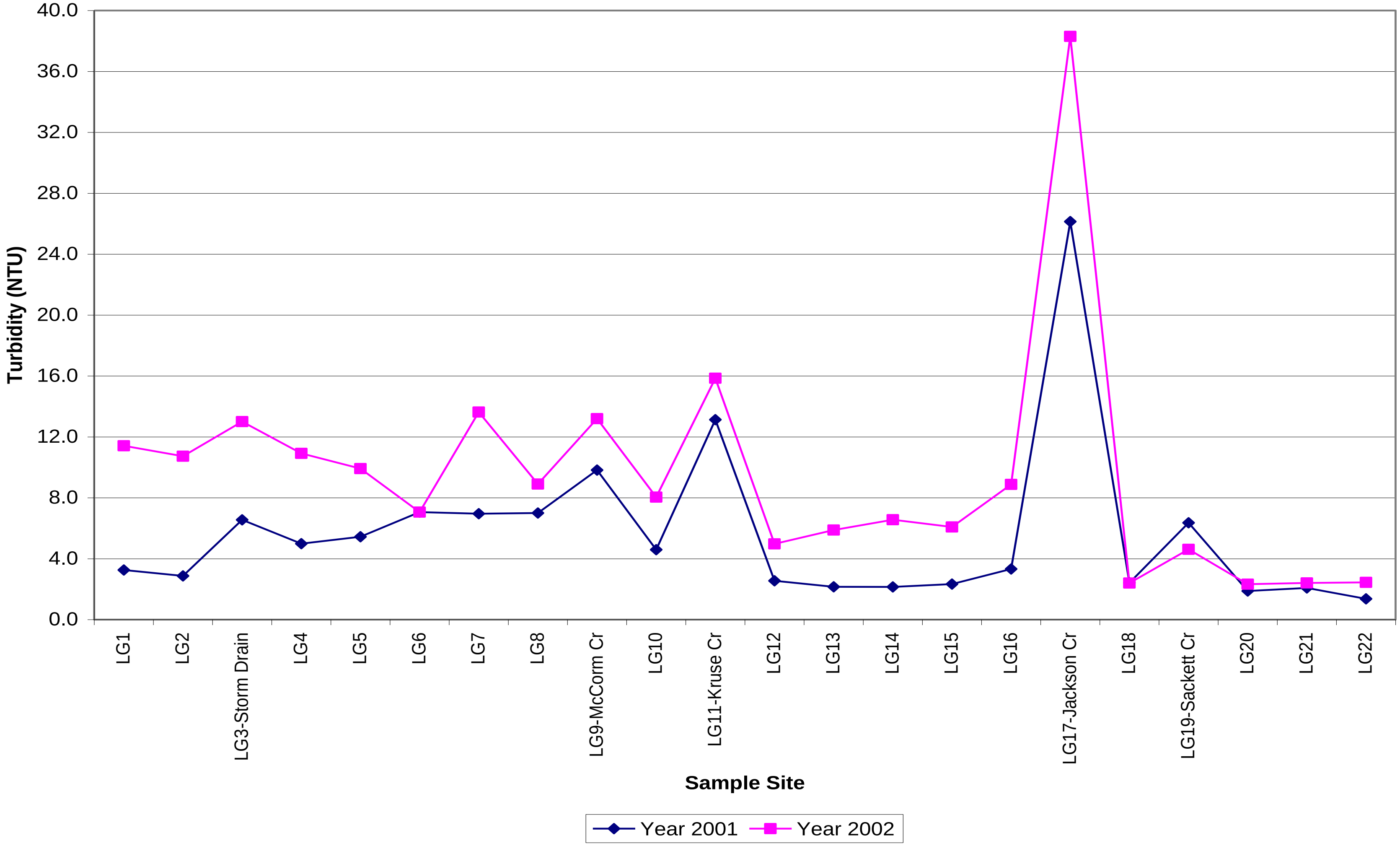


Figure 8-32. Scatterplot with Linear Regression that Shows the Relationship Between Discharge and Turbidity at Little Goose Creek site LG4

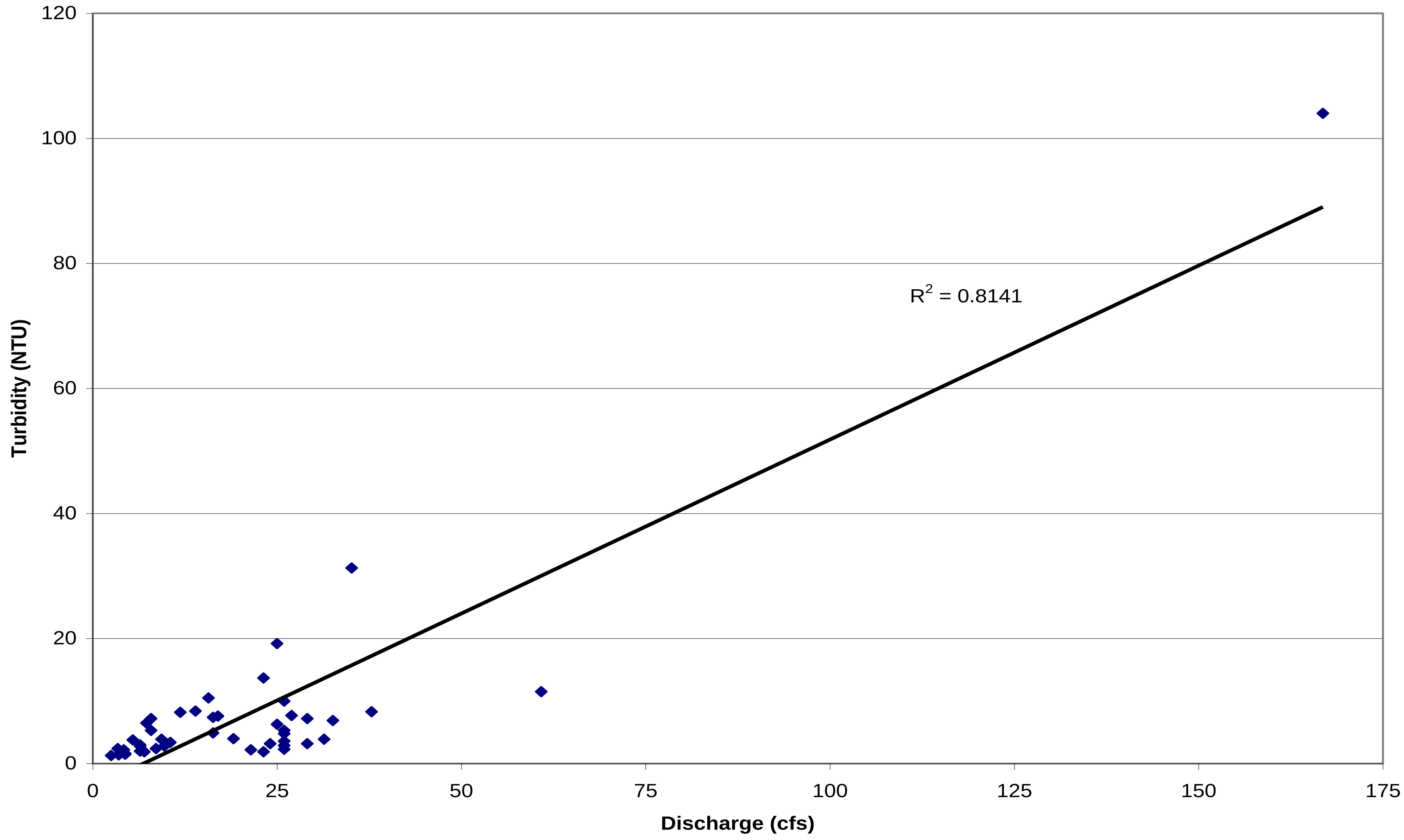


Figure 8-33. Mean Annual Total Suspended Solids Values for Goose Creek and Big Goose Creek Monitoring Stations

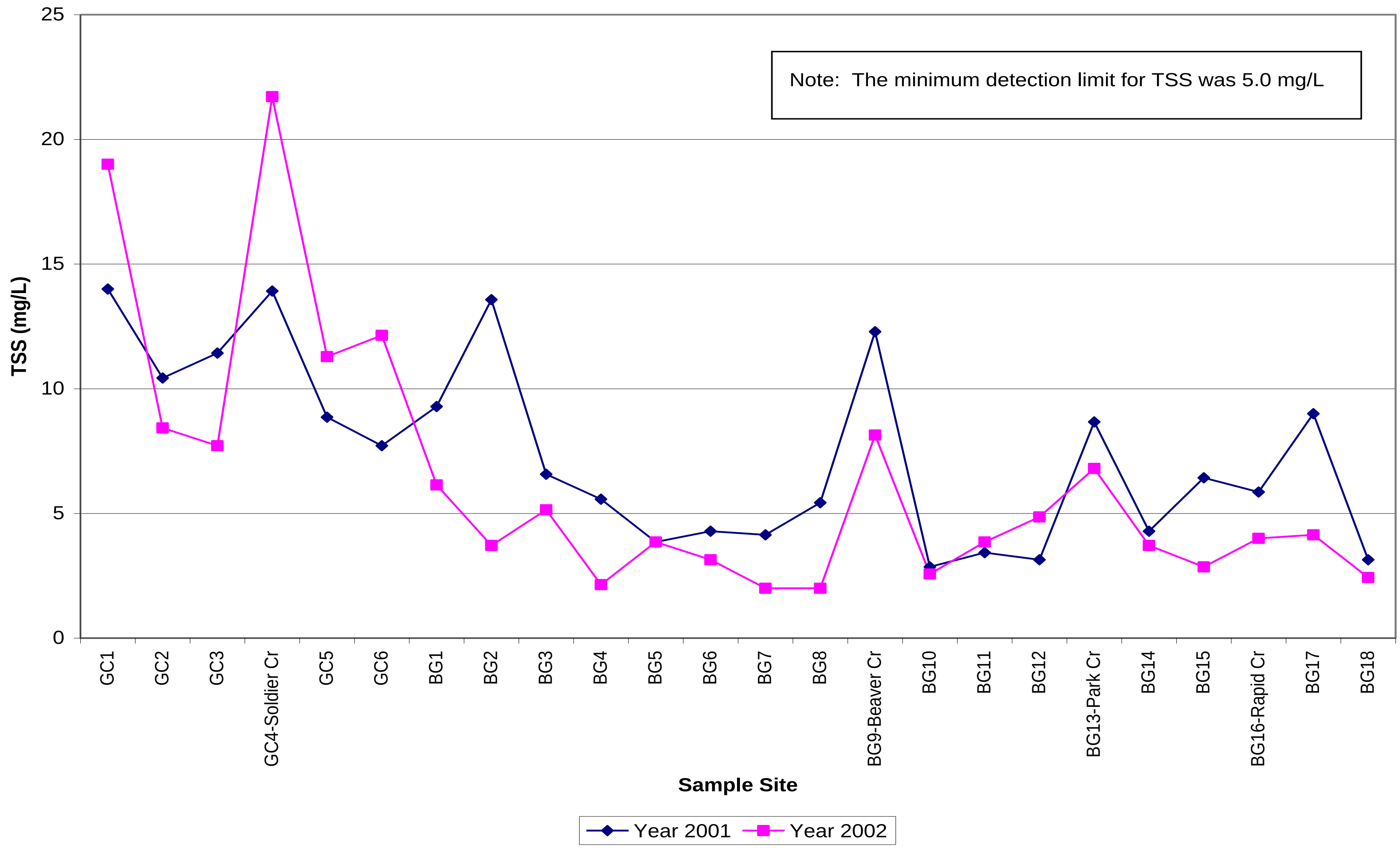


Figure 8-34. Mean Annual Total Suspended Solids Values for Little Goose Creek Monitoring Stations

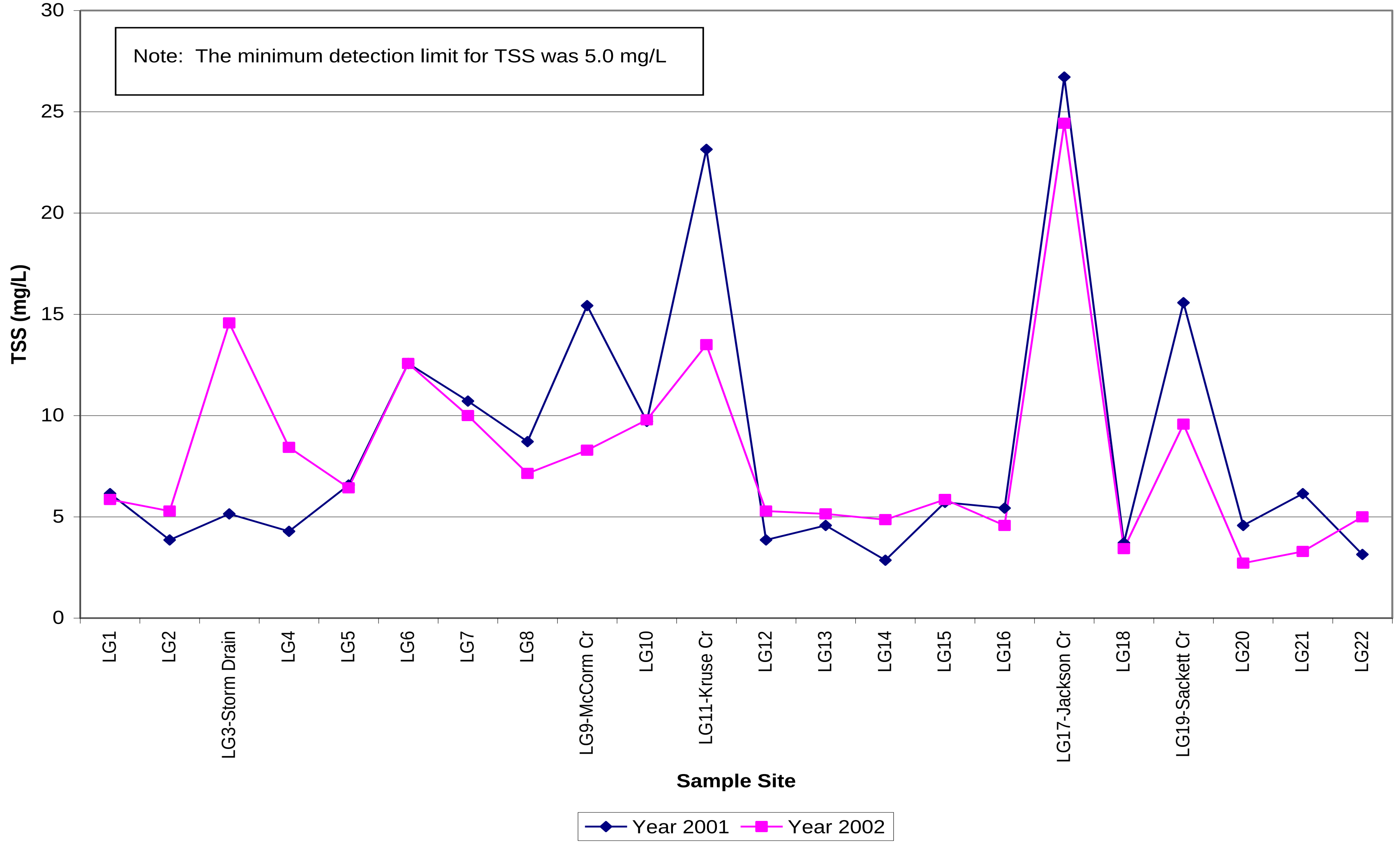


Figure 8-35. Scatterplot with Linear Regression that Shows the Relationship Between Turbidity and TSS for all Goose Creek Proper Monitoring Stations (GC1, GC2, GC3, GC5, and GC6)

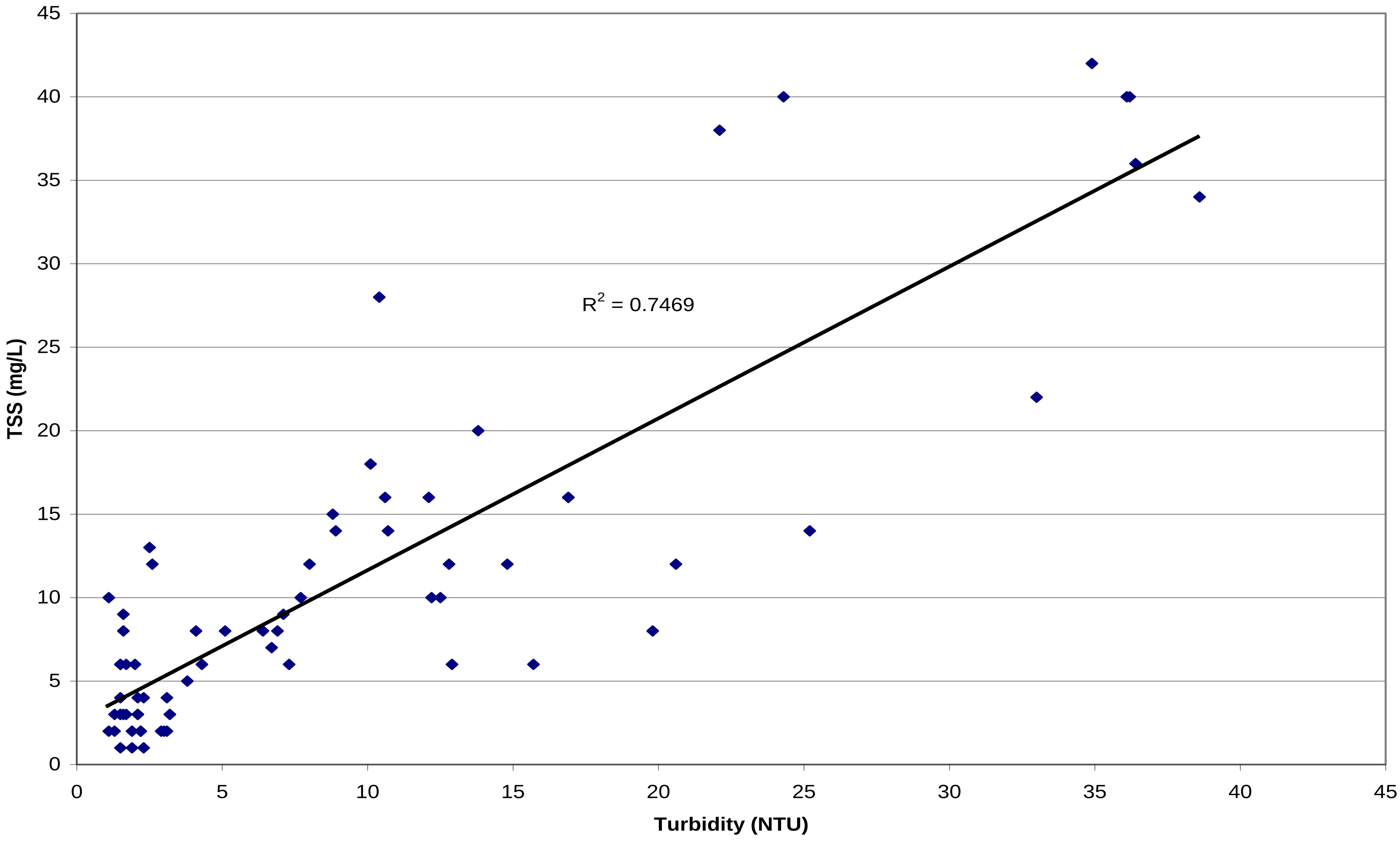


Figure 8-36. Mean Annual Total Alkalinity Values for Goose Creek and Big Goose Creek Monitoring Stations

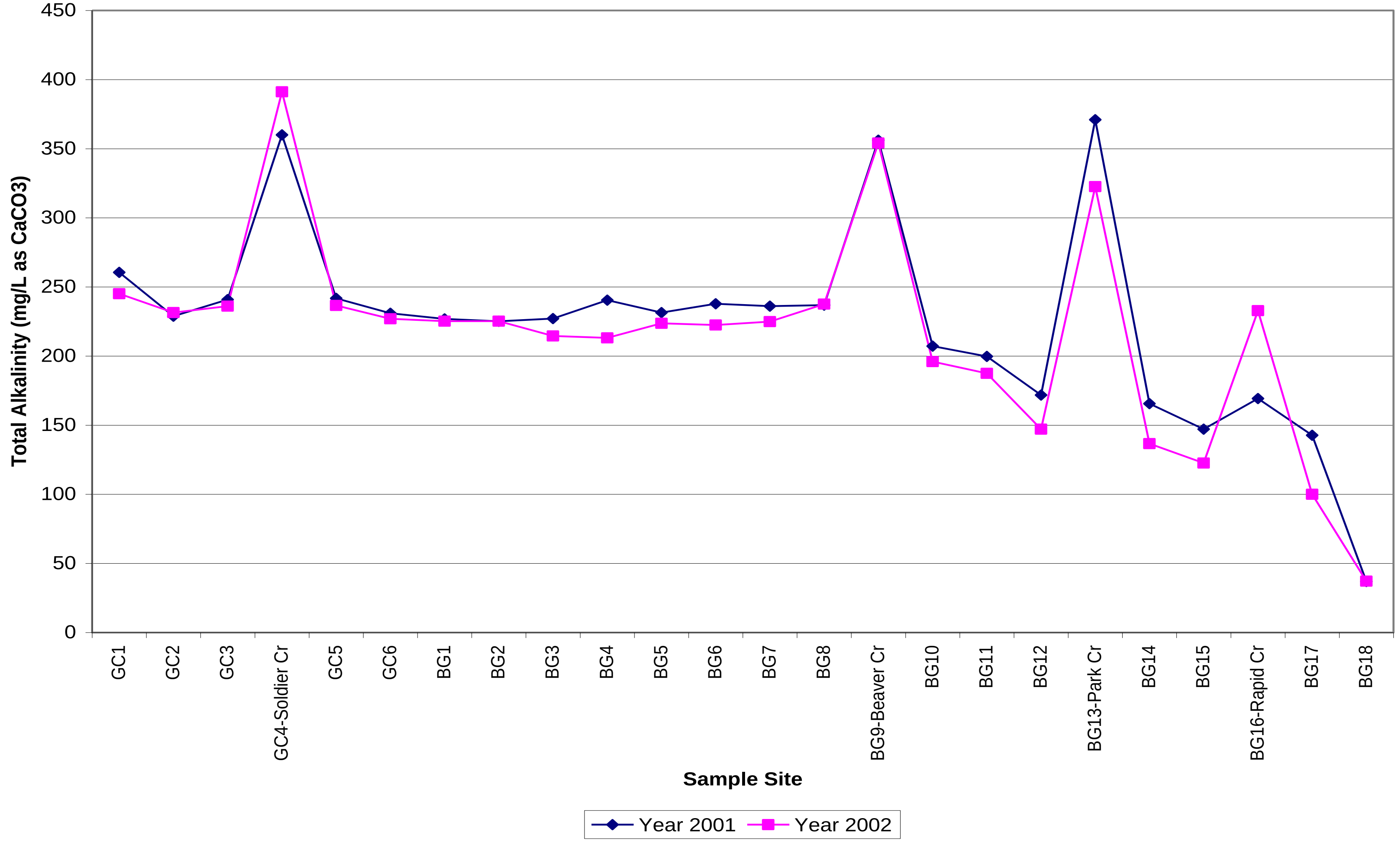


Figure 8-37. Mean Annual Total Alkalinity Values for Little Goose Creek Monitoring Stations

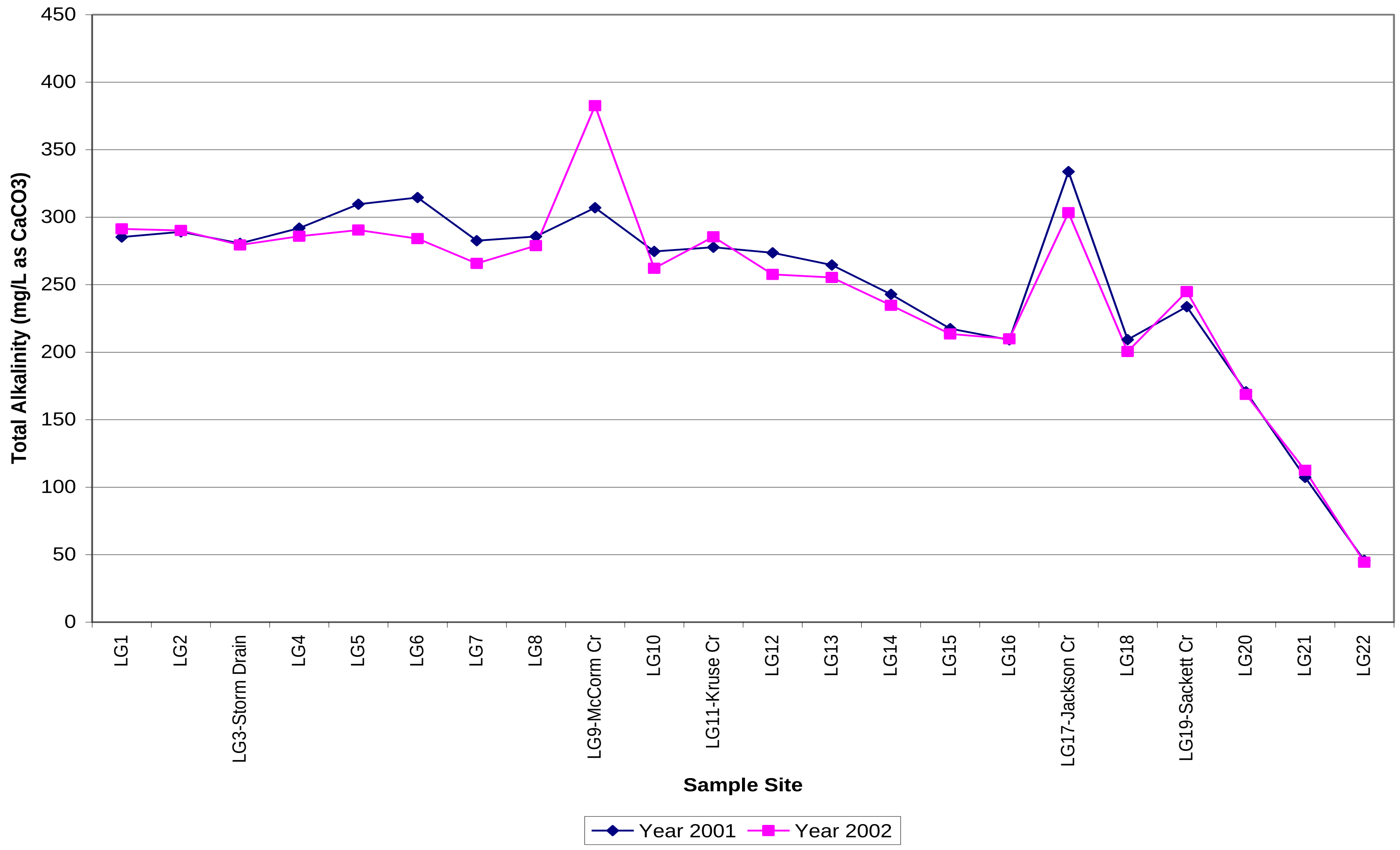


Figure 8-38. Mean Annual Total Sulfate Values for Goose Creek and Big Goose Creek Monitoring Stations

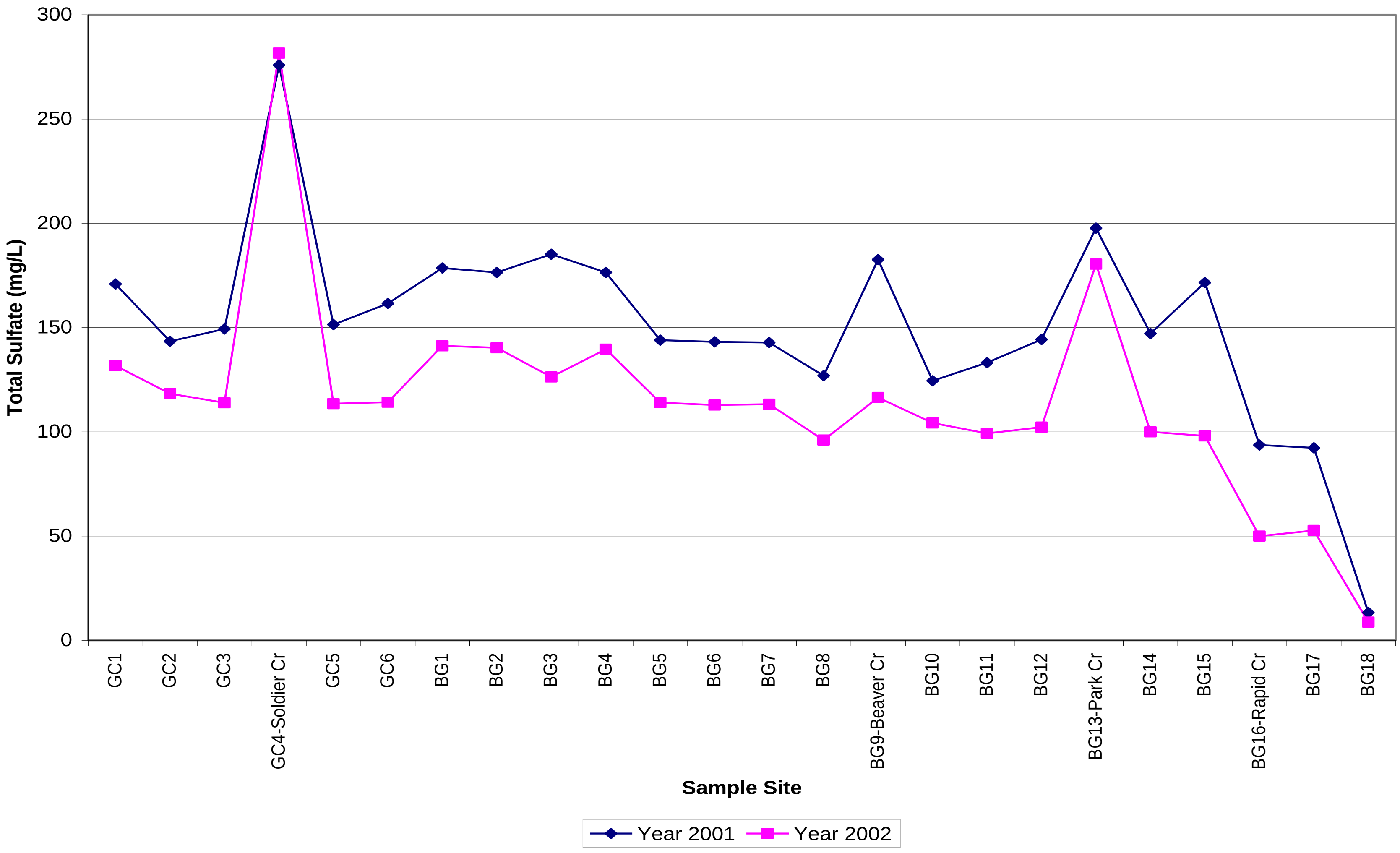


Figure 8-39. Mean Annual Total Sulfate Values for Little Goose Creek Monitoring Stations

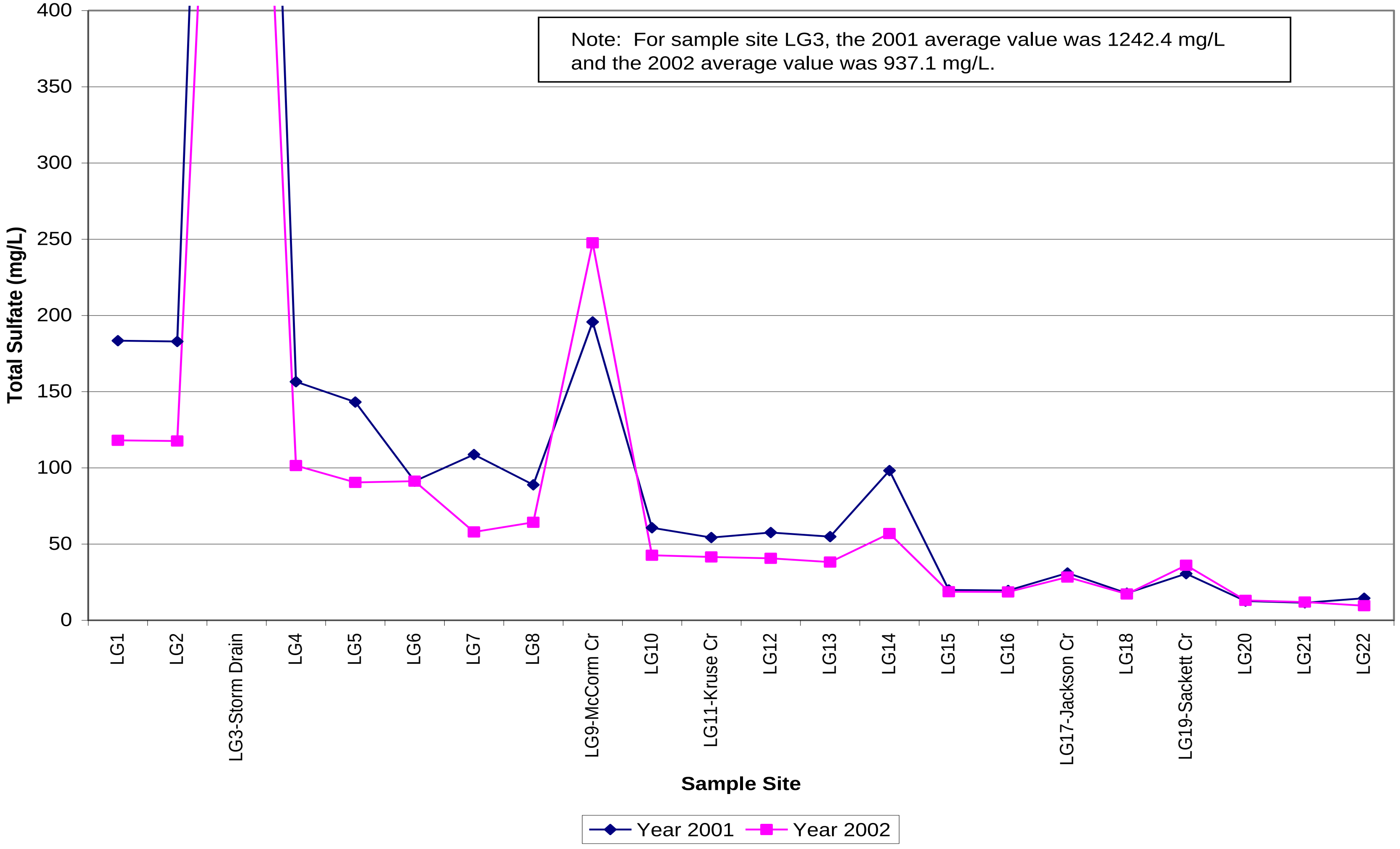


Figure 8-40. Mean Annual Total Chloride Values for Goose Creek and Big Goose Creek Monitoring Stations

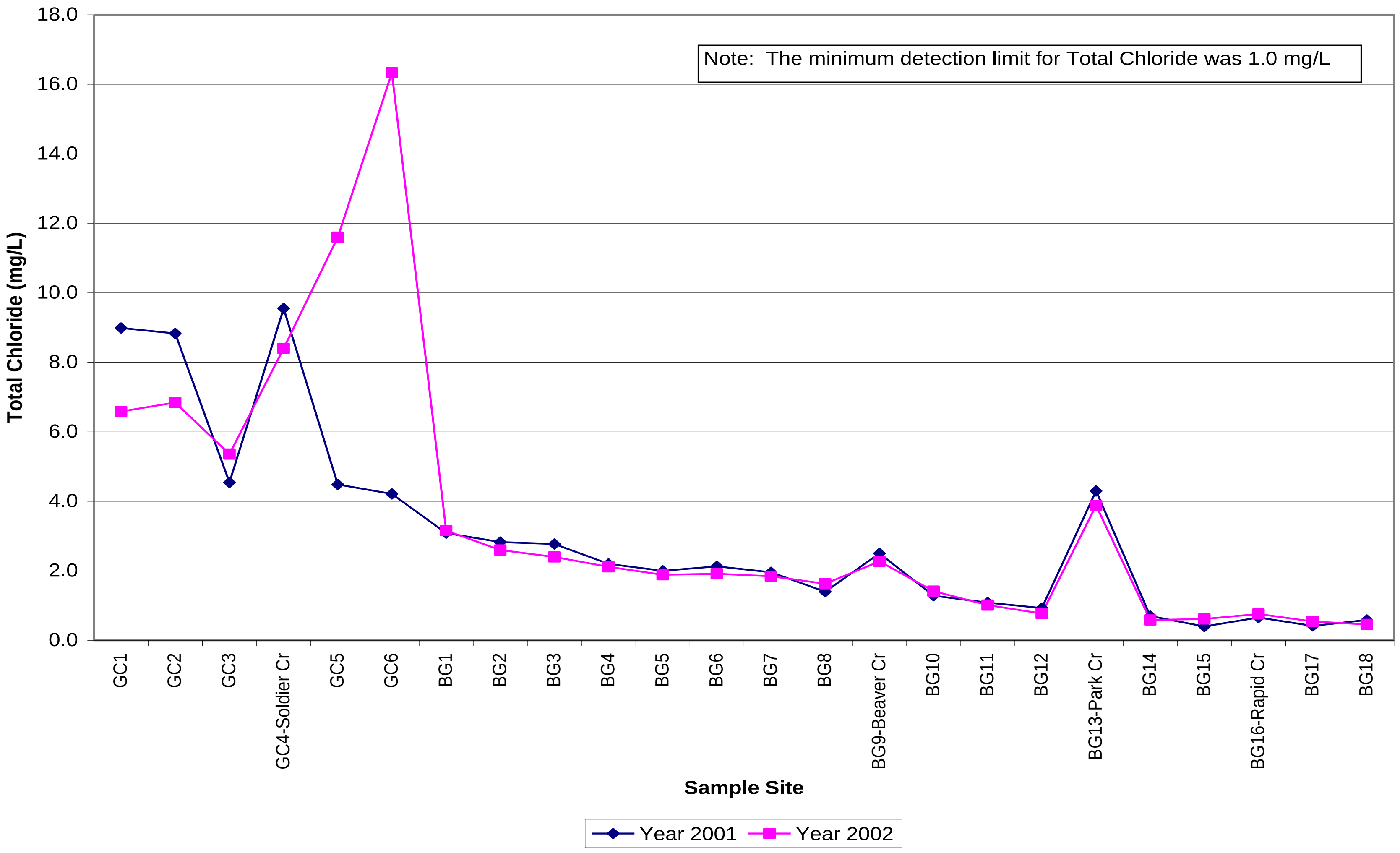


Figure 8-41. Mean Annual Total Chloride Values for Little Goose Creek Monitoring Stations

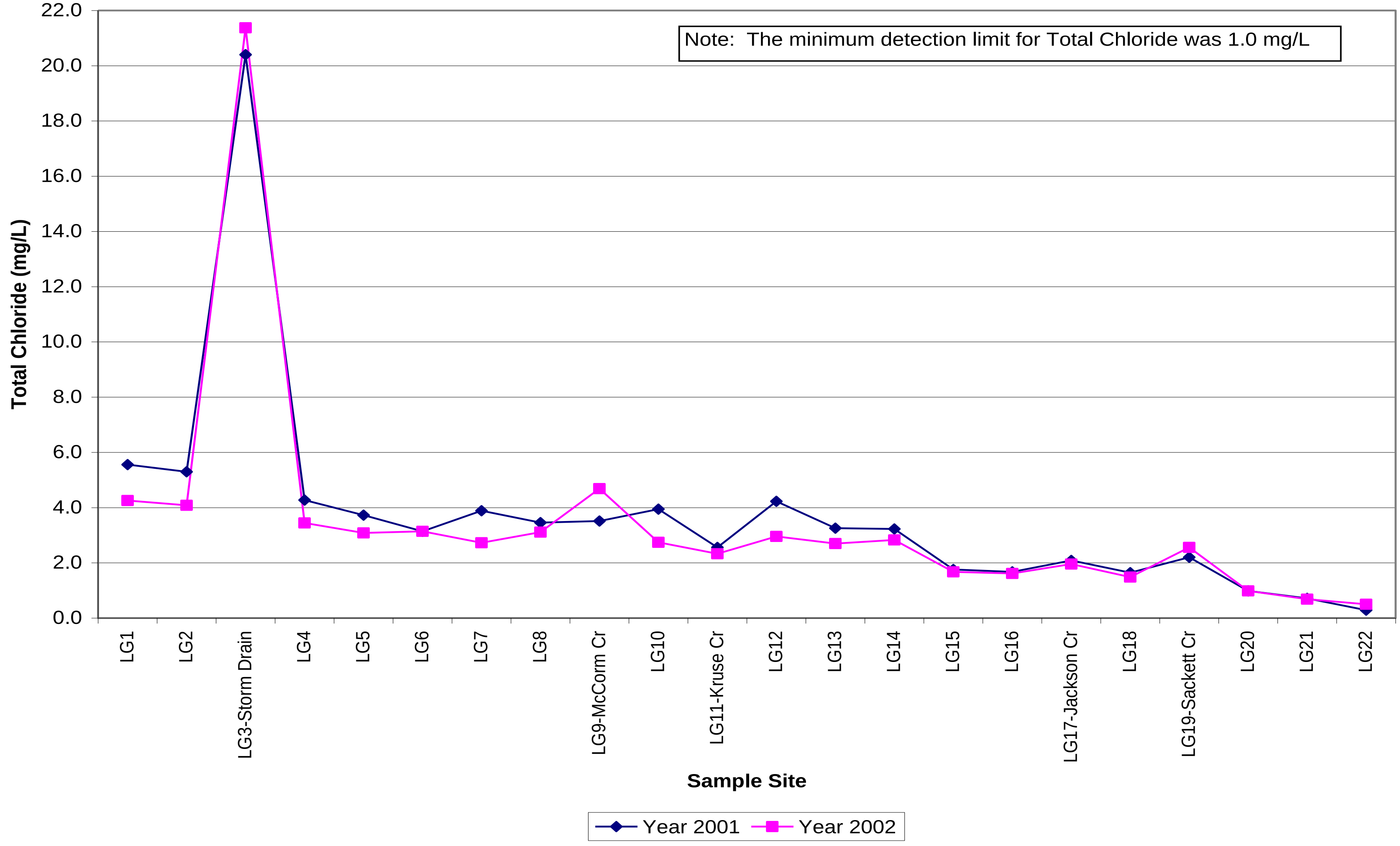


Figure 8-42. Mean Annual Total Nitrate Nitrogen Values for Goose Creek and Big Goose Creek Monitoring Stations

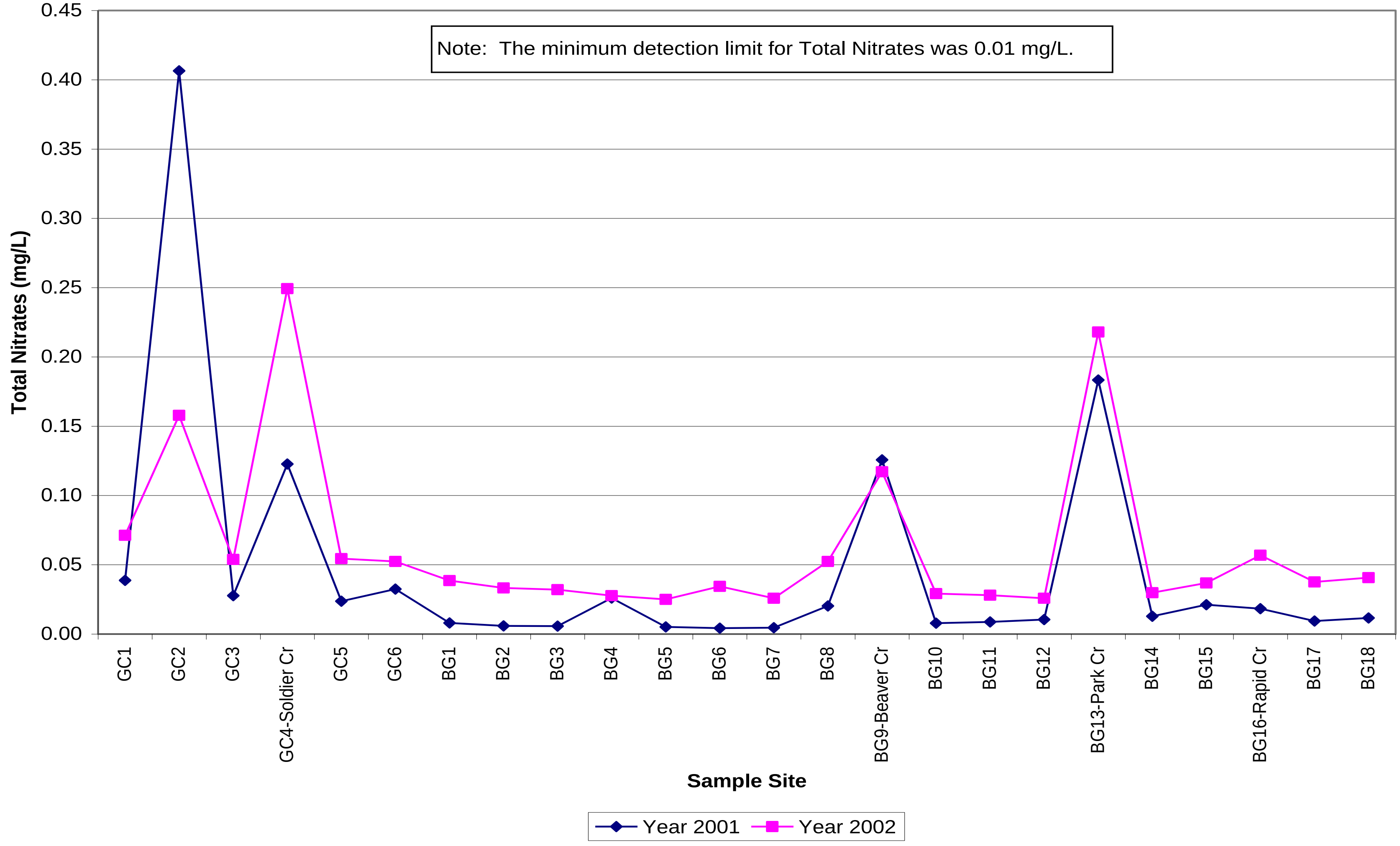


Figure 8-43. Mean Annual Total Nitrate Nitrogen Values for Little Goose Creek Monitoring Stations

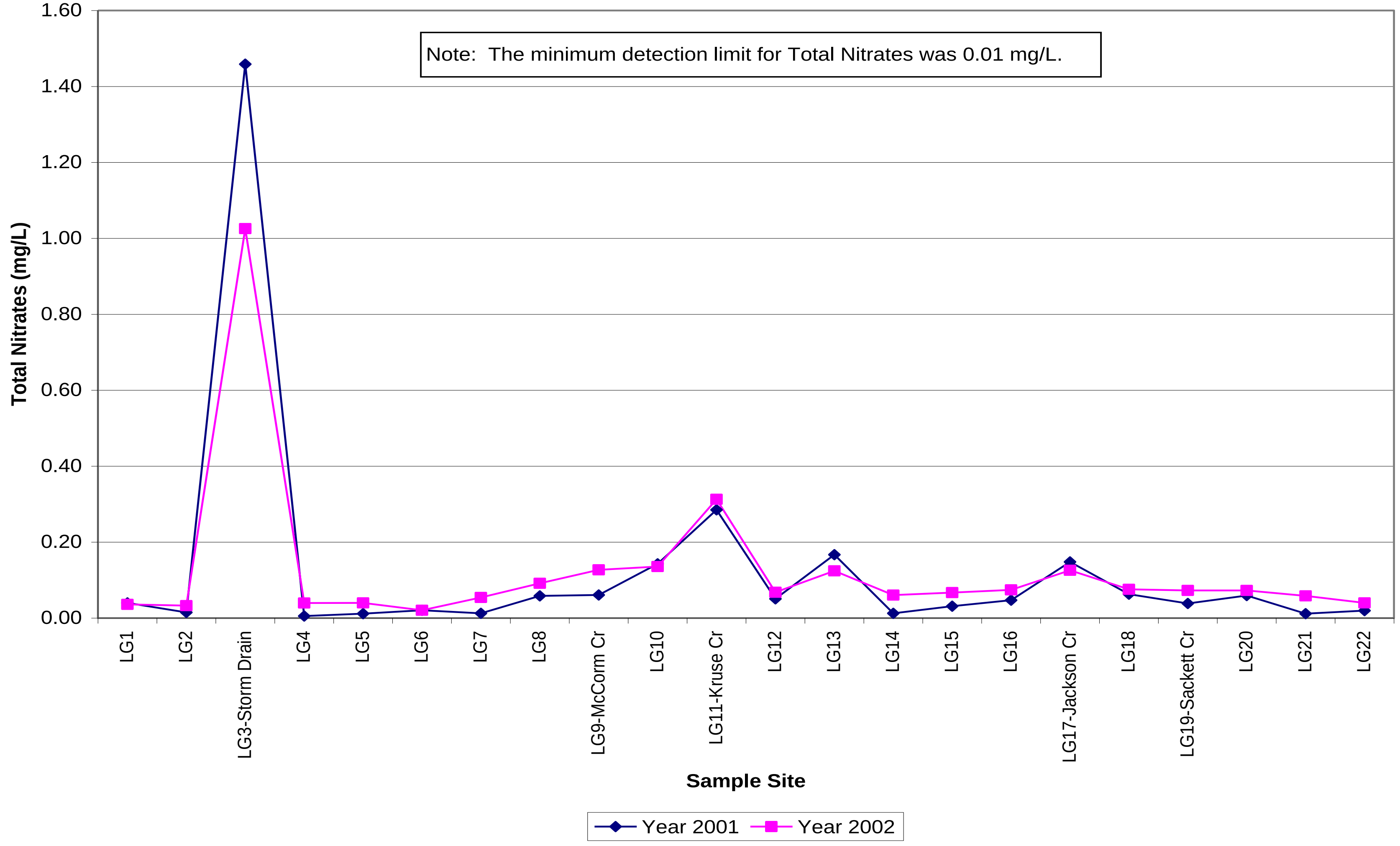


Figure 8-44. Mean Annual Total Phosphorus Values for Goose Creek and Big Goose Creek Monitoring Stations

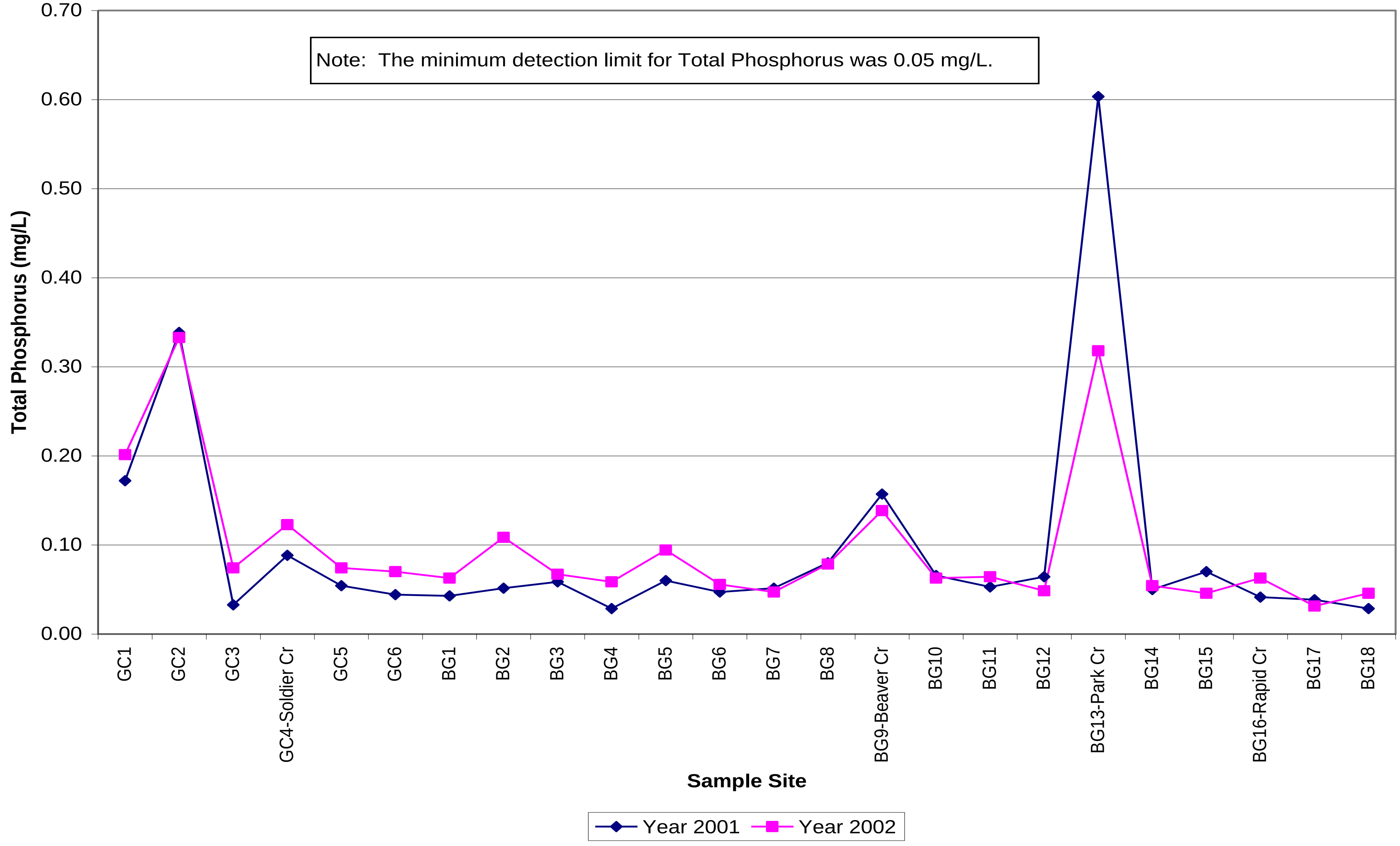


Figure 8-45. Mean Annual Total Phosphorus Values for Little Goose Creek Monitoring Stations

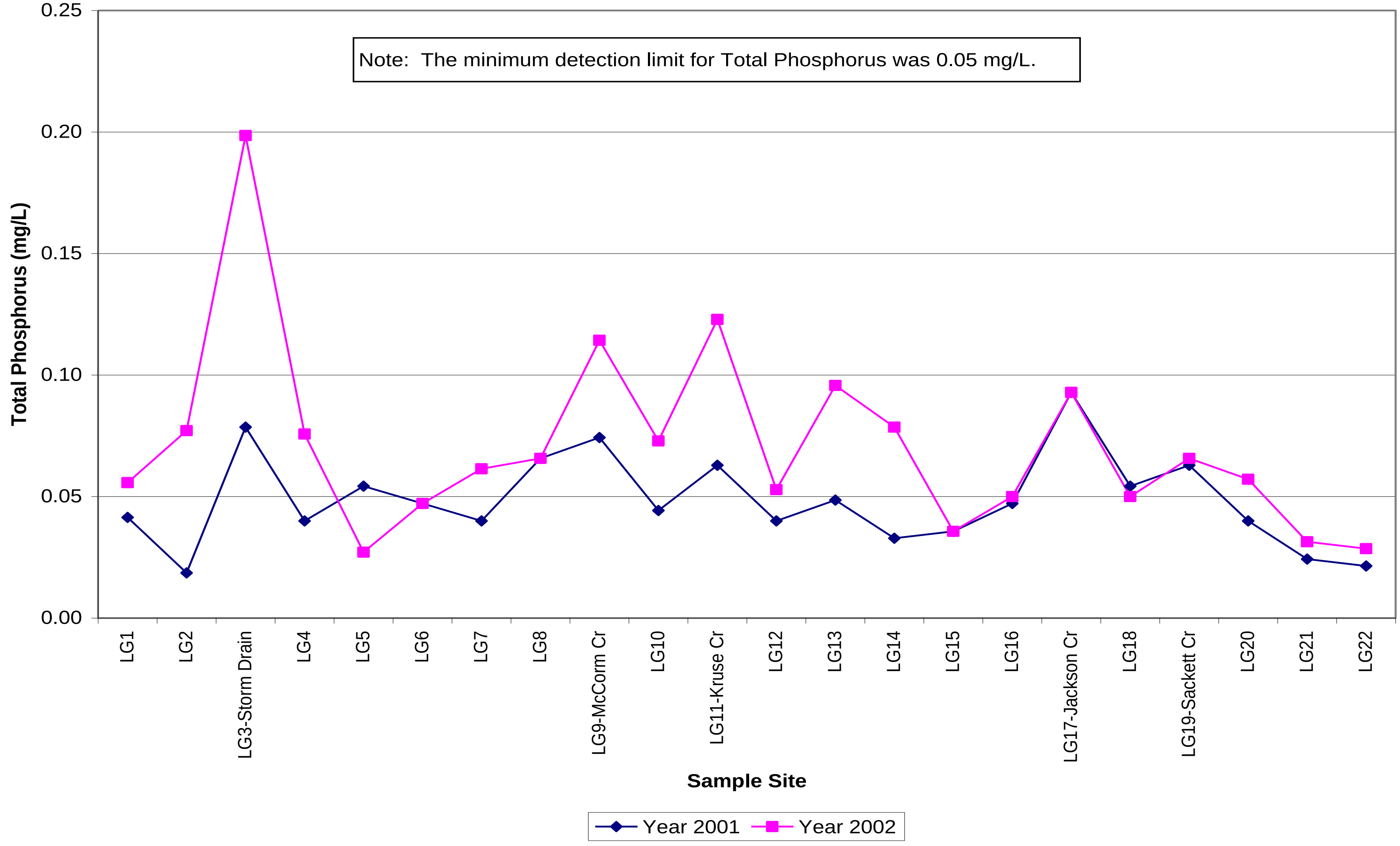


Figure 8-46. Mean Annual Total Ammonia Values for Goose Creek and Big Goose Creek Monitoring Stations

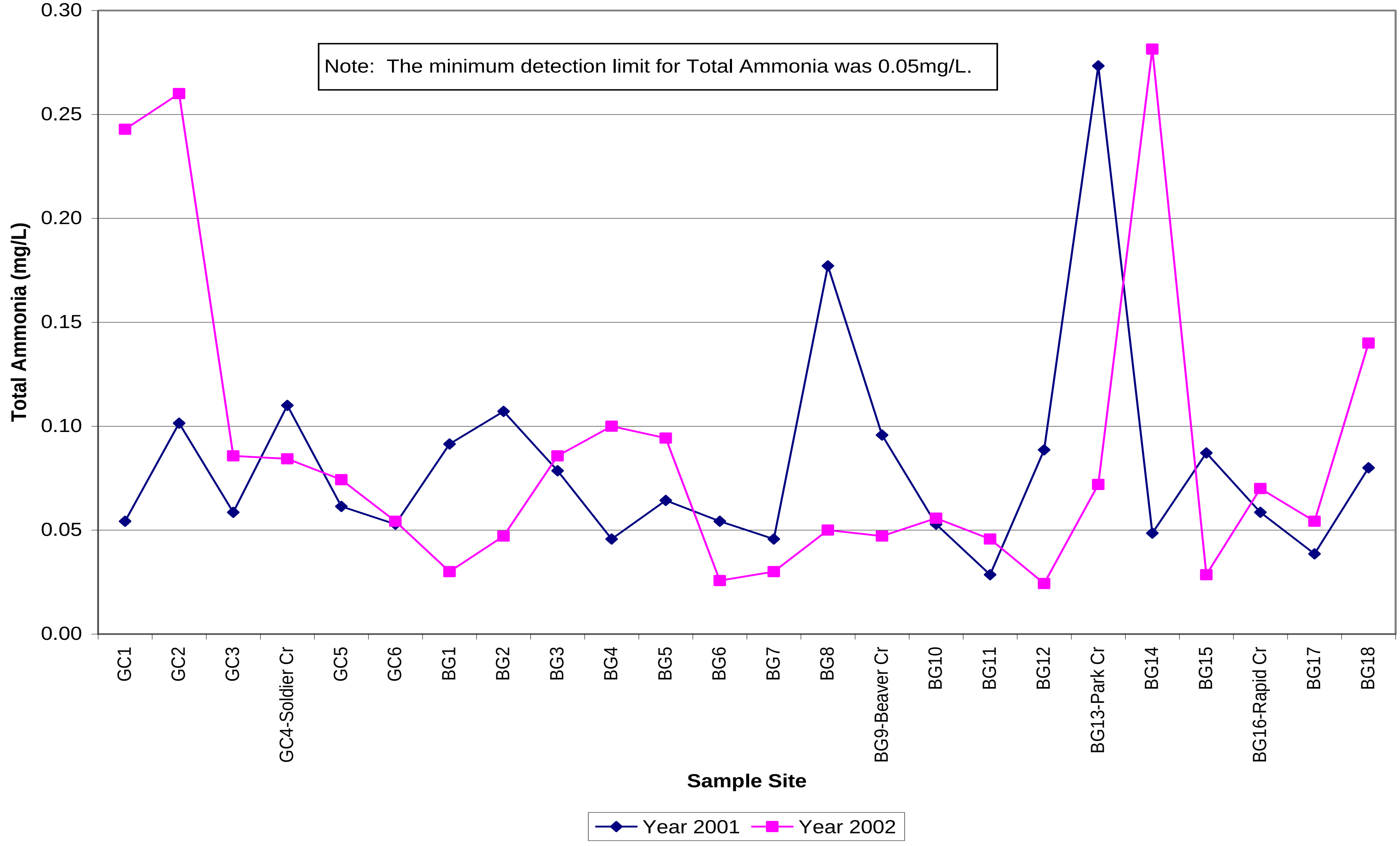


Figure 8-47. Mean Annual Total Ammonia Values for Little Goose Creek Monitoring Stations

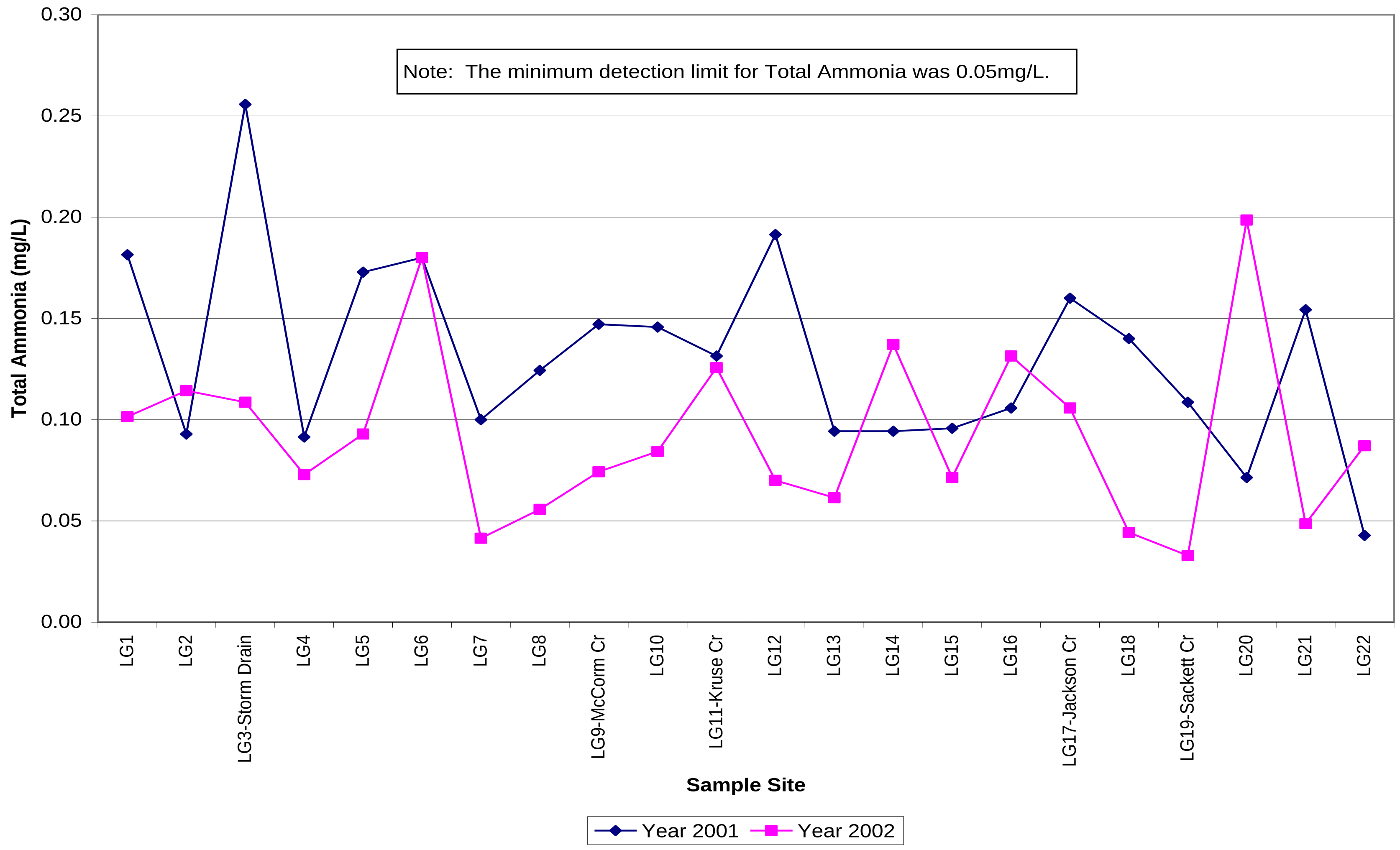


Figure 8-48. Mean Annual Total Hardness Values for Goose Creek and Big Goose Creek Monitoring Stations

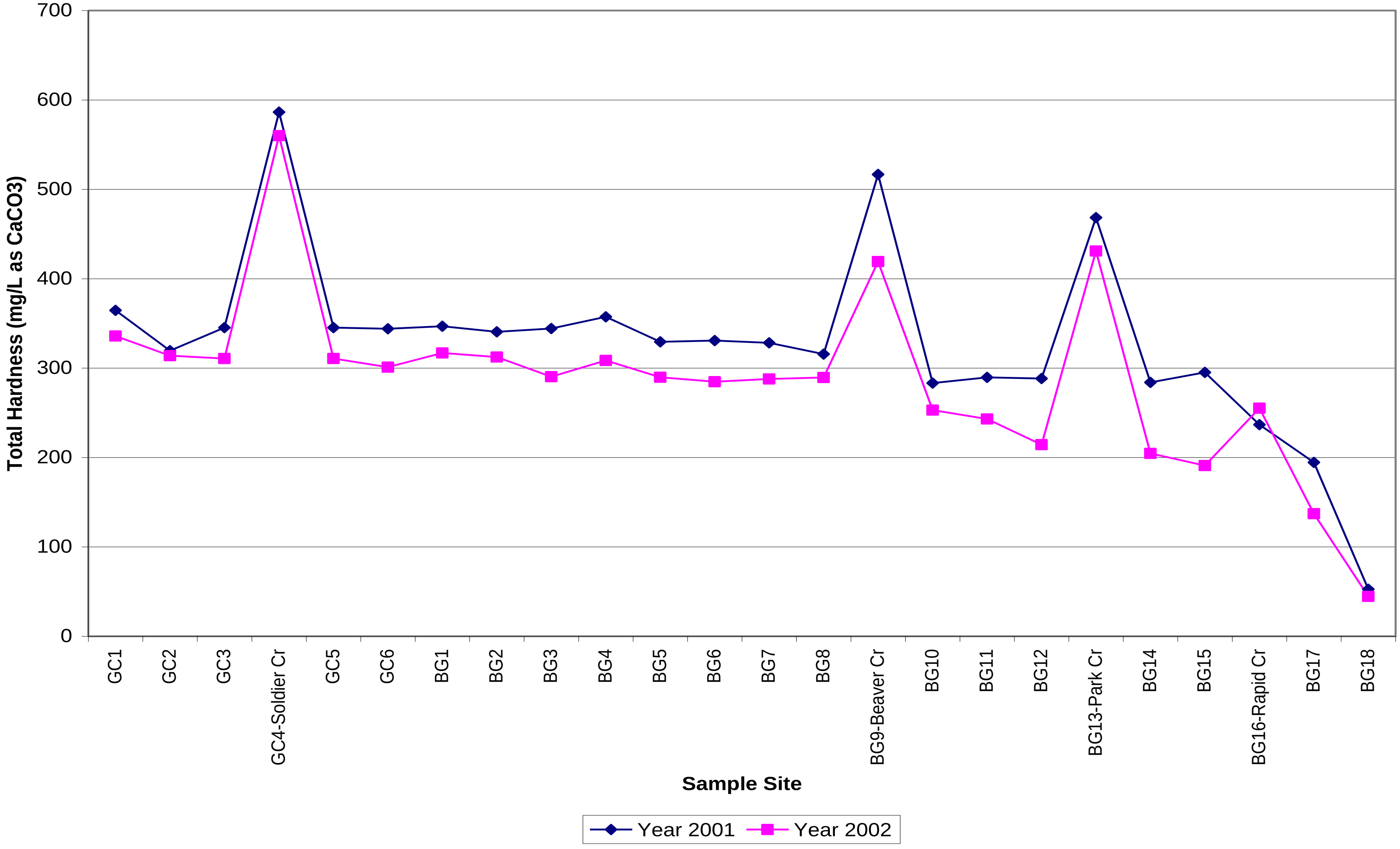


Figure 8-49. Mean Annual Total Hardness Values for Little Goose Creek Monitoring Stations

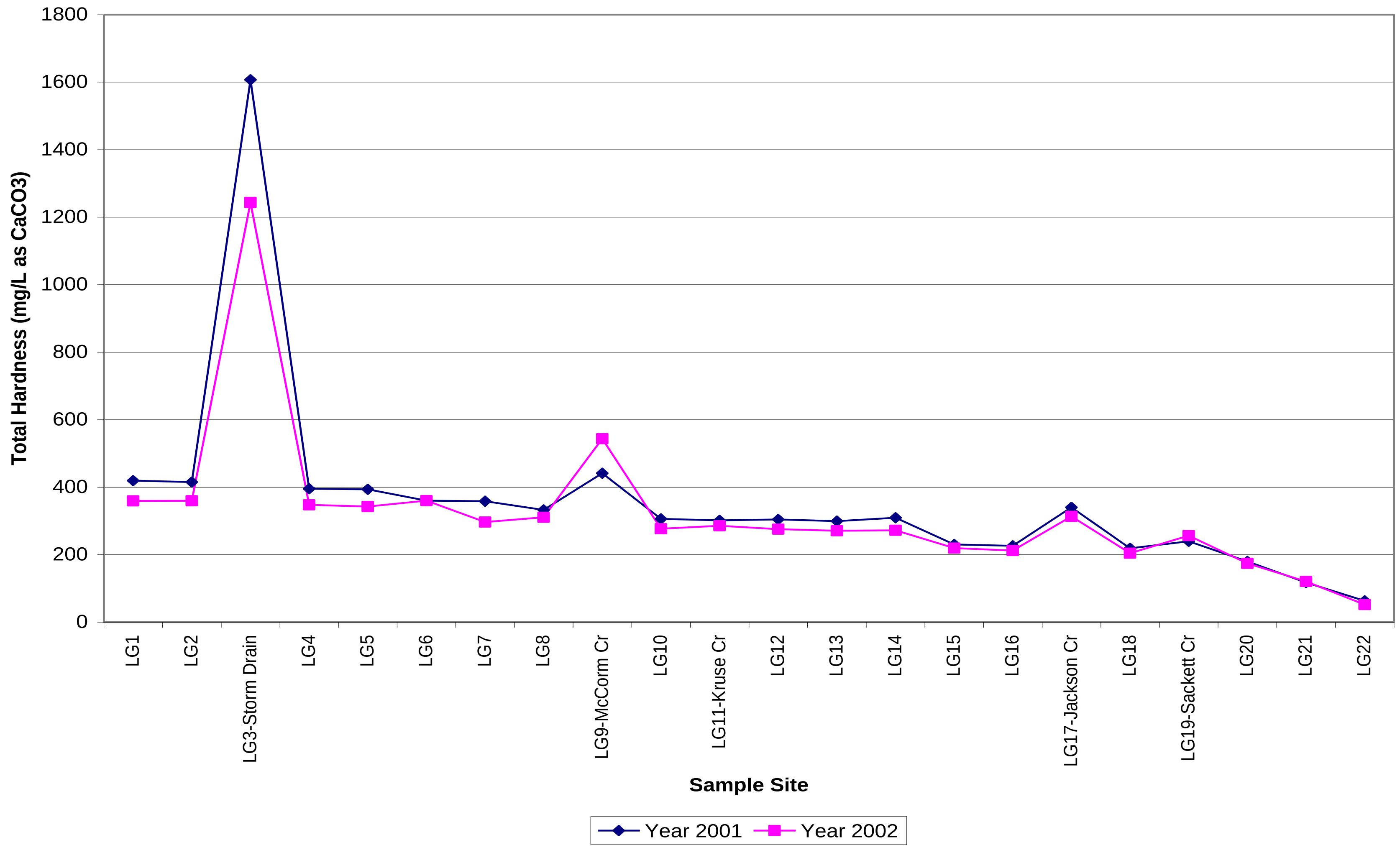


Figure 8-50. Summary of Fecal Coliform Geometric Means by Month for Goose Creek Monitoring Stations During 2001 and 2002

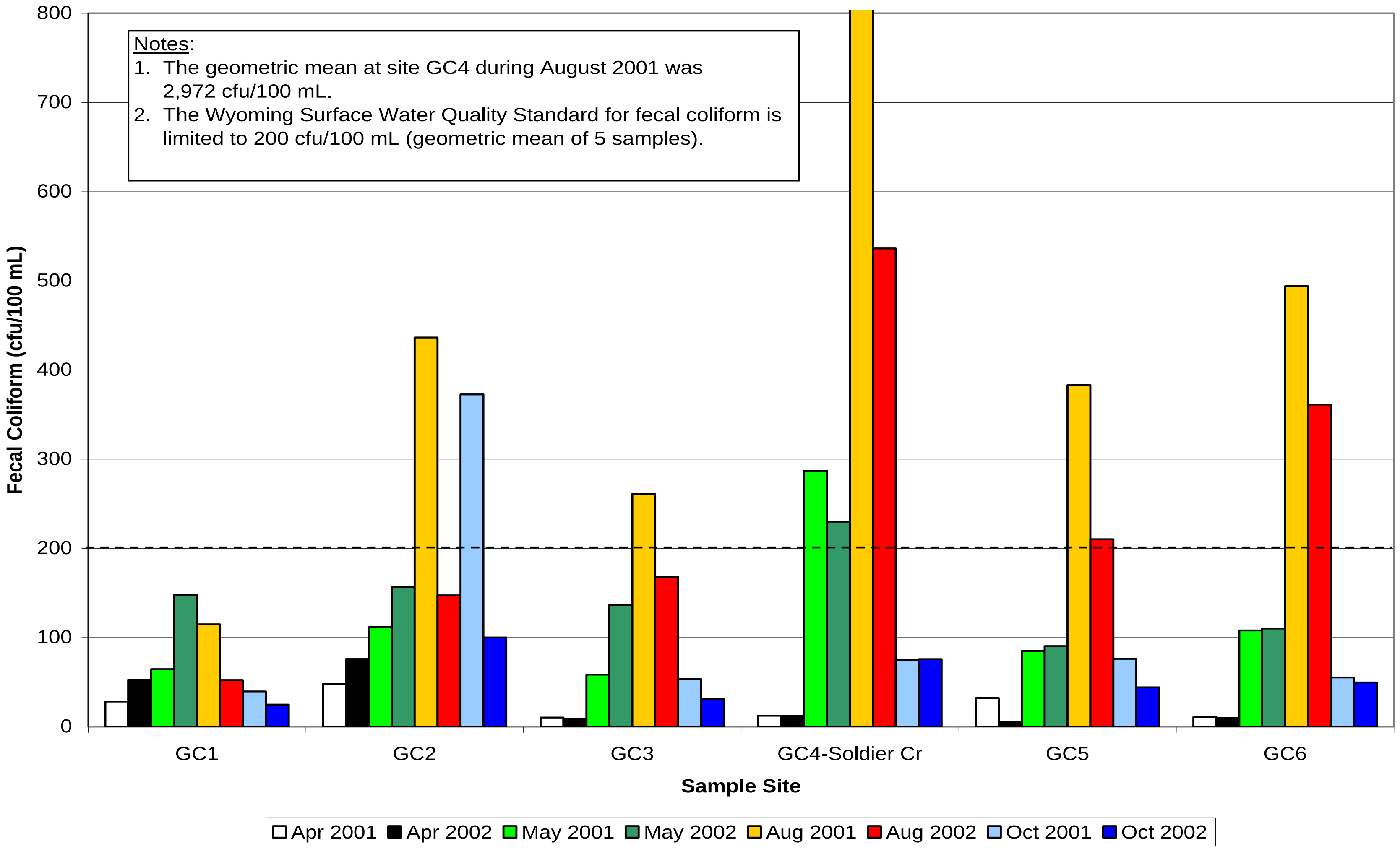


Figure 8-51. Summary of Fecal Coliform Geometric Means by Month for Big Goose Creek Monitoring Stations (BG1-BG9) During 2001 and 2002

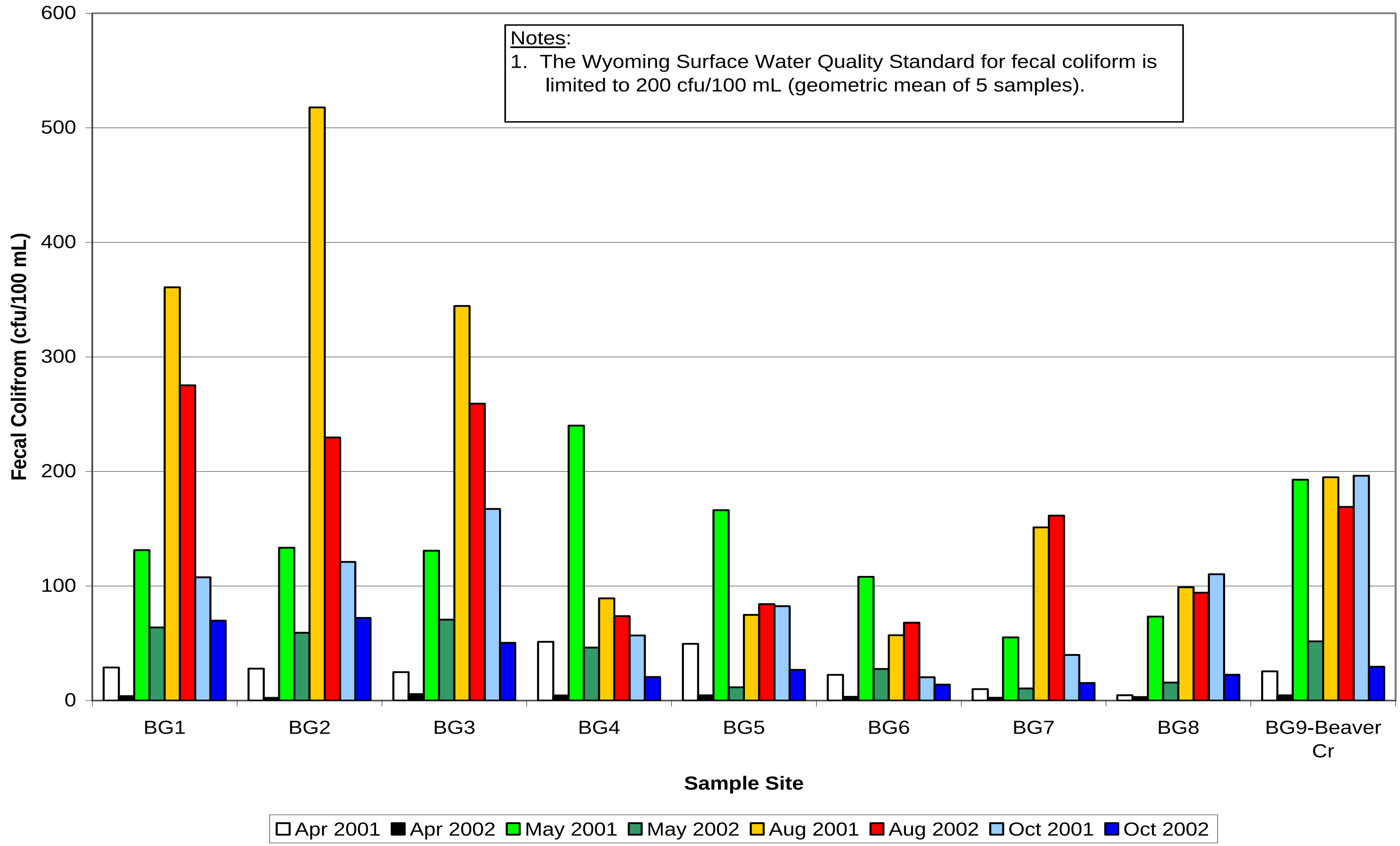


Figure 8-52. Summary of Fecal Coliform Geometric Means by Month for Big Goose Creek Monitoring Stations (BG10-BG18) During 2001 and 2002

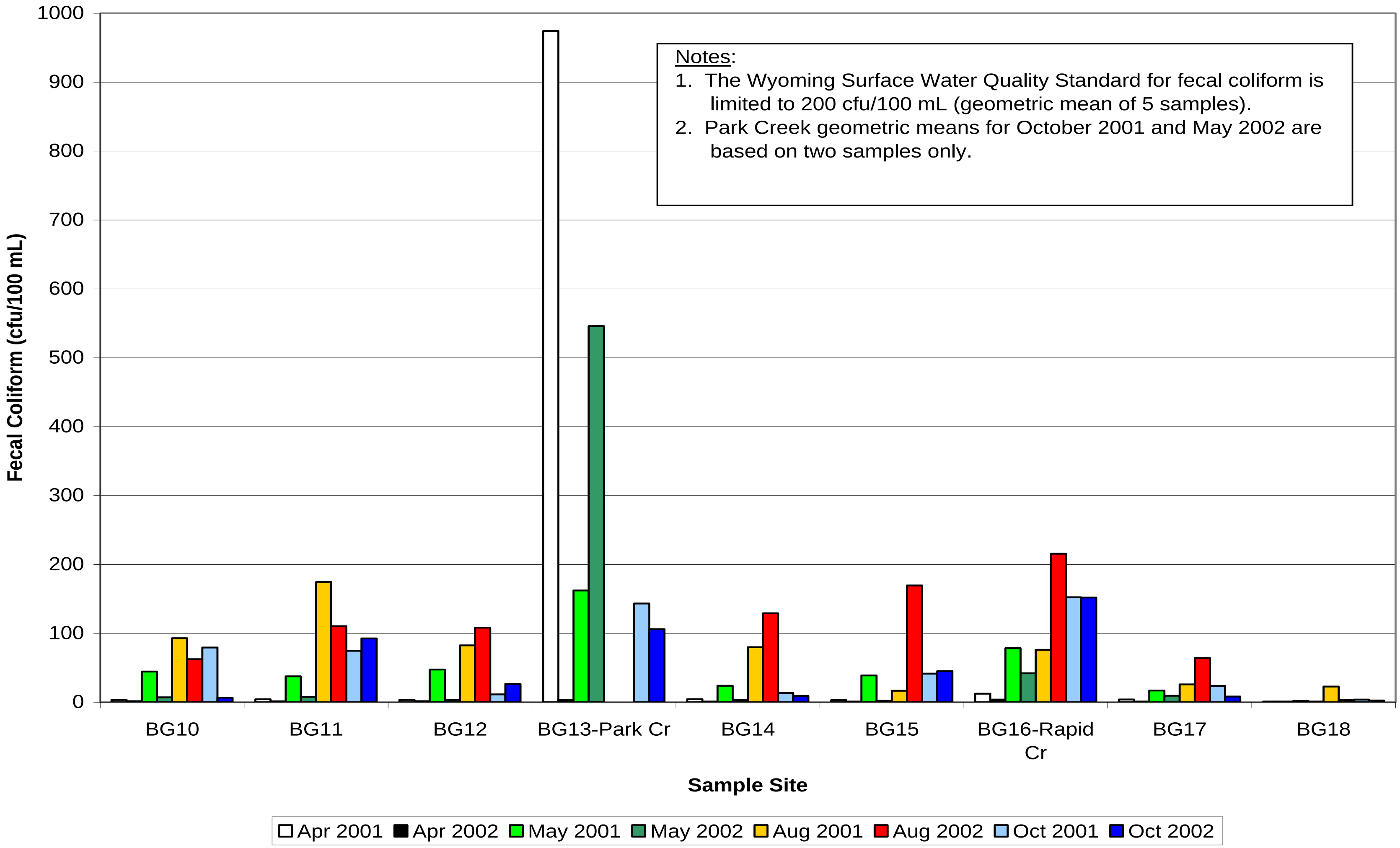


Figure 8-53. Summary of Fecal Coliform Geometric Means by Month for Little Goose Creek Monitoring Stations (LG1-LG8) During 2001 and 2002

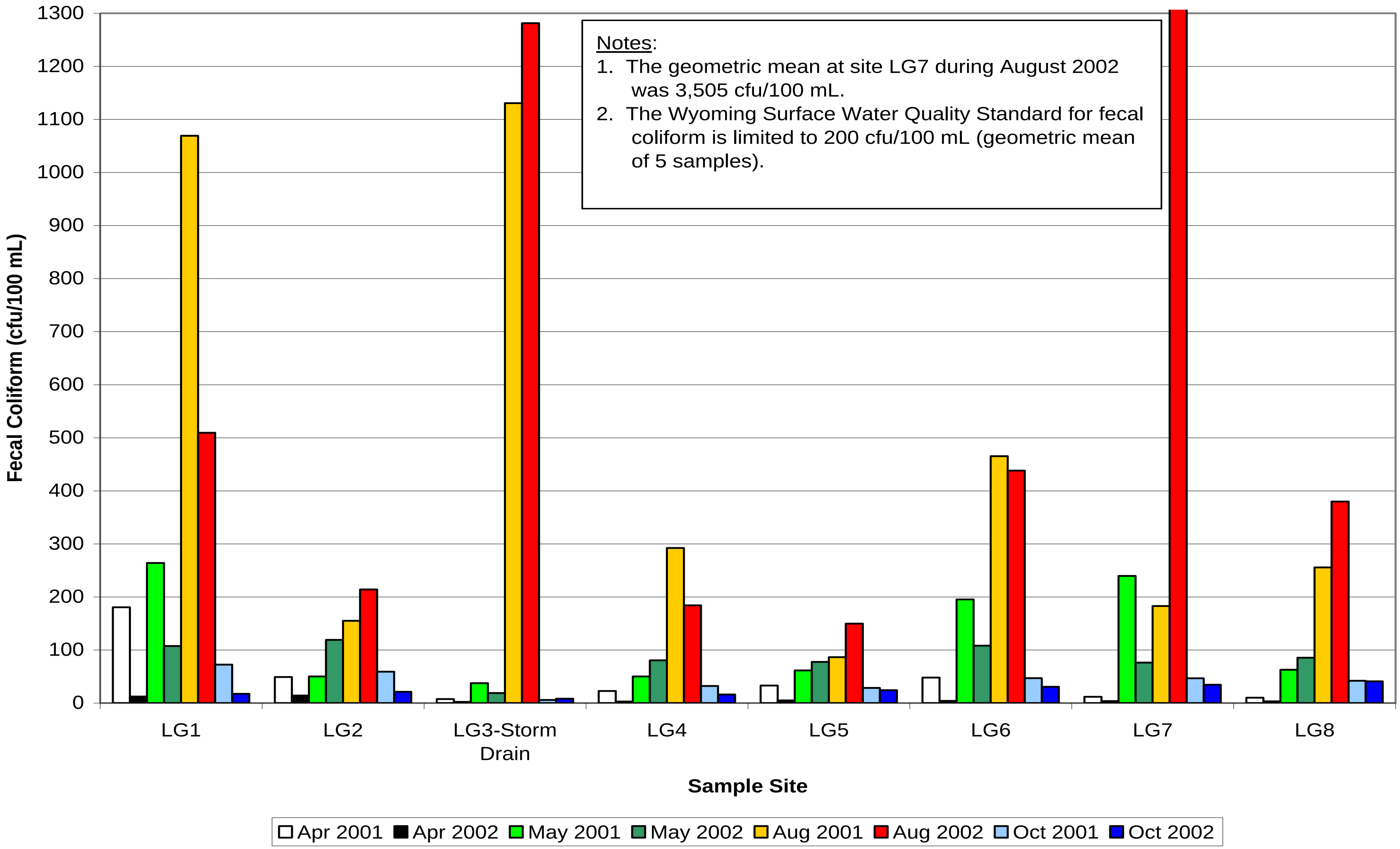


Figure 8-54. Summary of Fecal Coliform Geometric Means by Month for Little Goose Creek Monitoring Stations (LG9-LG16) During 2001 and 2002

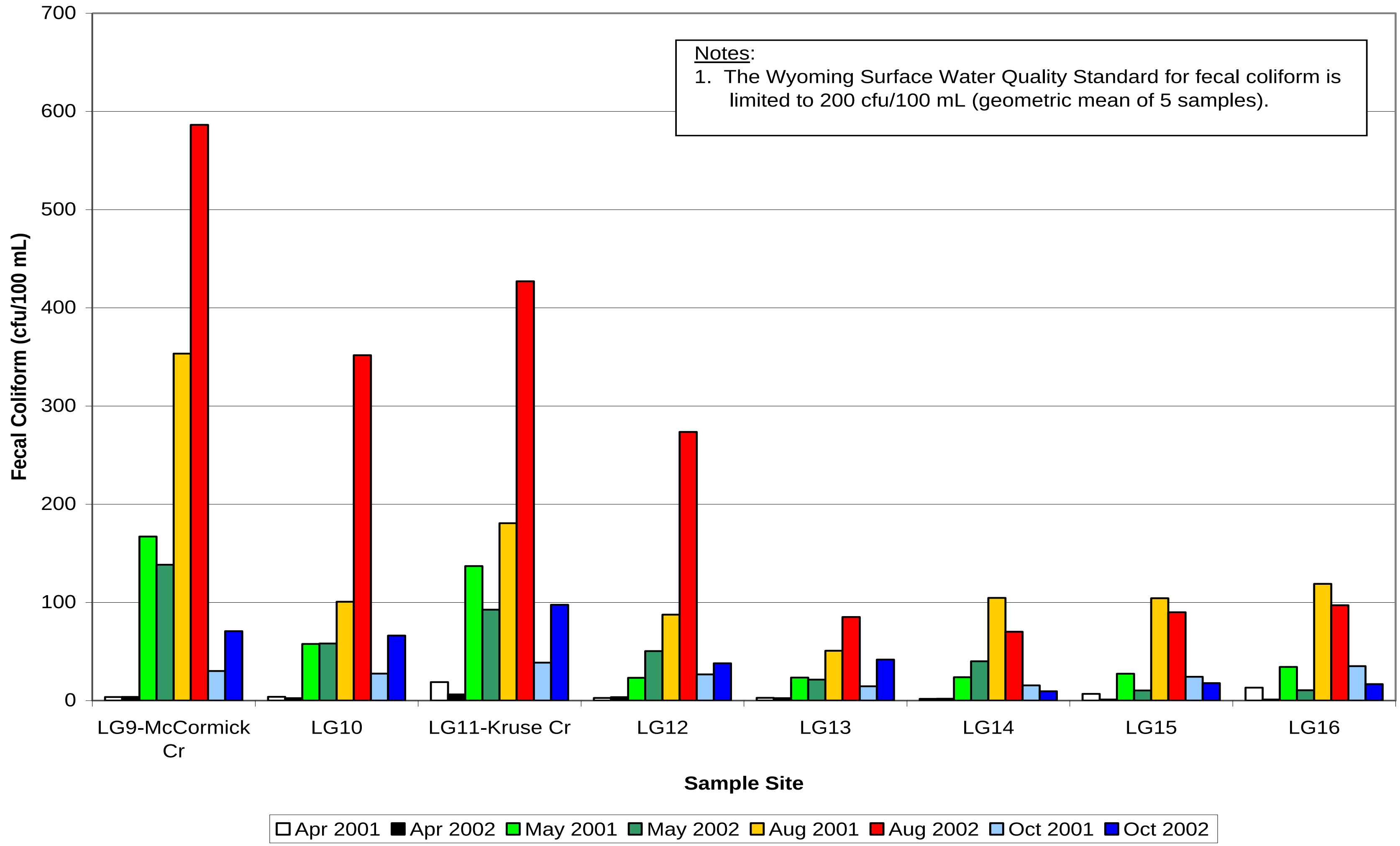


Figure 8-55. Summary of Fecal Coliform Geometric Means by Month for Little Goose Creek Monitoring Stations (LG17-LG22) During 2001 and 2002

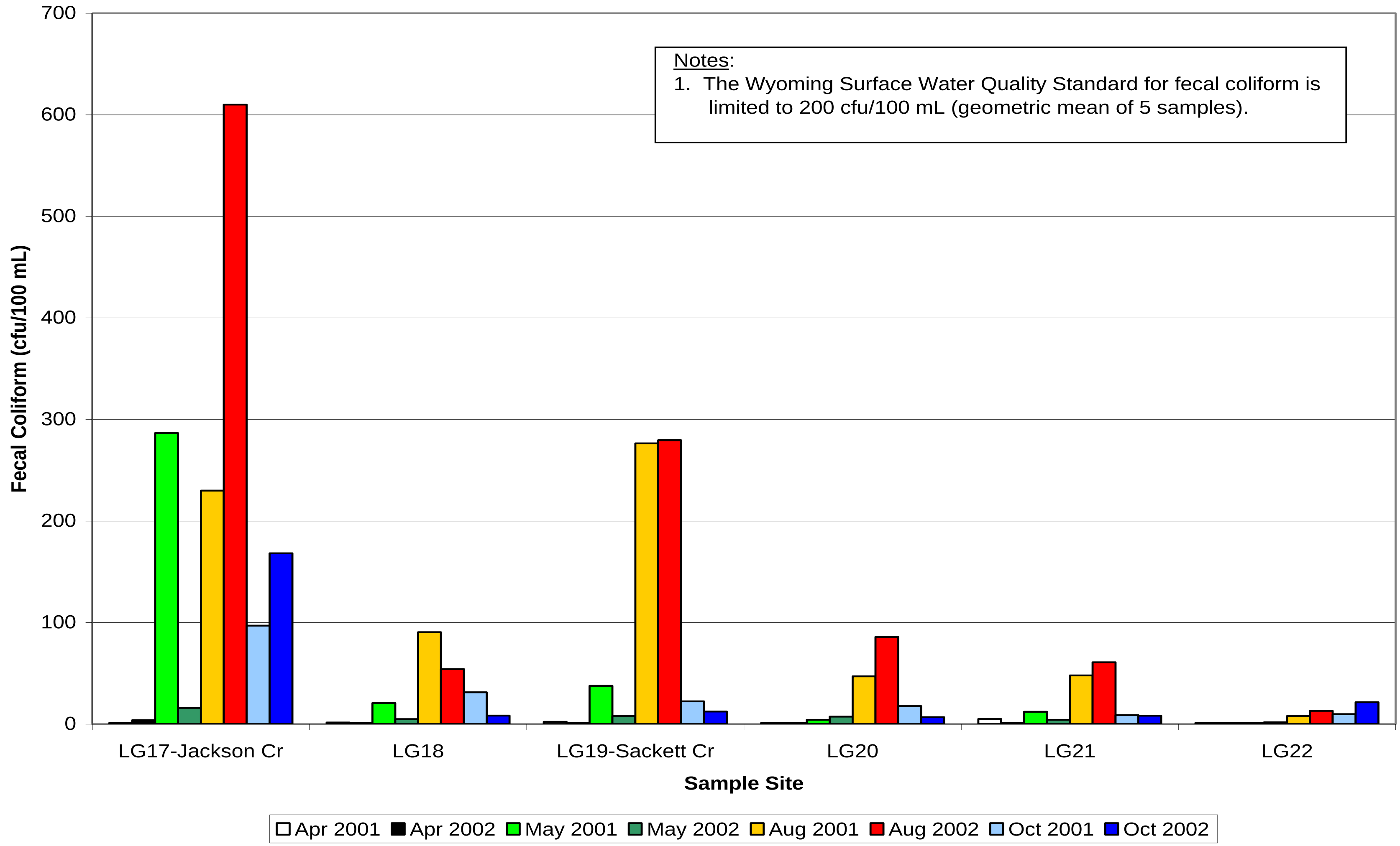


Figure 8-56. Estimated Fecal Coliform Loading for Goose Creek Monitoring Sites During May and August, 2001 and 2002. Loading was Calculated Using the Average of Five Discharge Measurements and the Geometric Mean of Five Fecal Coliform Samples

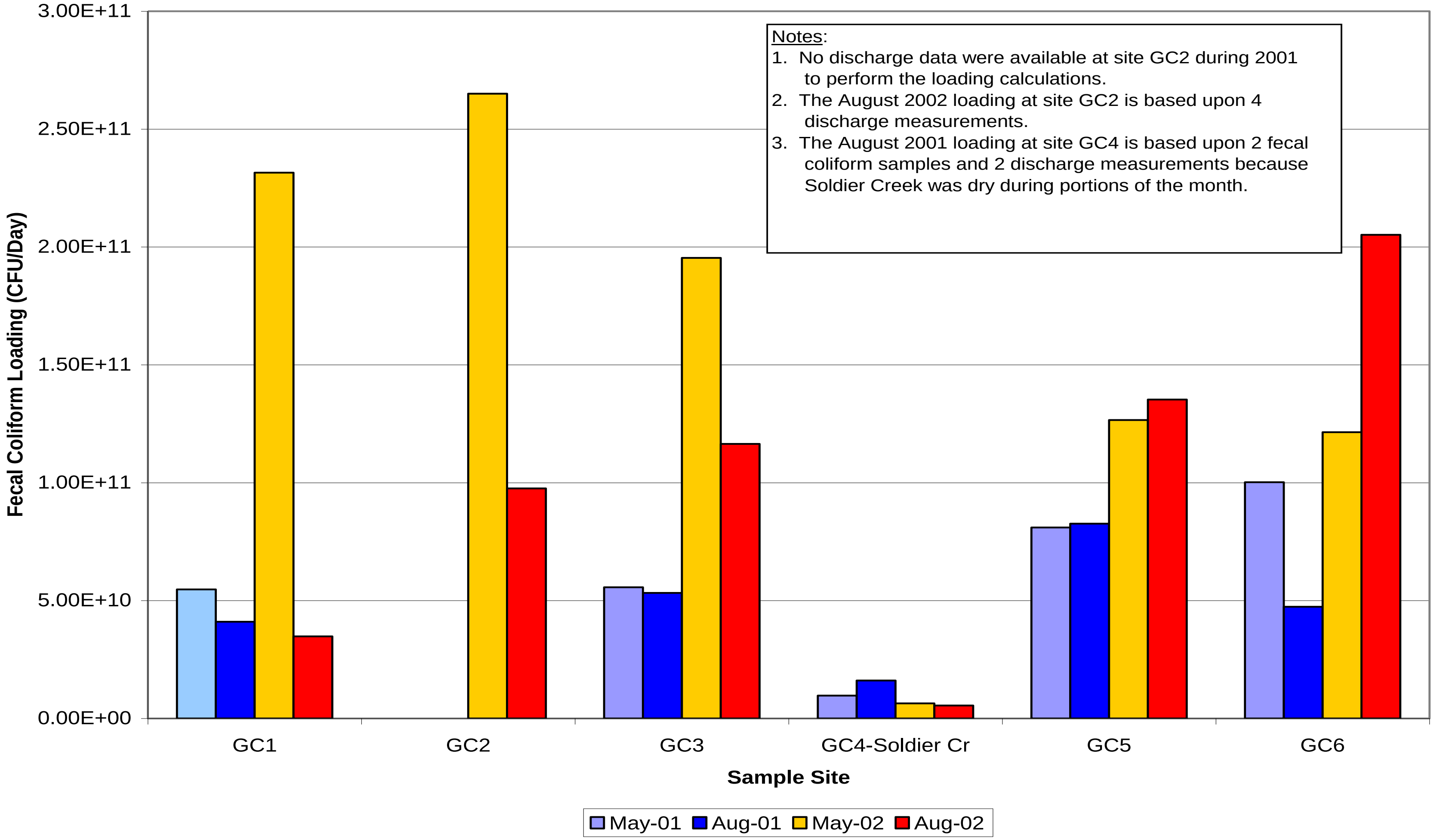


Figure 8-57. Estimated Fecal Coliform Loading for Big Goose Creek Monitoring Sites (BG1-BG9) During May and August, 2001 and 2002. Loading was Calculated Using the Average of Five Discharge Measurements and the Geometric Mean of Five Fecal Coliform Samples

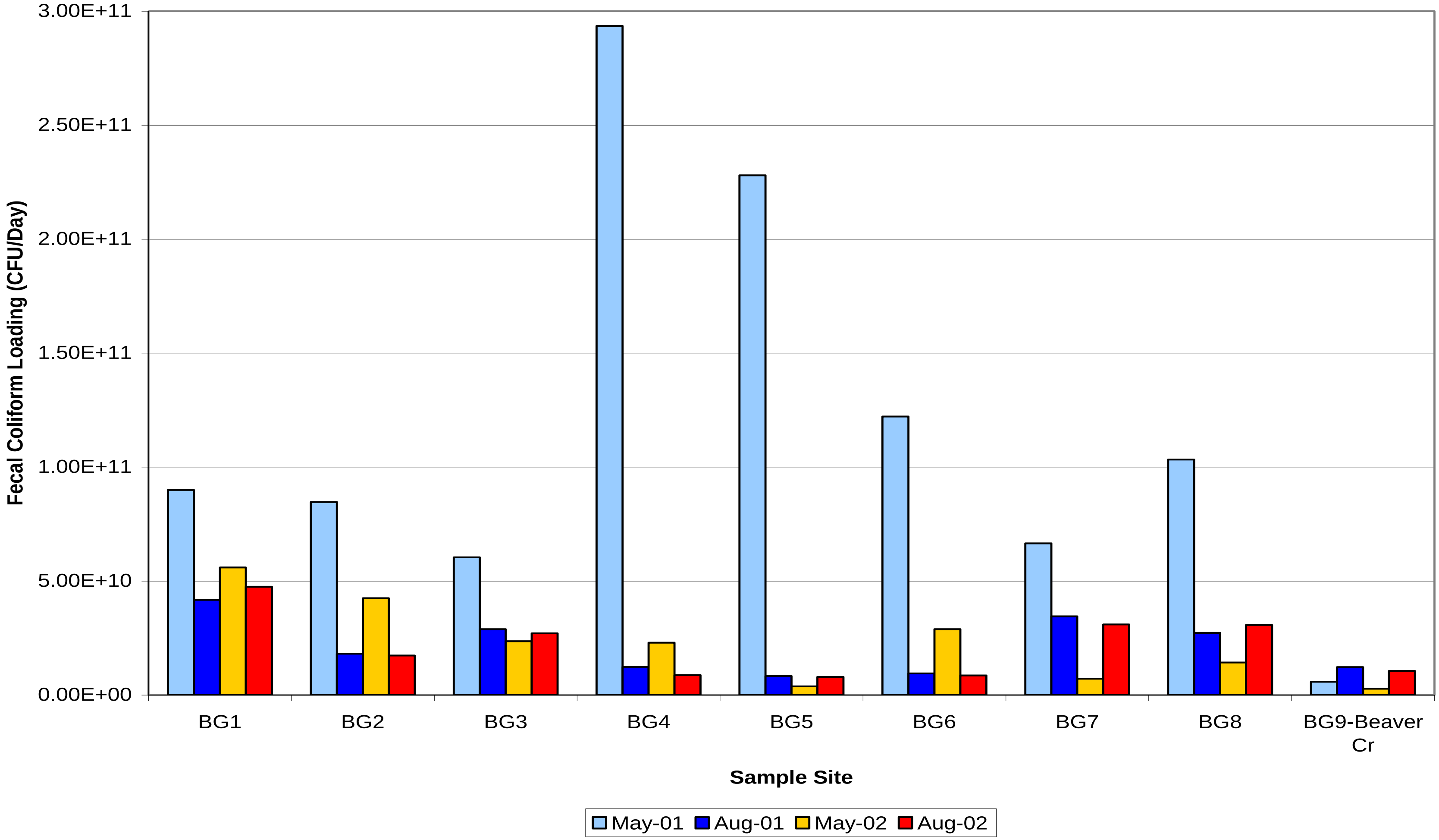


Figure 8-58. Estimated Fecal Coliform Loading for Big Goose Creek Monitoring Sites (BG10-BG18) During May and August, 2001 and 2002. Loading was Calculated Using the Average of Five Discharge Measurements and the Geometric Mean of Five Fecal Coliform Samples

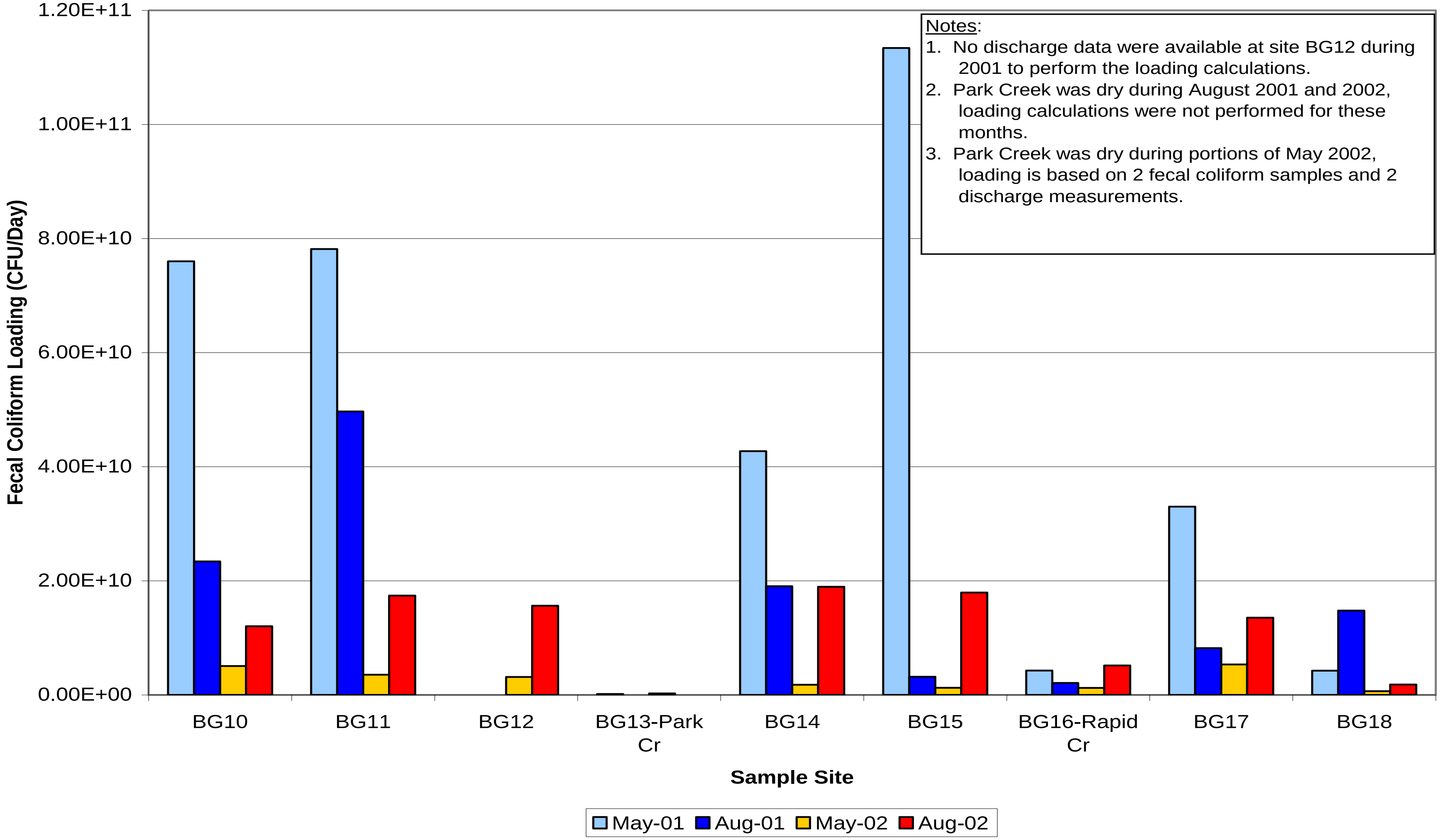


Figure 8-59. Estimated Fecal Coliform Loading for Little Goose Creek Monitoring Sites (LG1-LG11) During May and August, 2001 and 2002. Loading was Calculated Using the Average of Five Discharge Measurements and the Geometric Mean of Five Fecal Coliform Samples

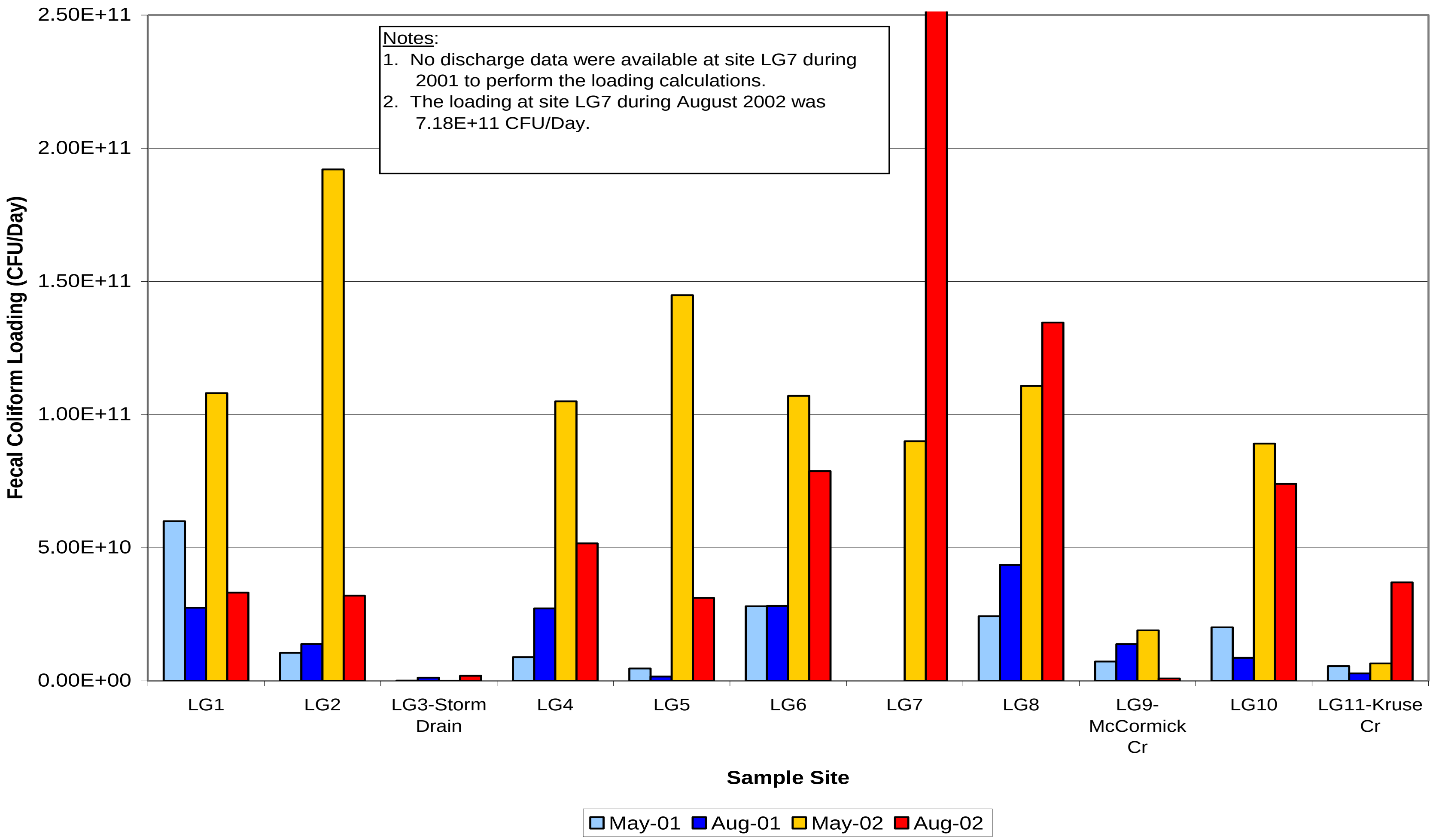


Figure 8-60. Estimated Fecal Coliform Loading for Little Goose Creek Monitoring Sites (LG12-LG22) During May and August, 2001 and 2002. Loading was Calculated Using the Average of Five Discharge Measurements and the Geometric Mean of Five Fecal Coliform Samples

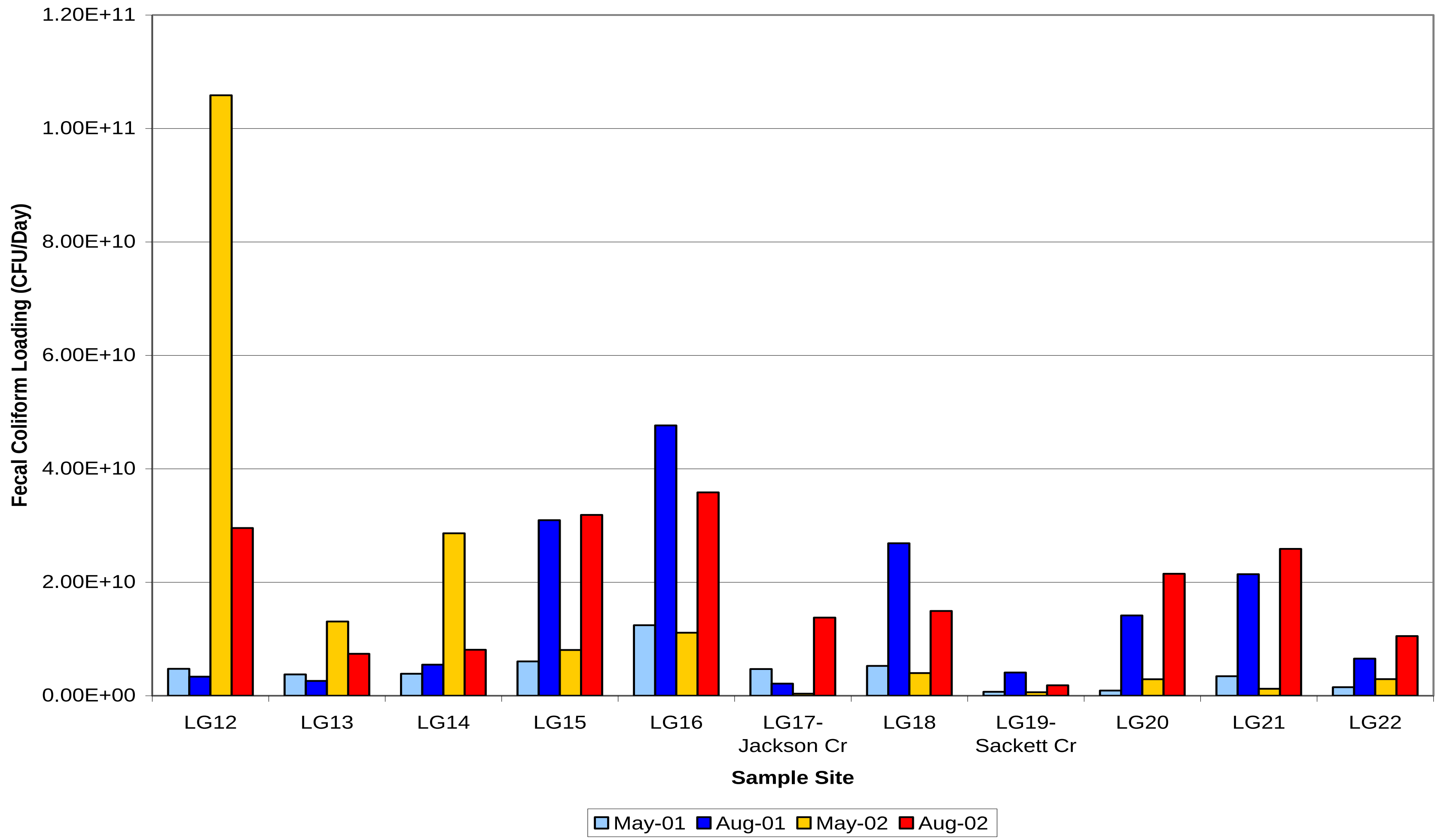


Figure 8-61. April 1, 2002 Fecal Coliform in Bed Sediment Sampling at Goose Creek Site GC2

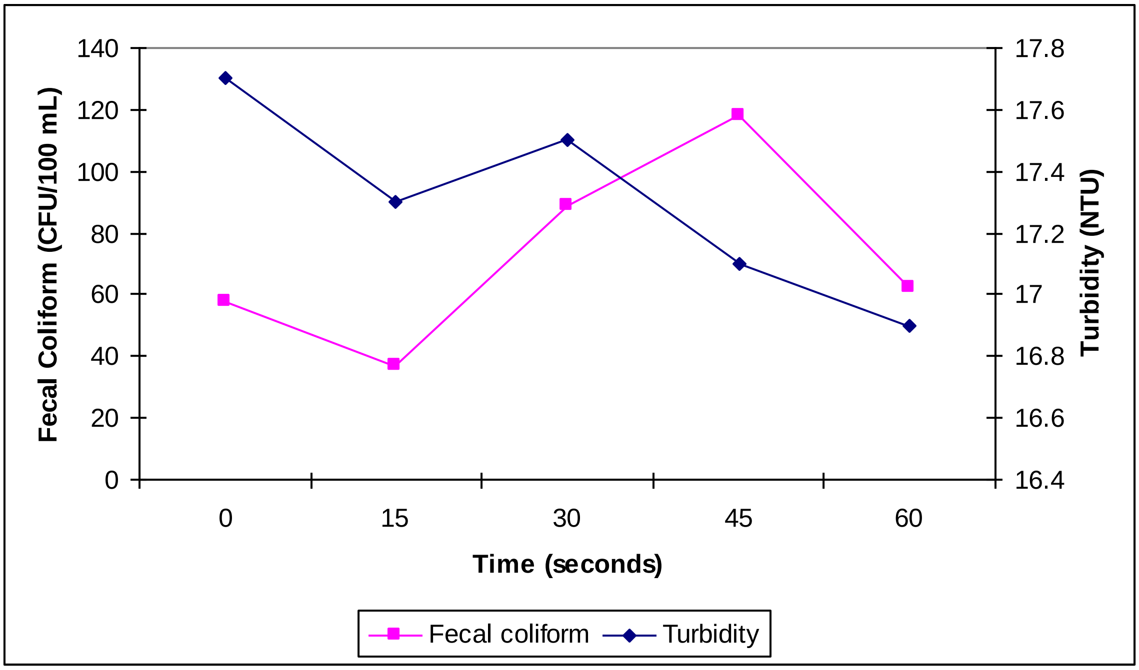


Figure 8-62. September 4, 2002 Fecal Coliform in Bed Sediment Sampling at Goose Creek Site GC2

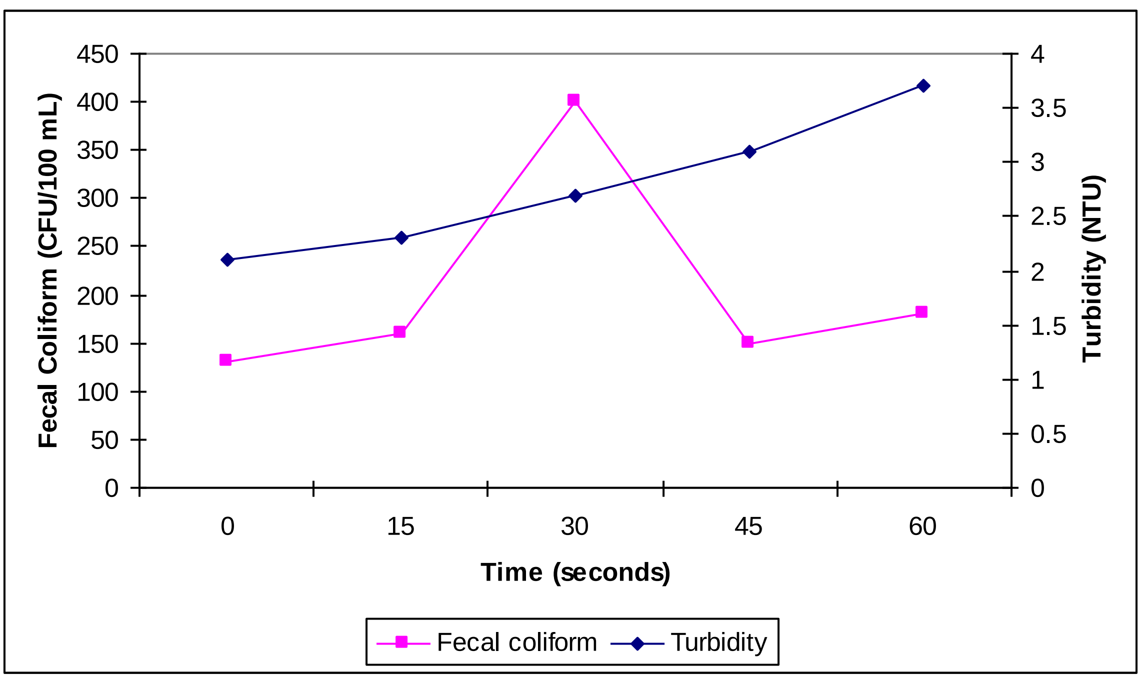


Figure 8-63. April 1, 2002 Fecal Coliform in Bed Sediment Sampling at Little Goose Creek Site LG8

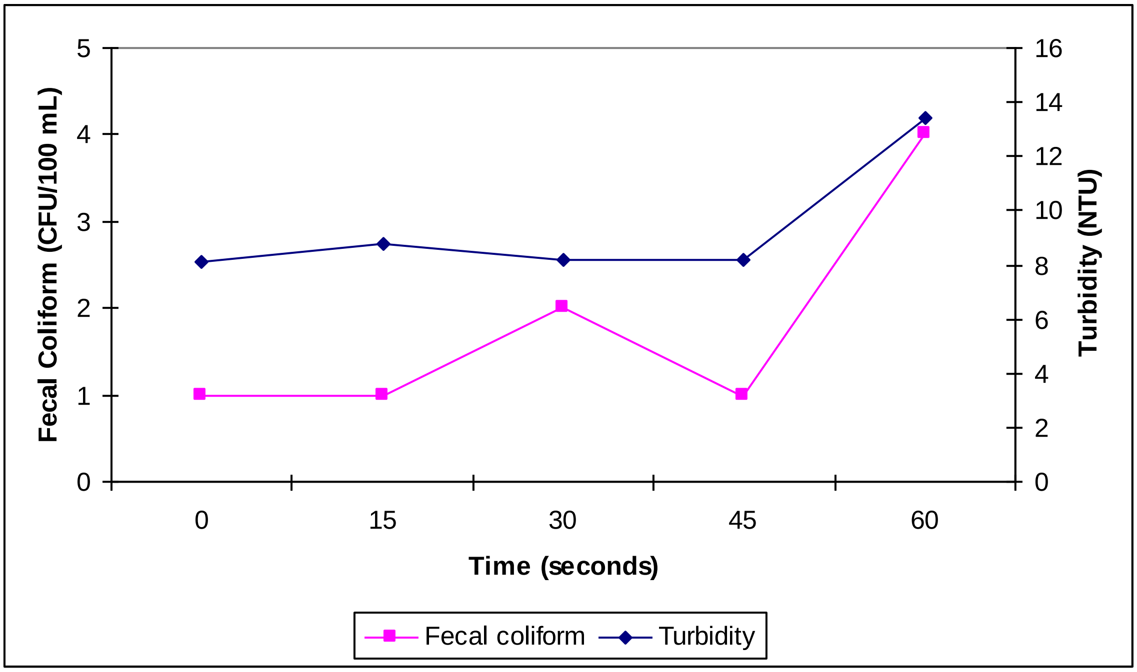


Figure 8-64. September 4, 2002 Fecal Coliform in Bed Sediment Sampling at Little Goose Creek Site LG8

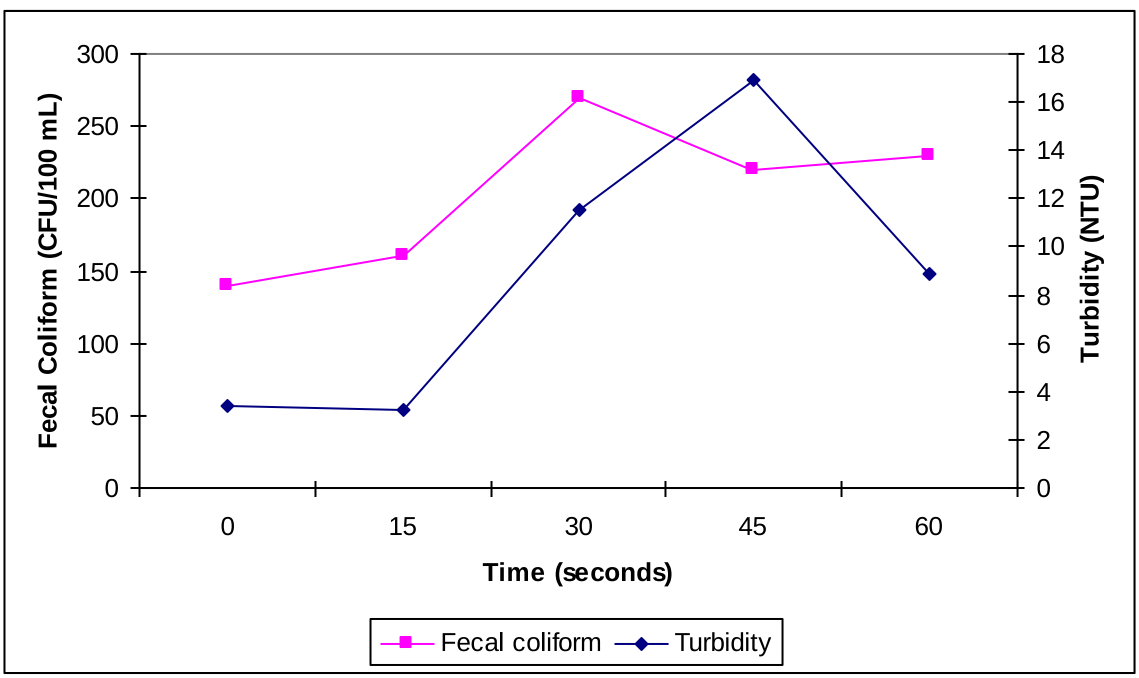


Figure 8-65. April 1, 2002 Fecal Coliform in Bed Sediment Sampling at Big Goose Creek Site BG18

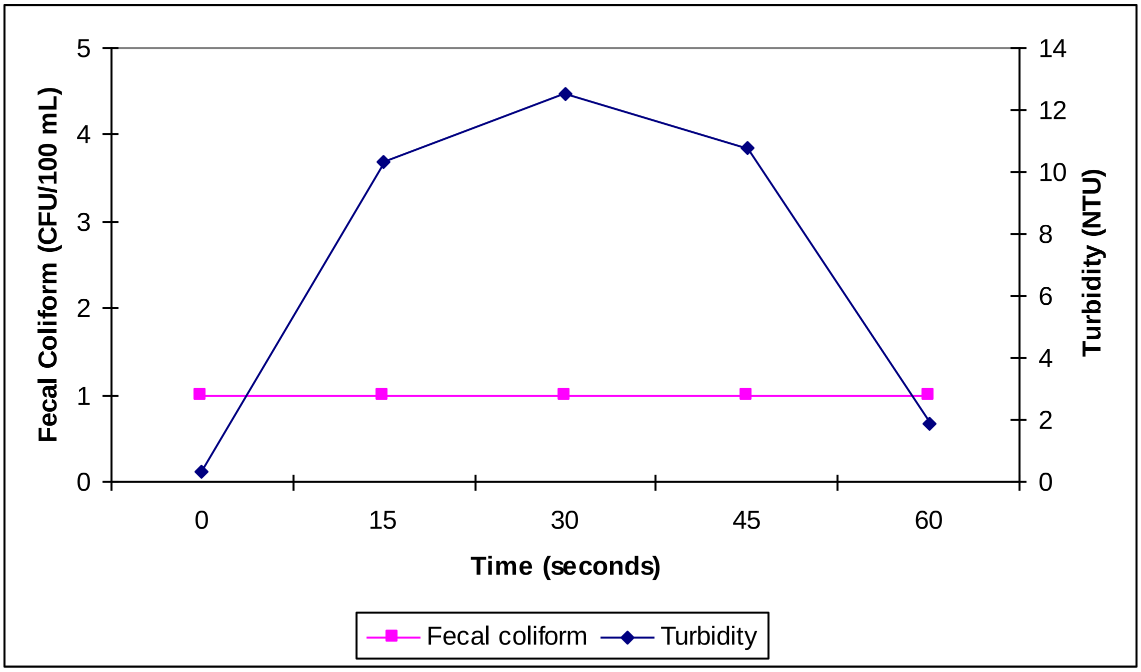


Figure 8-66. September 4, 2002 Fecal Coliform in Bed Sediment Sampling at Big Goose Creek Site BG18

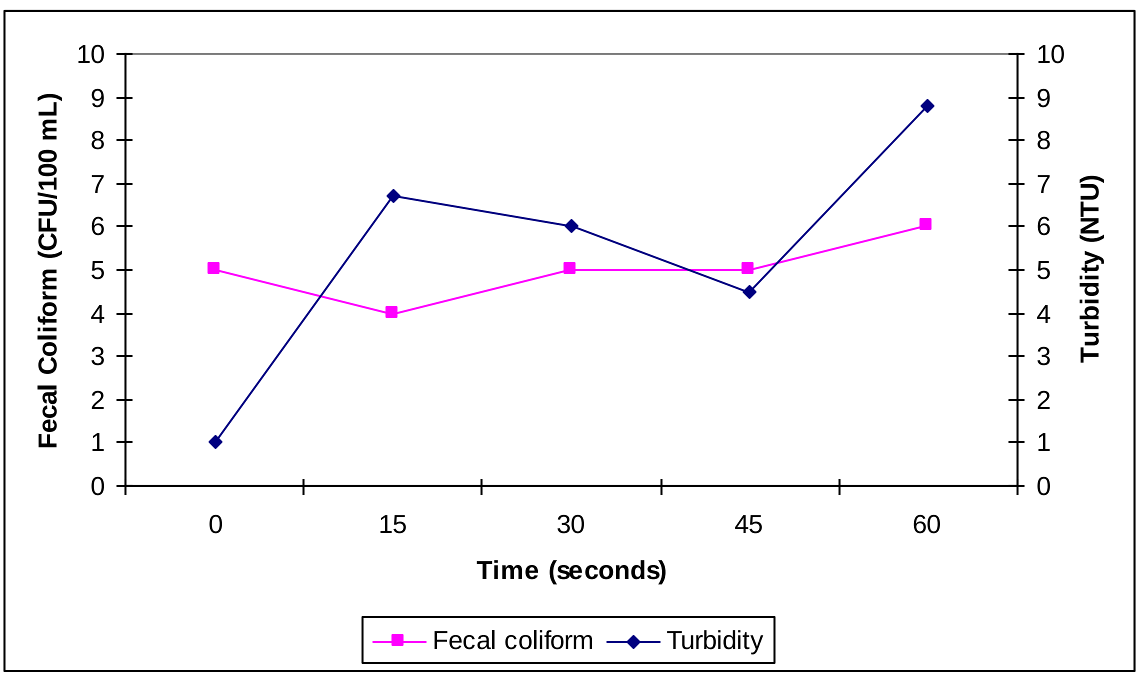


Figure 8-67. Comparison of E. coli and Fecal Coliform Geometric Means for Samples Collected at the Same Sites on the Same Days During August 2002

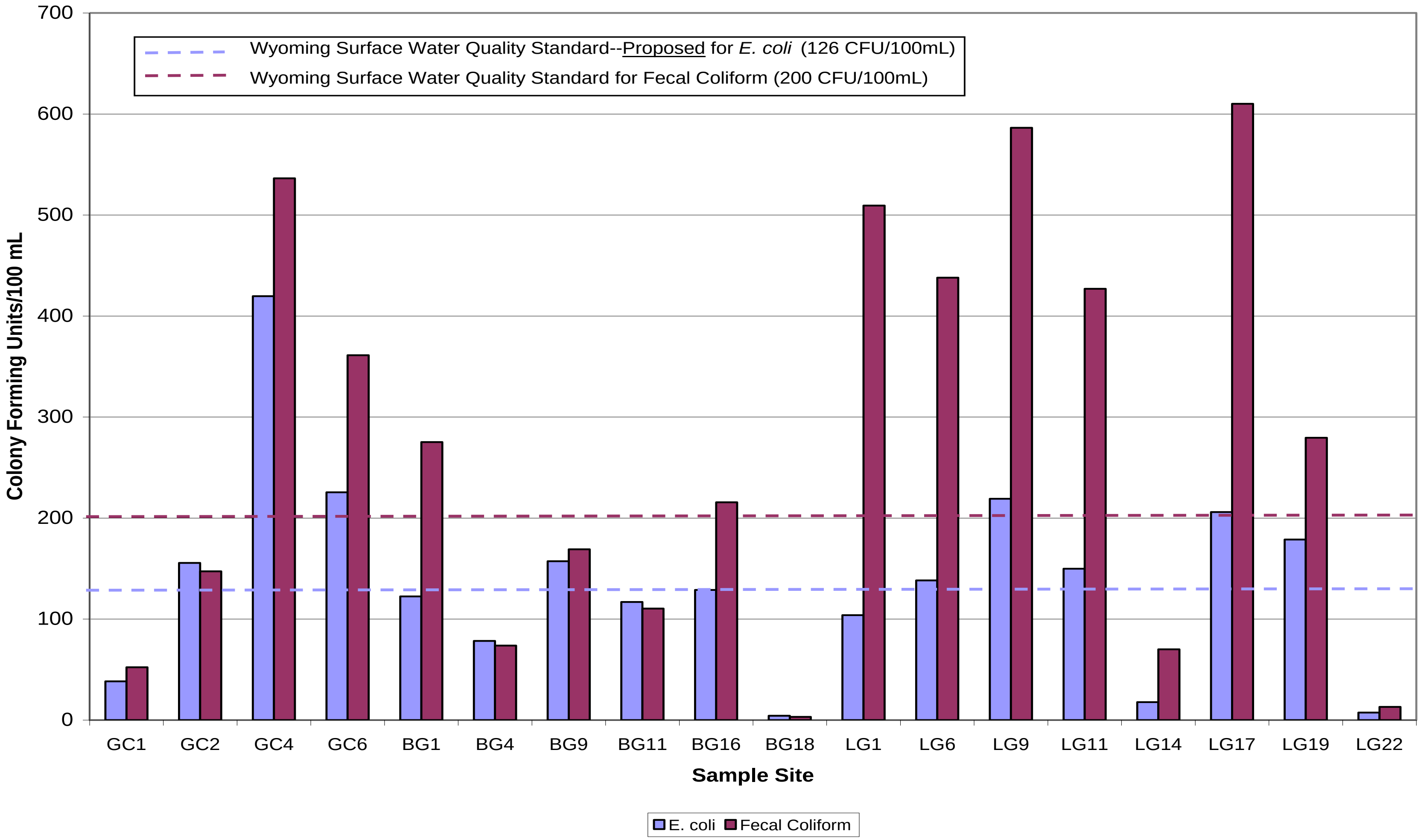


Figure 8-68. Scatterplot with Linear Regression that Shows the Relationship Between all Samples Taken During 2002 and the Corresponding Fecal Coliform Samples

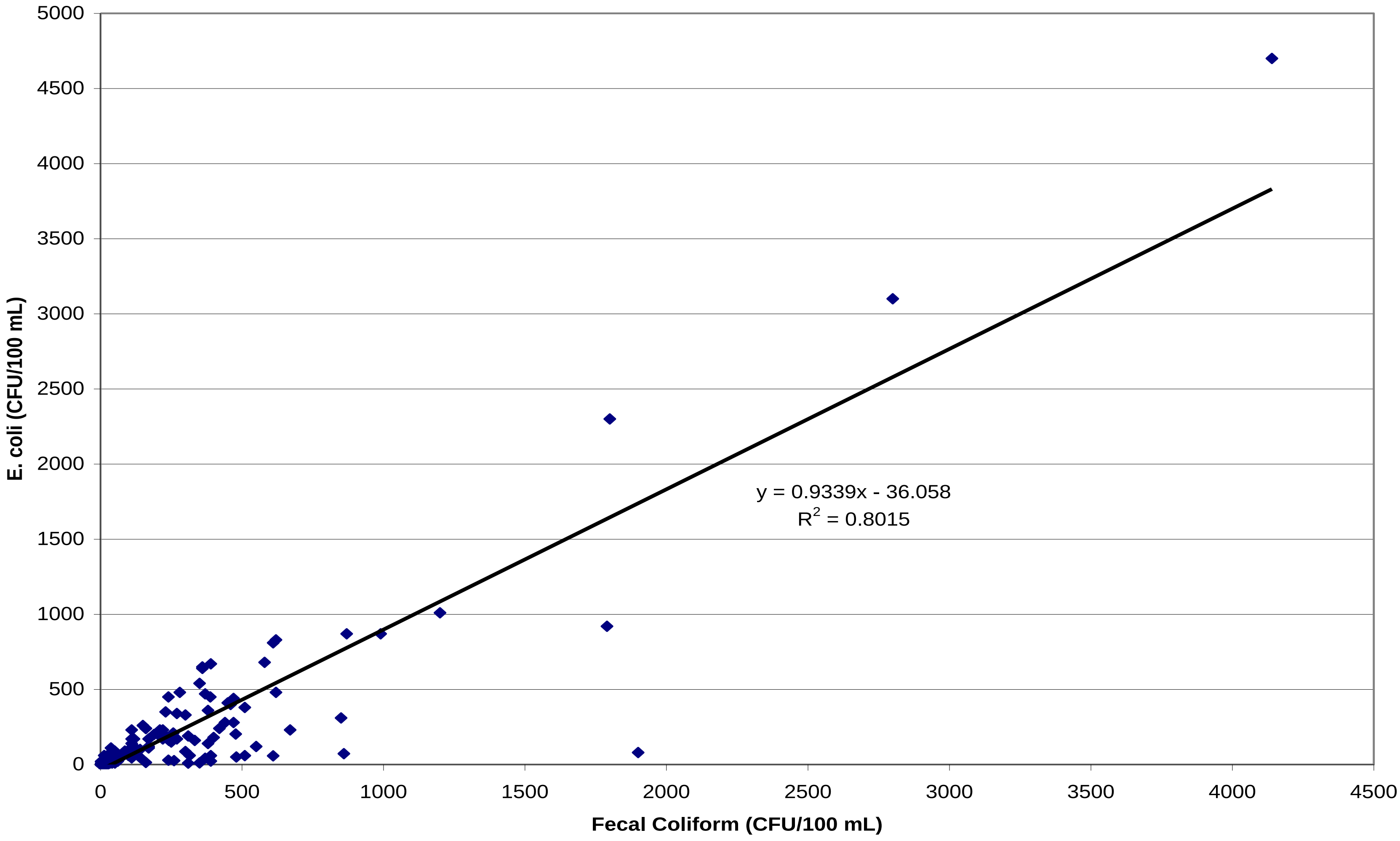


Figure 8-69. Comparison of Wyoming Department of Environmental Quality (WDEQ) 1998 and 1999 Fecal Coliform Data to 2001 and 2002 Goose Creeks Watershed Assessment (GCWA) Data for Common Goose Creek and Big Goose Creek Sample Stations

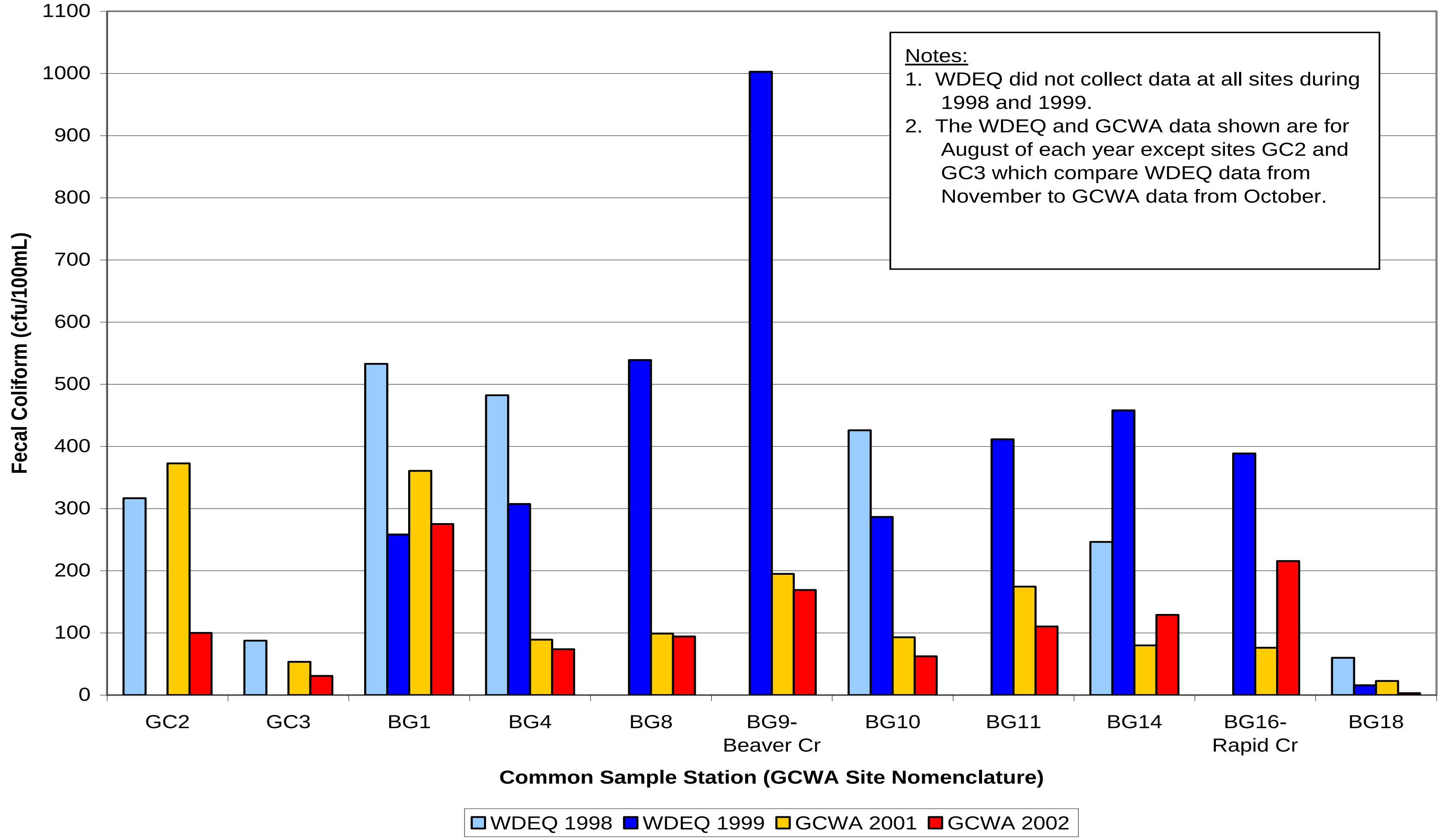


Figure 8-70. Comparison of Wyoming Department of Environmental Quality (WDEQ) 1998 and 1999 Fecal Coliform Data to 2001 and 2002 Goose Creeks Watershed Assessment (GCWA) Data for Common Little Goose Creek Sample Stations

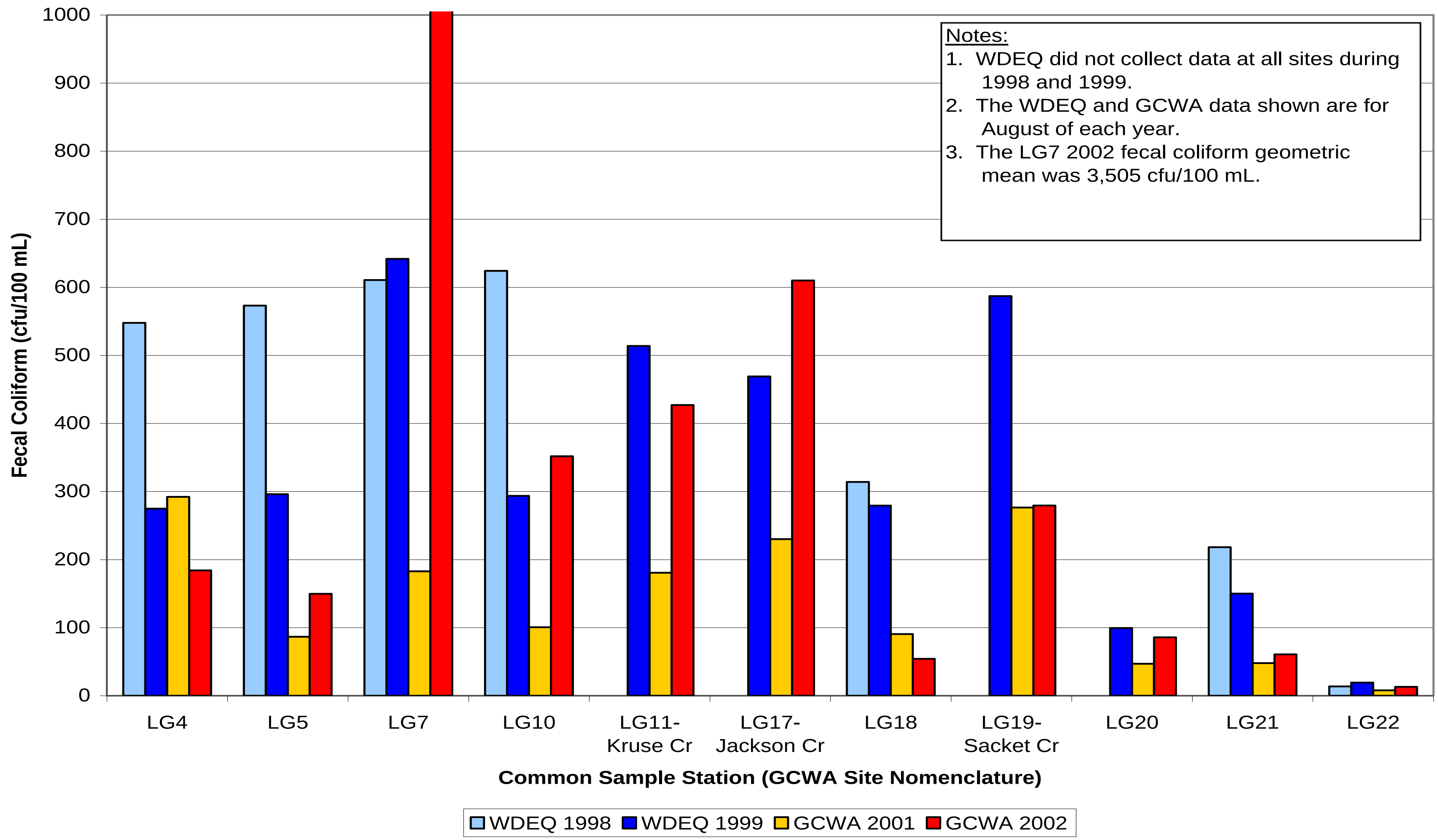


Figure 8-71. WDEQ Fecal Coliform Data Collected During the 1993 – 1994 Salt Monitoring Project

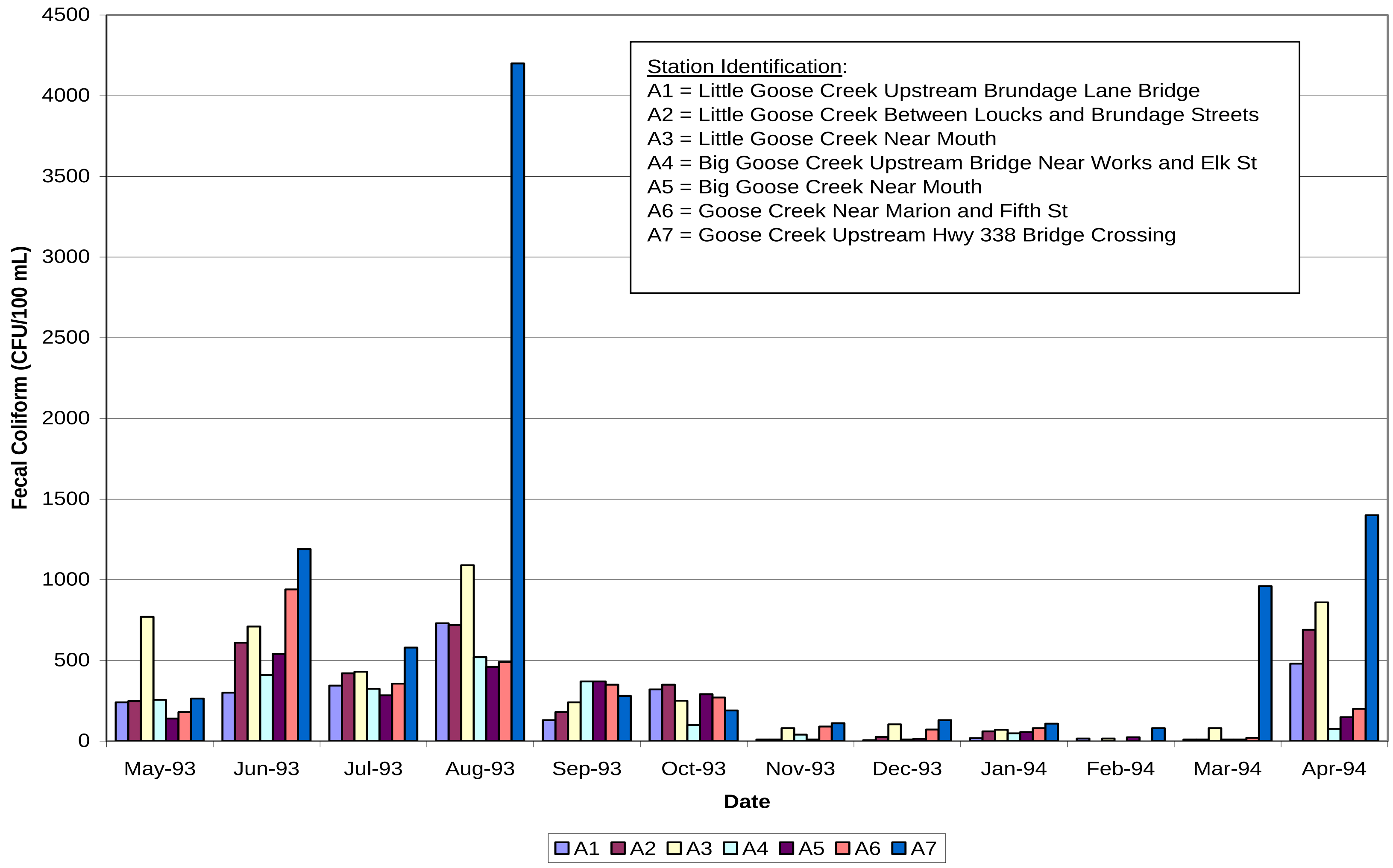


Figure 8-72. Time Series Trend of USGS Fecal Coliform Data at Station No. 06305700 (Goose Creek Near Acme, Wyoming)

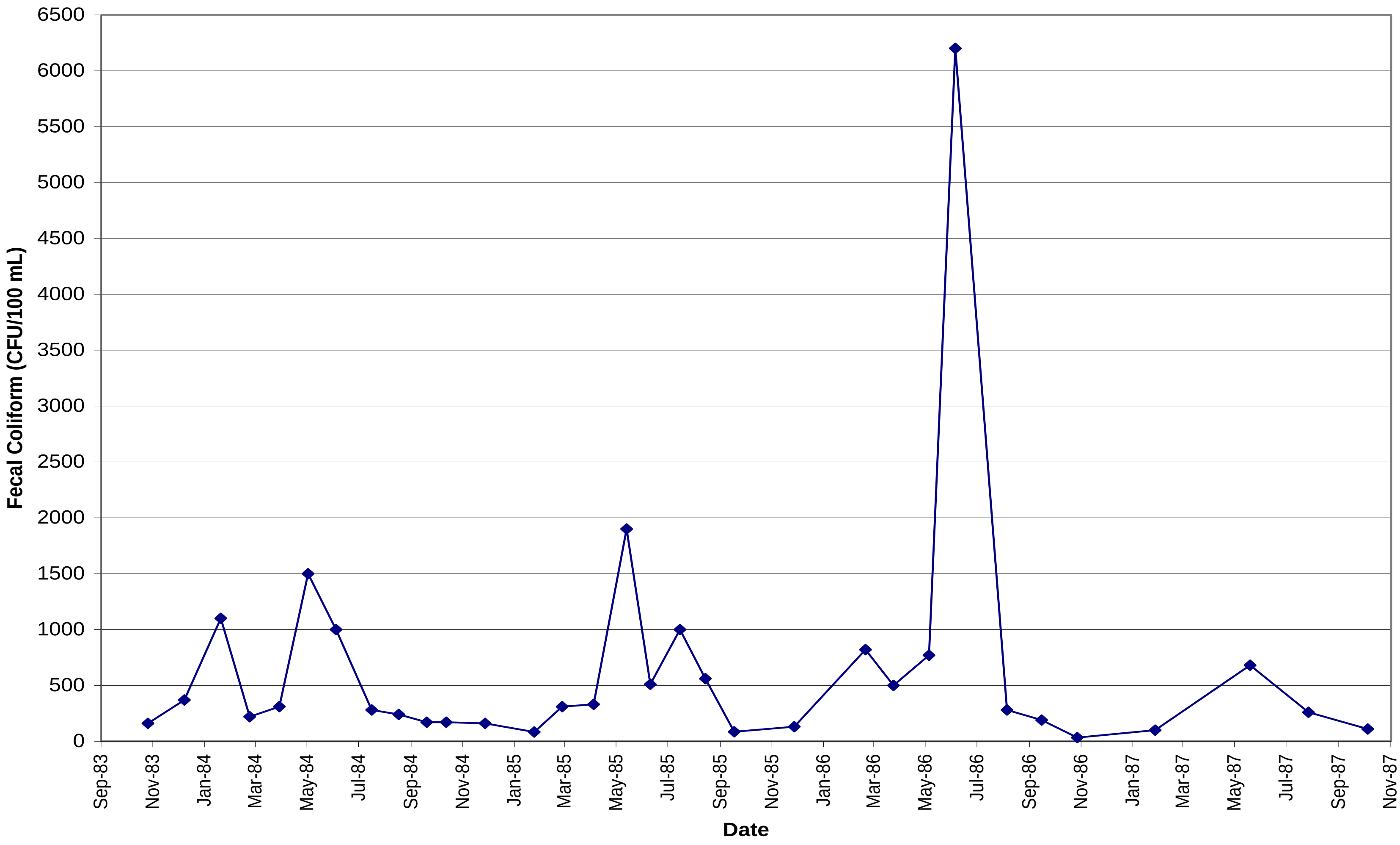


Figure 8-73. Time Series Trend of USGS Fecal Coliform Data at Station No. 06305500 (Goose Creek Below Sheridan)

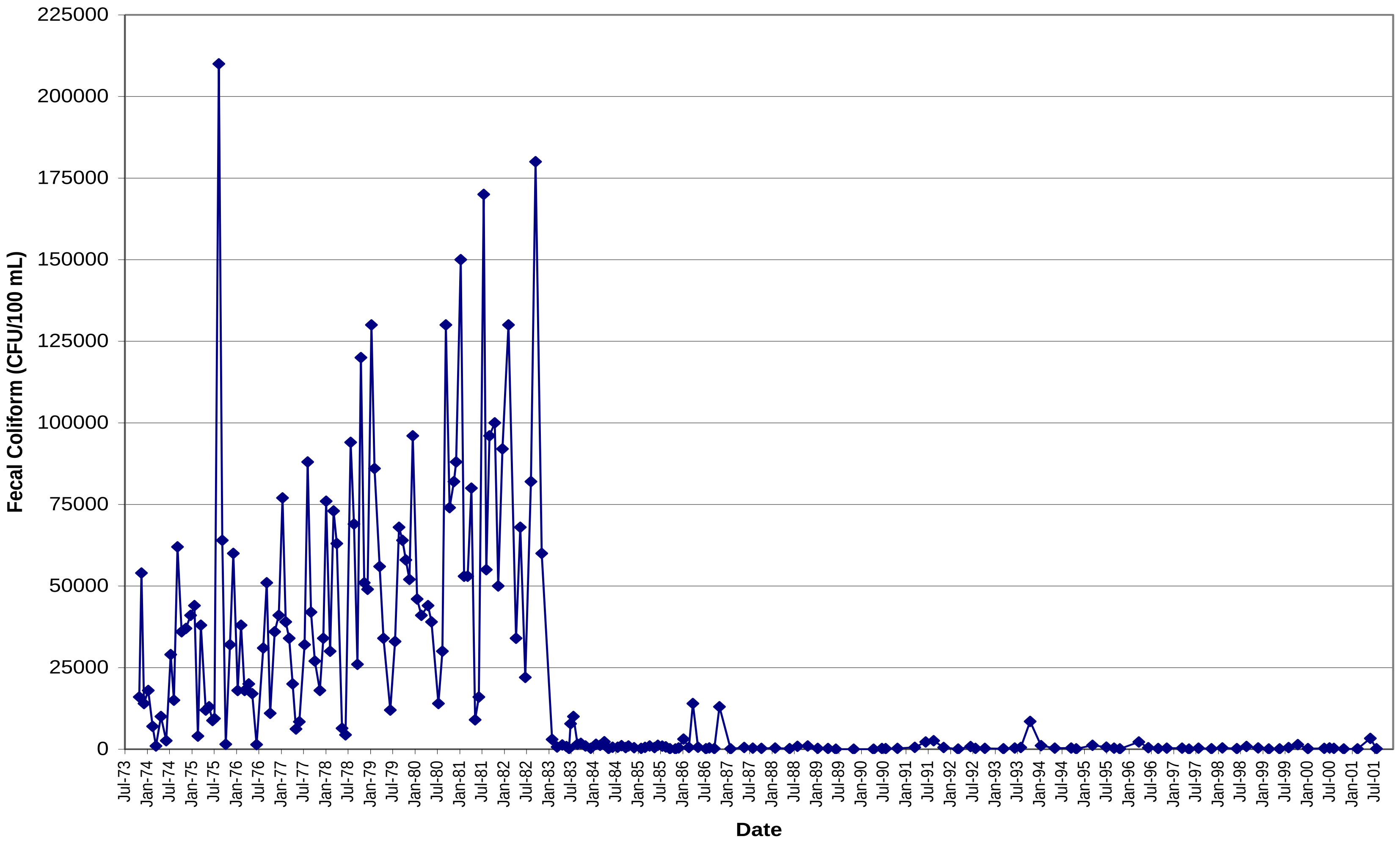


Figure 8-74. Time Series Trend of USGS Fecal Coliform Data at Station No. 06302000 (Big Goose Creek Near Sheridan, Wyoming)

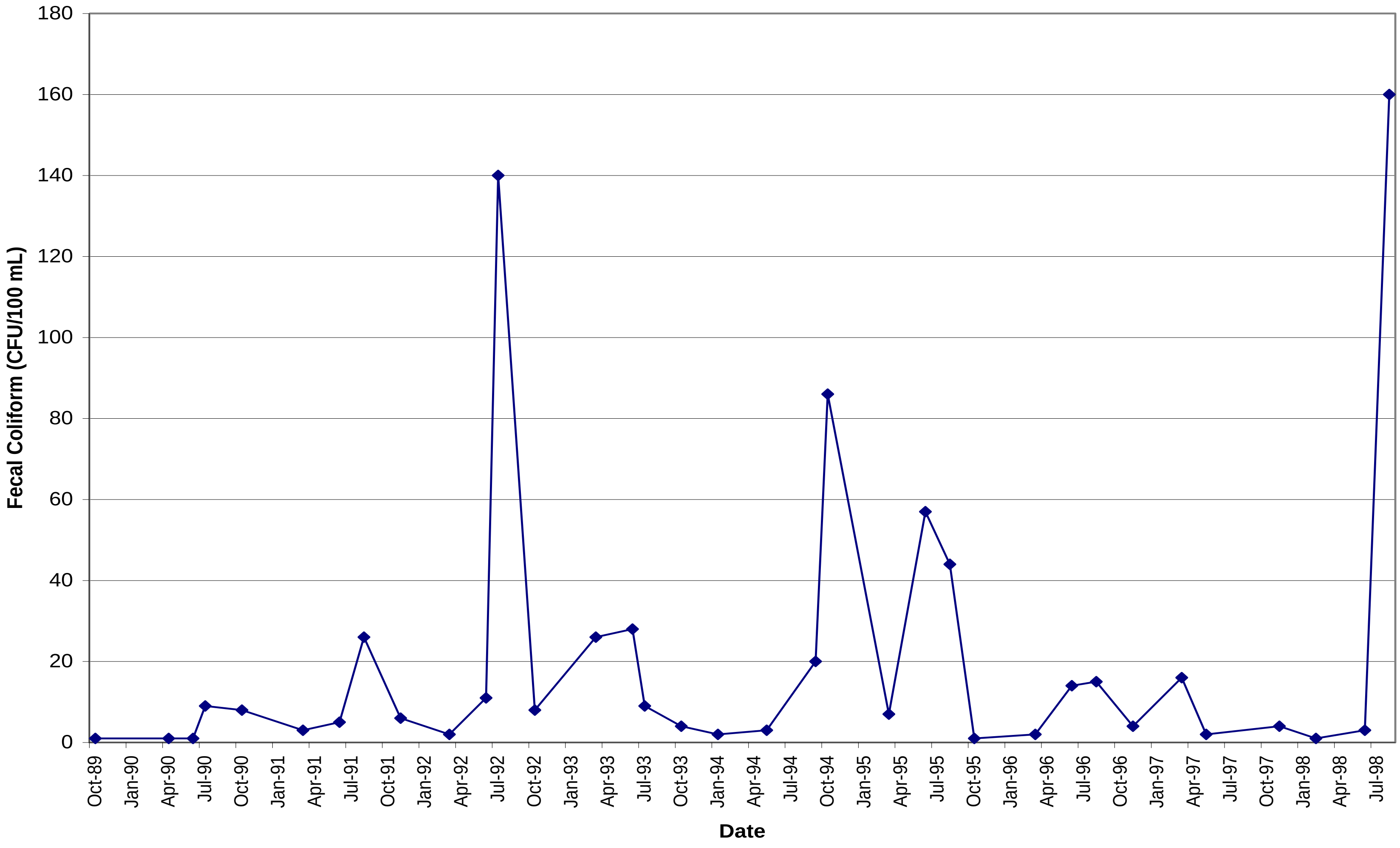


Figure 8-75. Time Series Trend of USGS Fecal Coliform Data at Station No. 06304500 (Little Goose Creek at Sheridan)

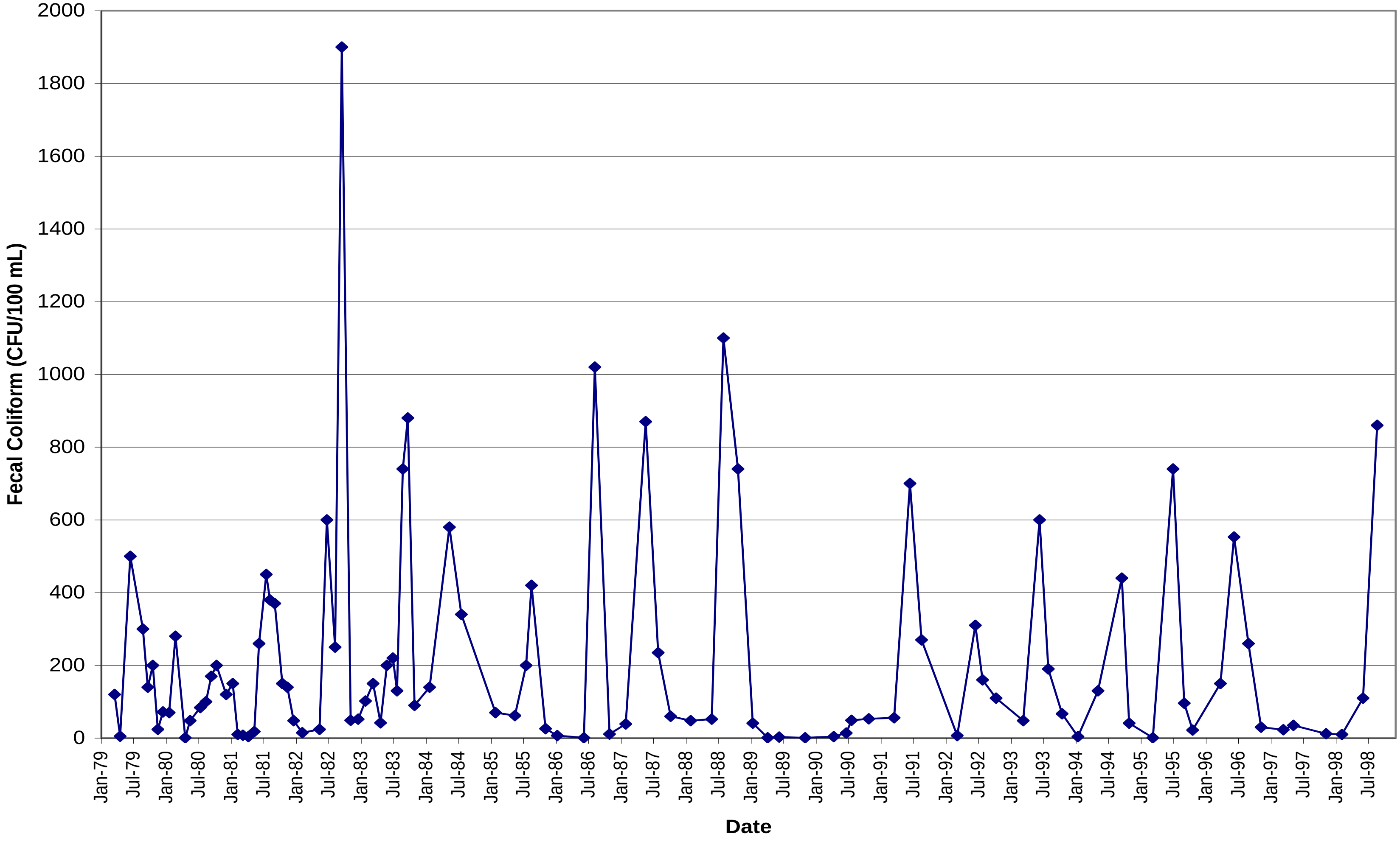


Figure 8-76. Biological Condition for Goose Creek Stations, 2001 and 2002.

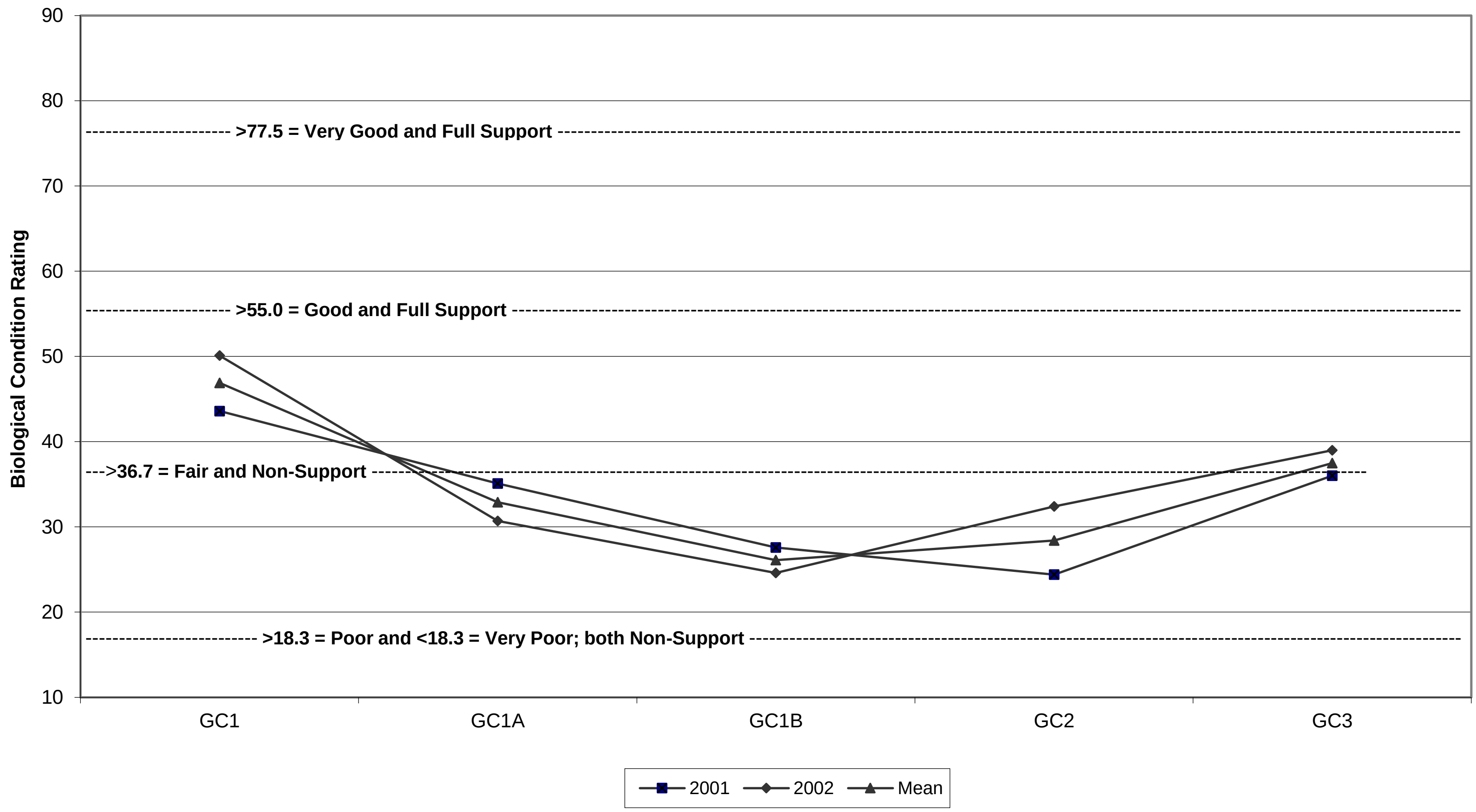


Figure 8-77. Biological Condition at Soldier Creek Stations, 1999.

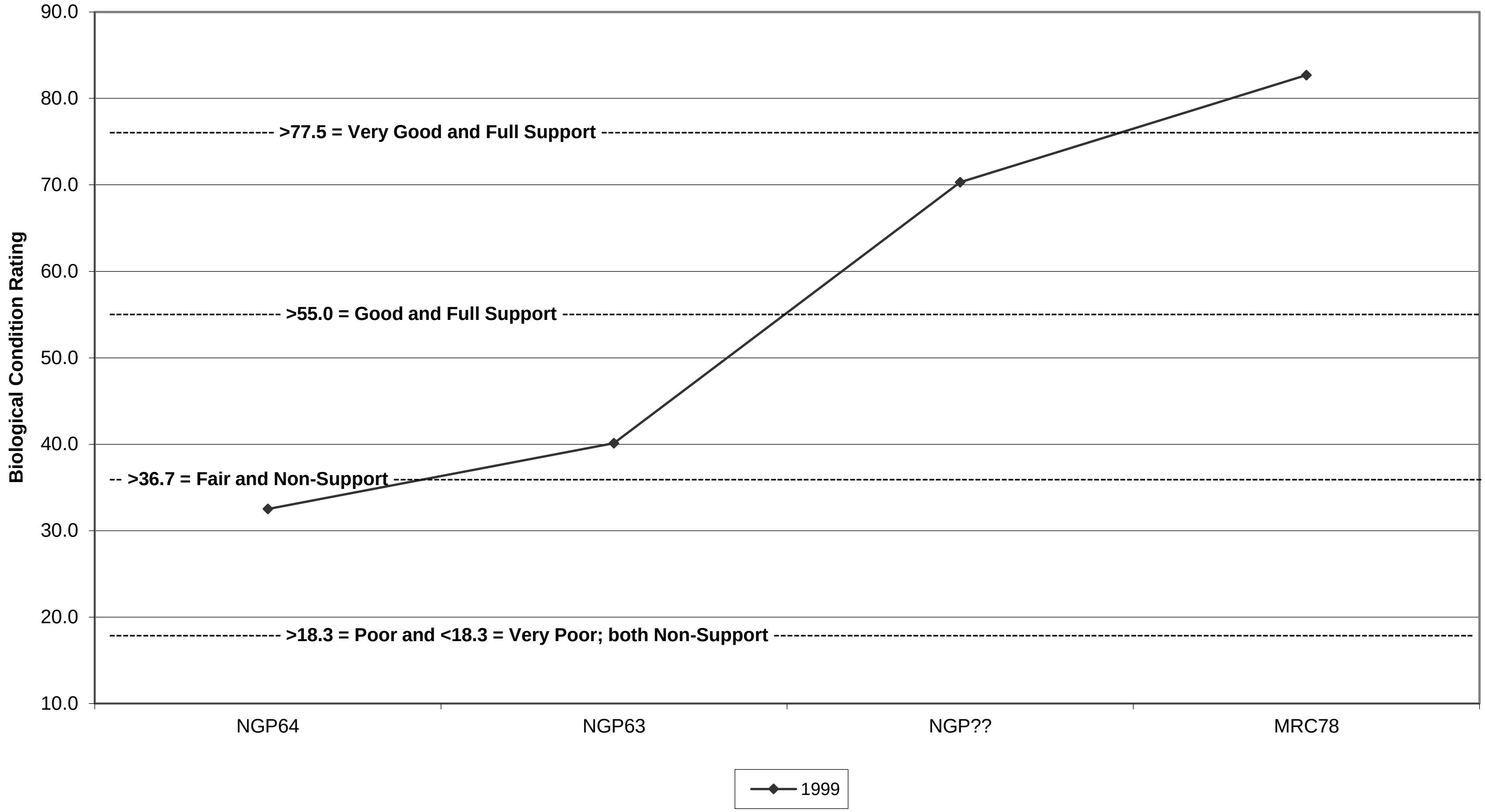


Figure 8-78. Biological Condition at Big Goose Creek Stations, 2001 and 2002.

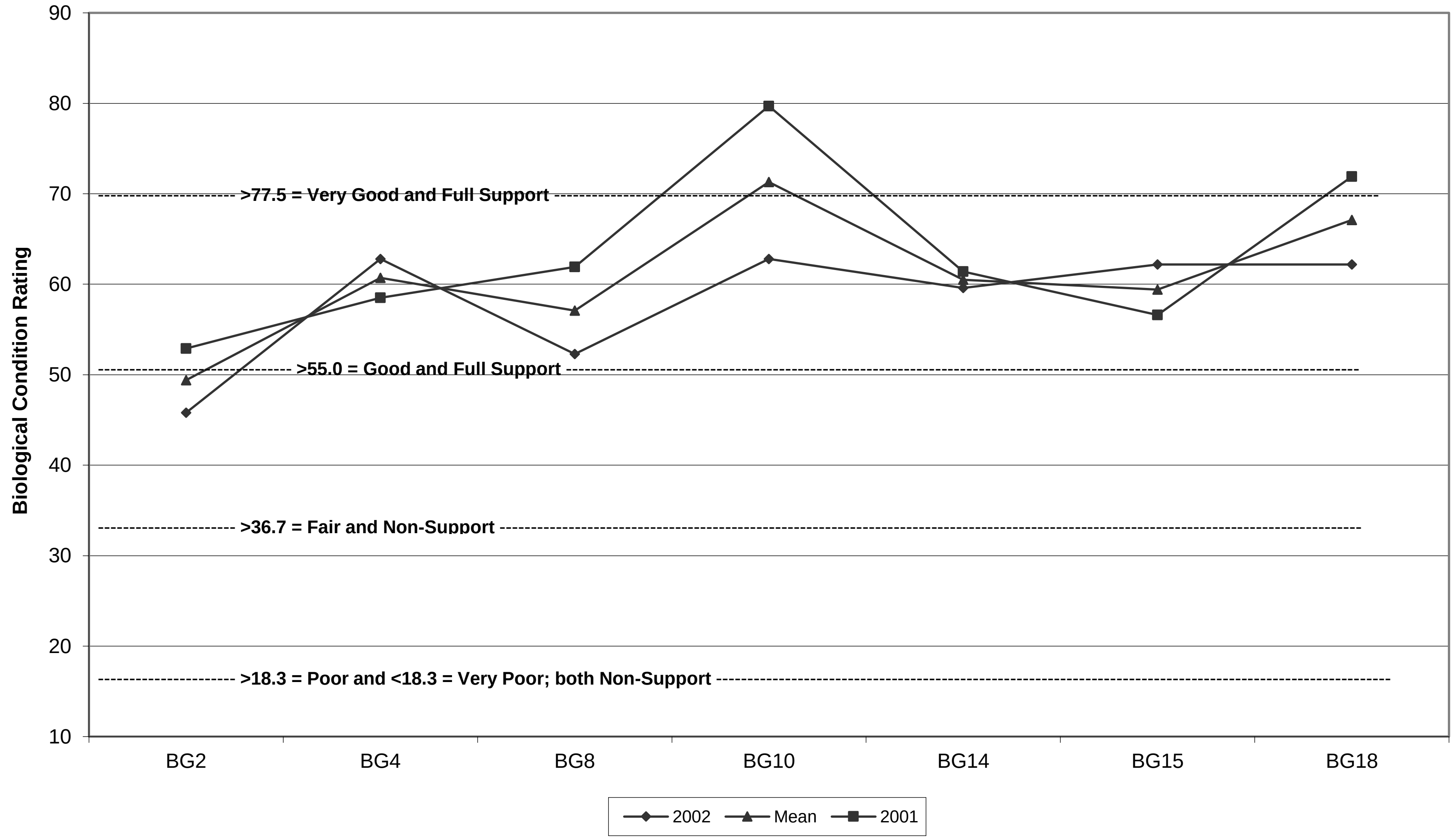


Figure 8-79. Biological Condition at Little Goose Creek Stations, 2001 and 2002.

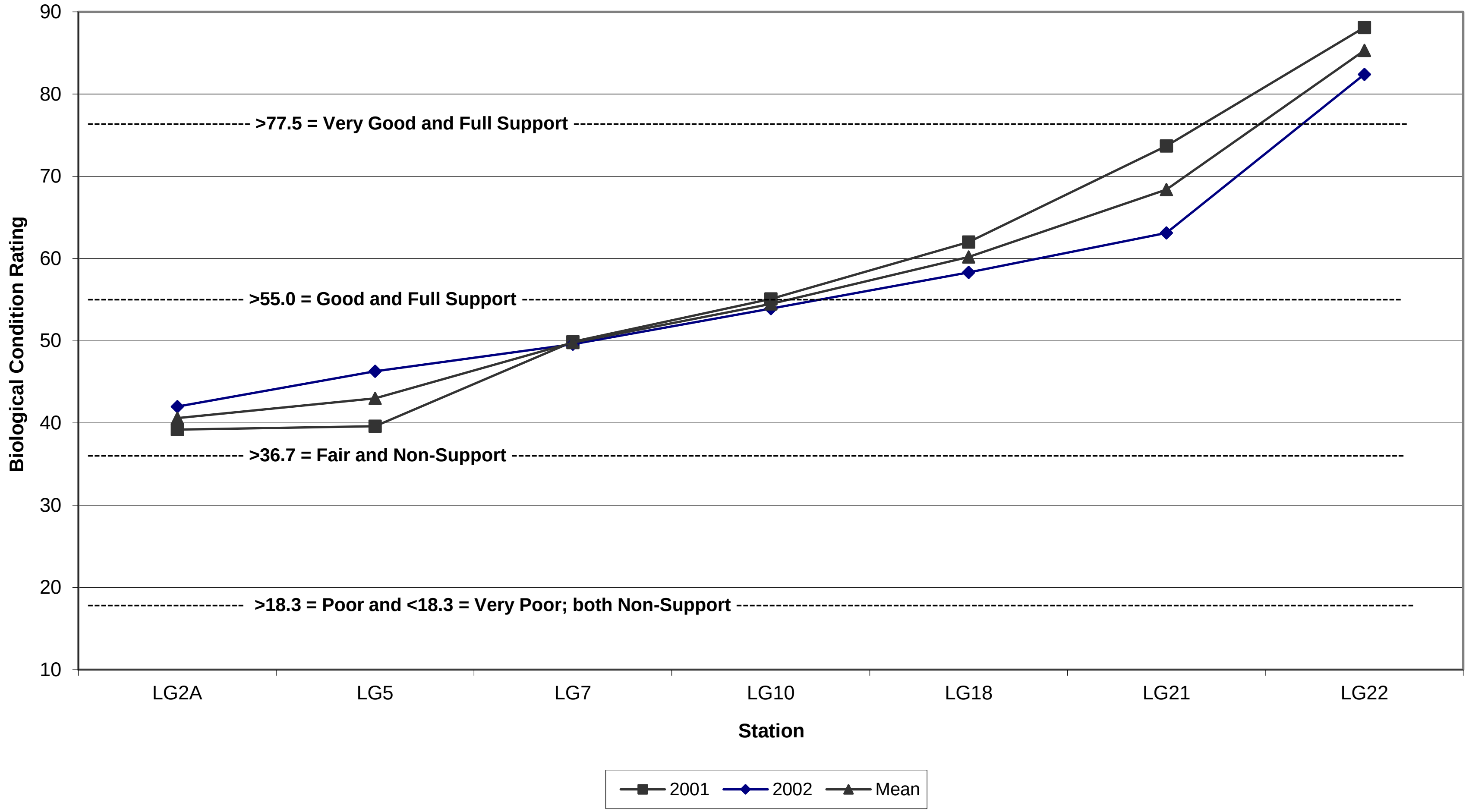


Figure 8-80. Goose Creek Watershed Stations Ranked by Biological Condition, 2001 and 2002; Including Soldier Creek Stations Sampled by WDEQ, 1999.

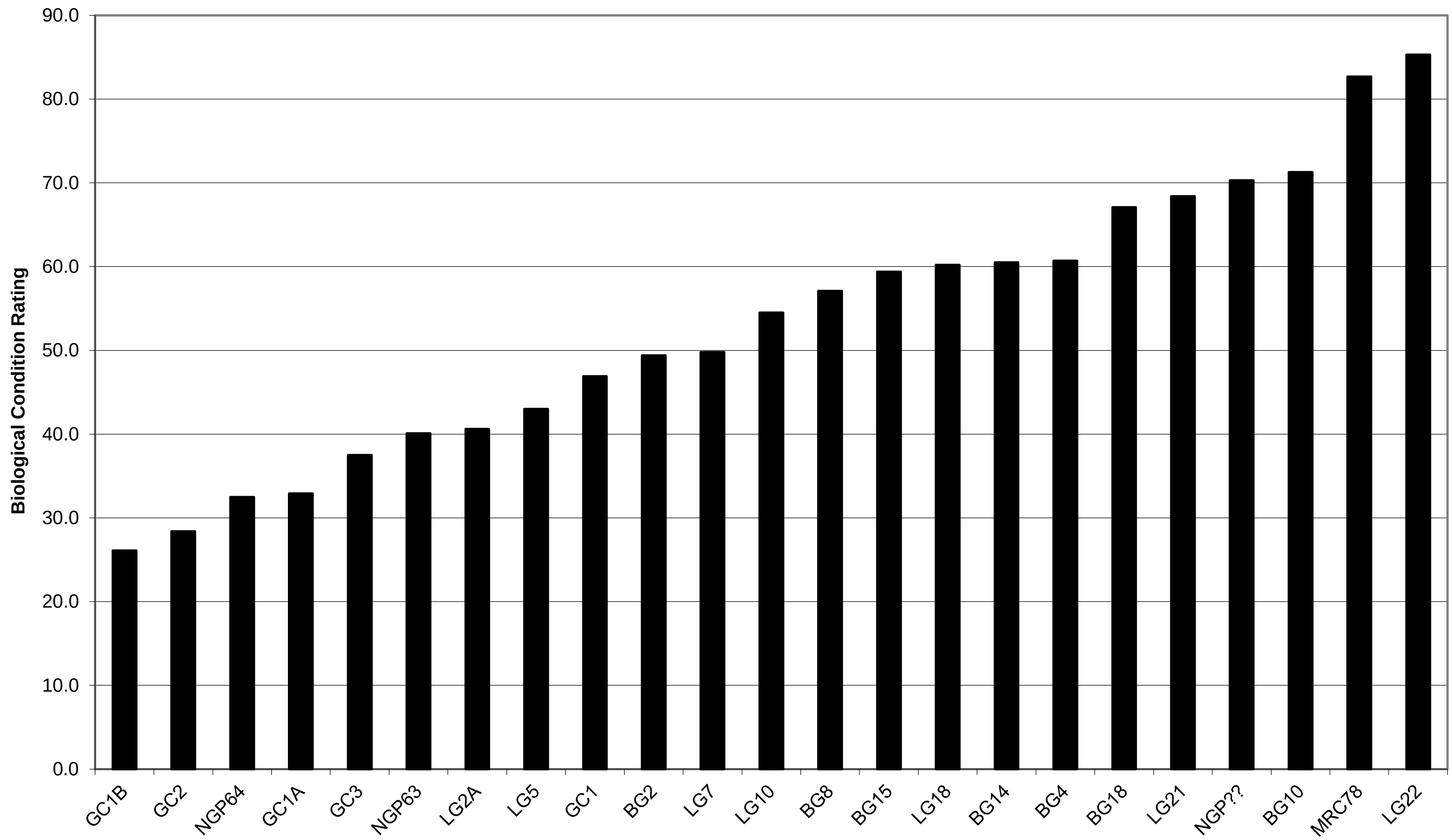


Figure 8-81. Mean Total Taxa and Mean Total EPT Taxa at Goose Creek Stations, 2001 and 2002.

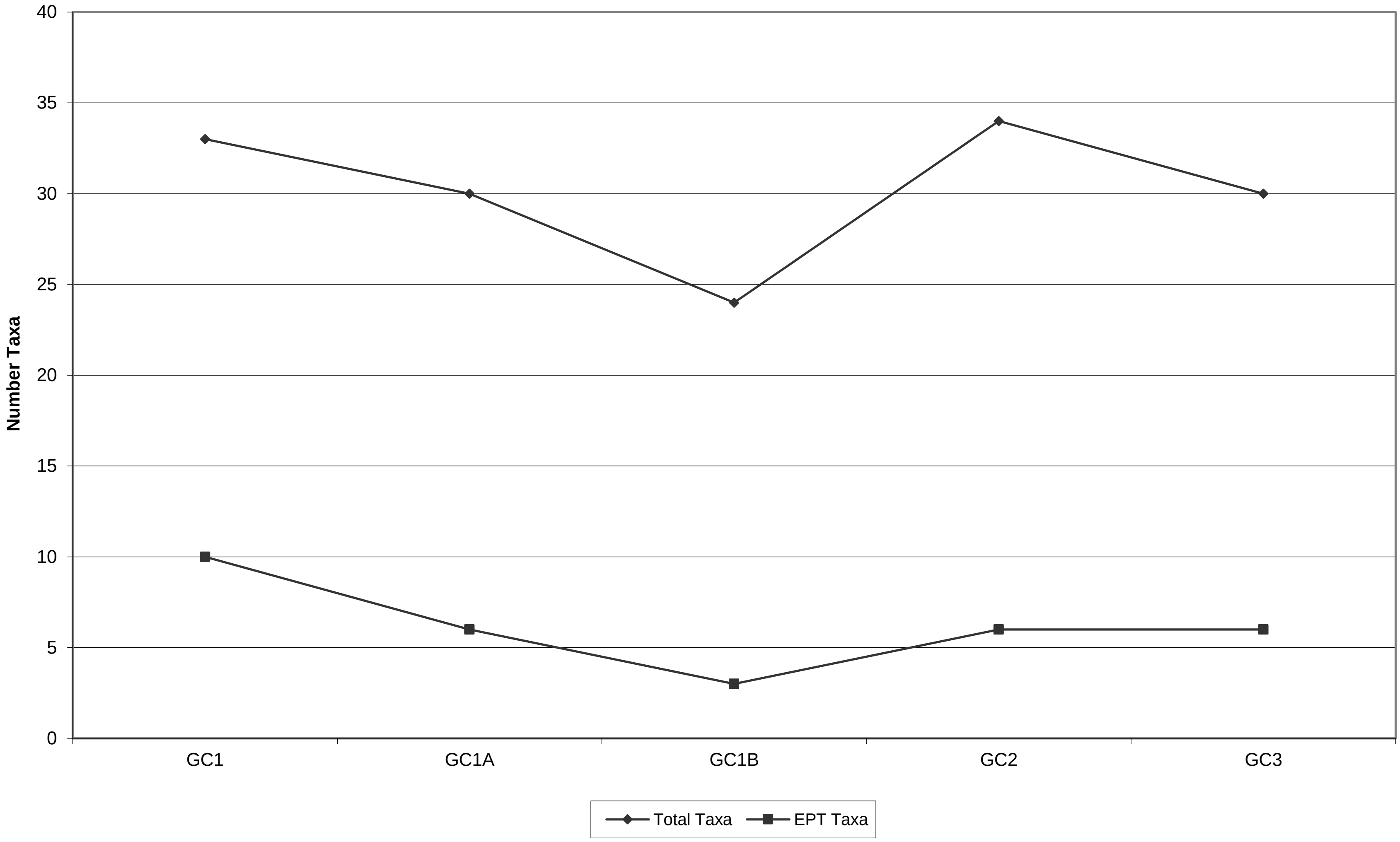


Figure 8-82. Mean % Scrapers, % Shredders, and % Multivoltine Taxa at Goose Creek Stations, 2001 and 2002.

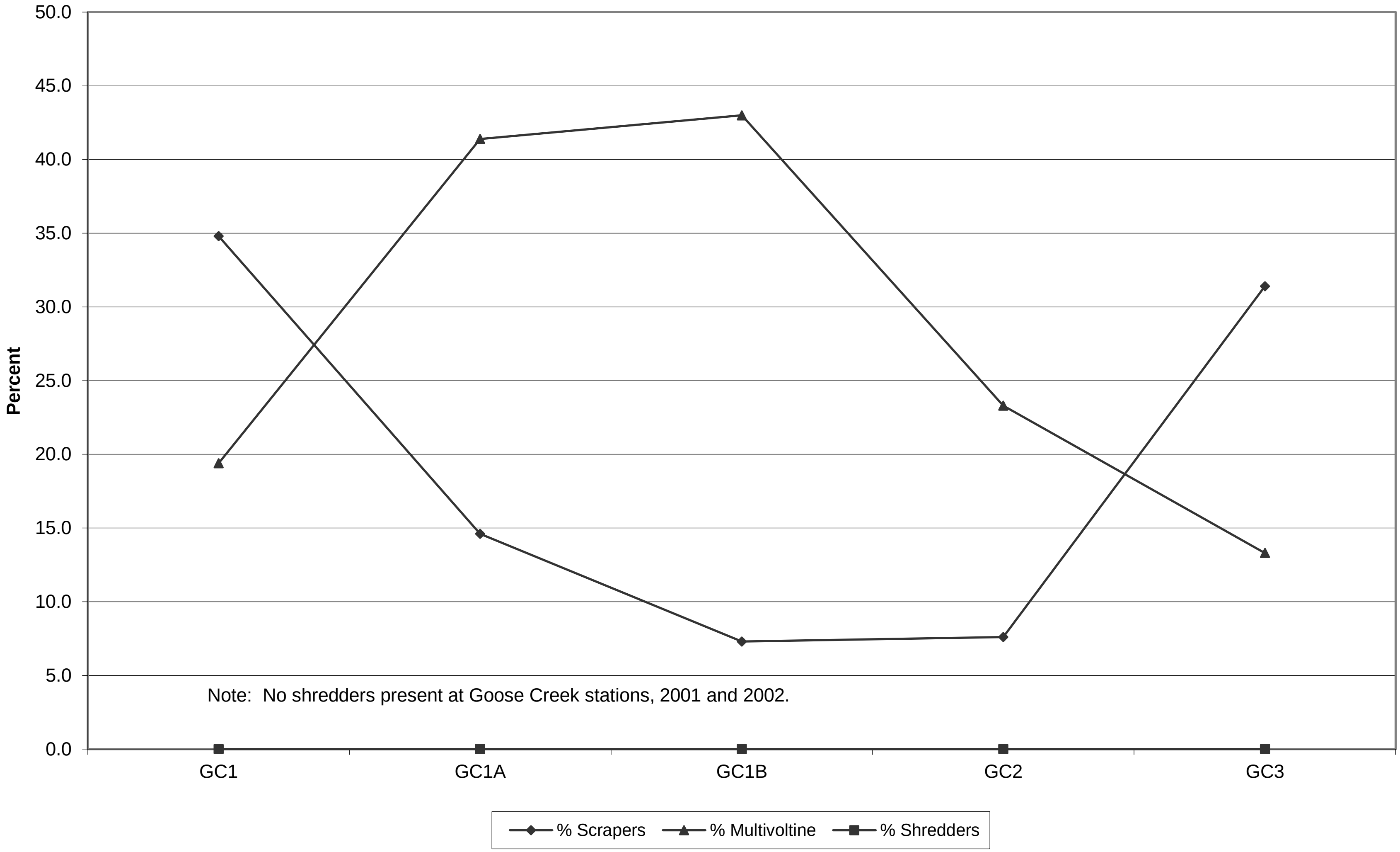


Figure 8-83. Relationship Between Embeddedness (silt cover) and % Scrapers at Goose Creek Watershed Stations, 2001 and 2002.

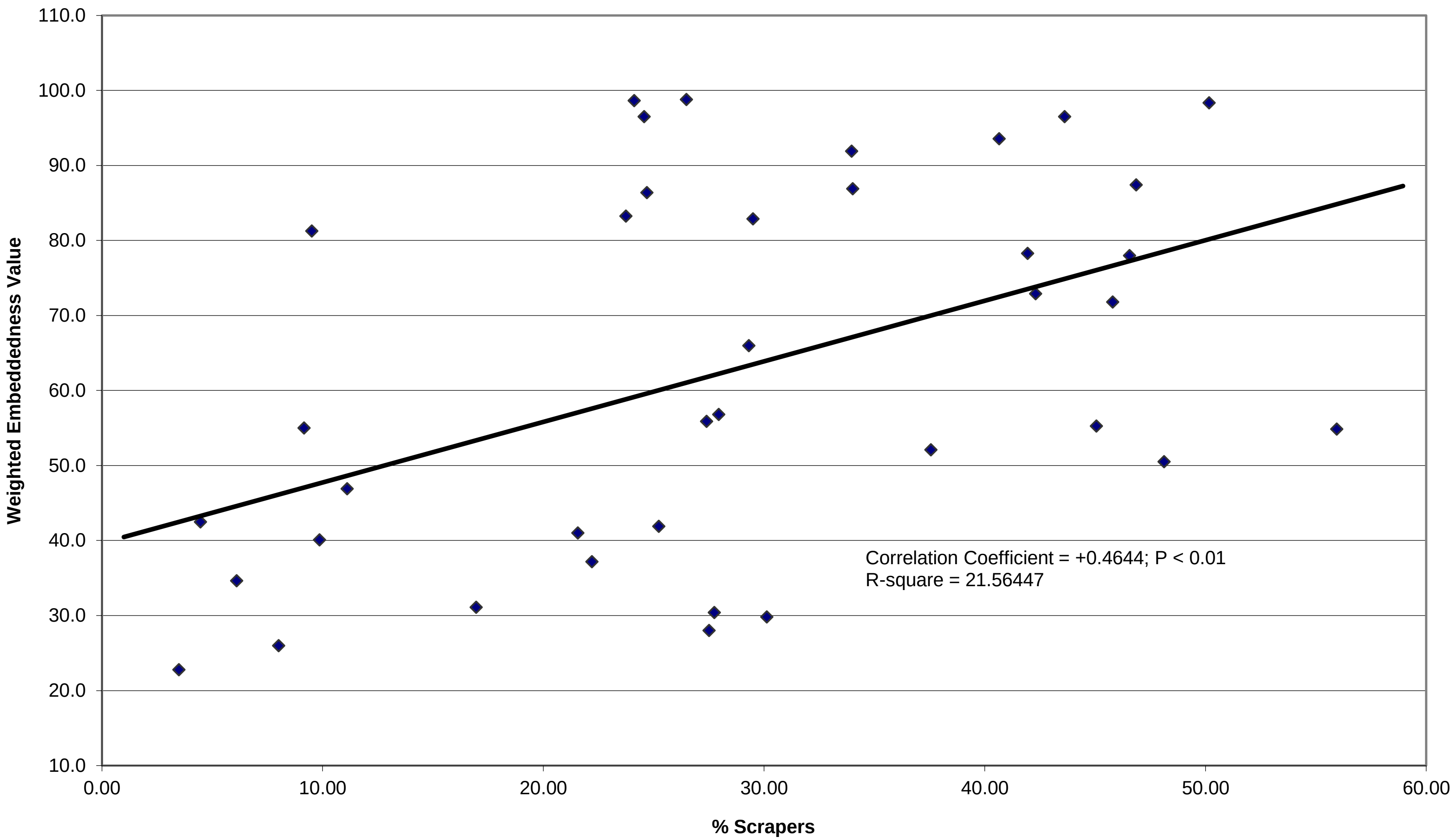


Figure 8-84. Mean Hilsenhoff Biotic Index (HBI) Values for Goose Creek, Big Goose Creek, and Little Goose Creek Stations 2001 and 2002. Note: Stations by Waterbody are Ordered from Downstream (left) to Upstream (right).

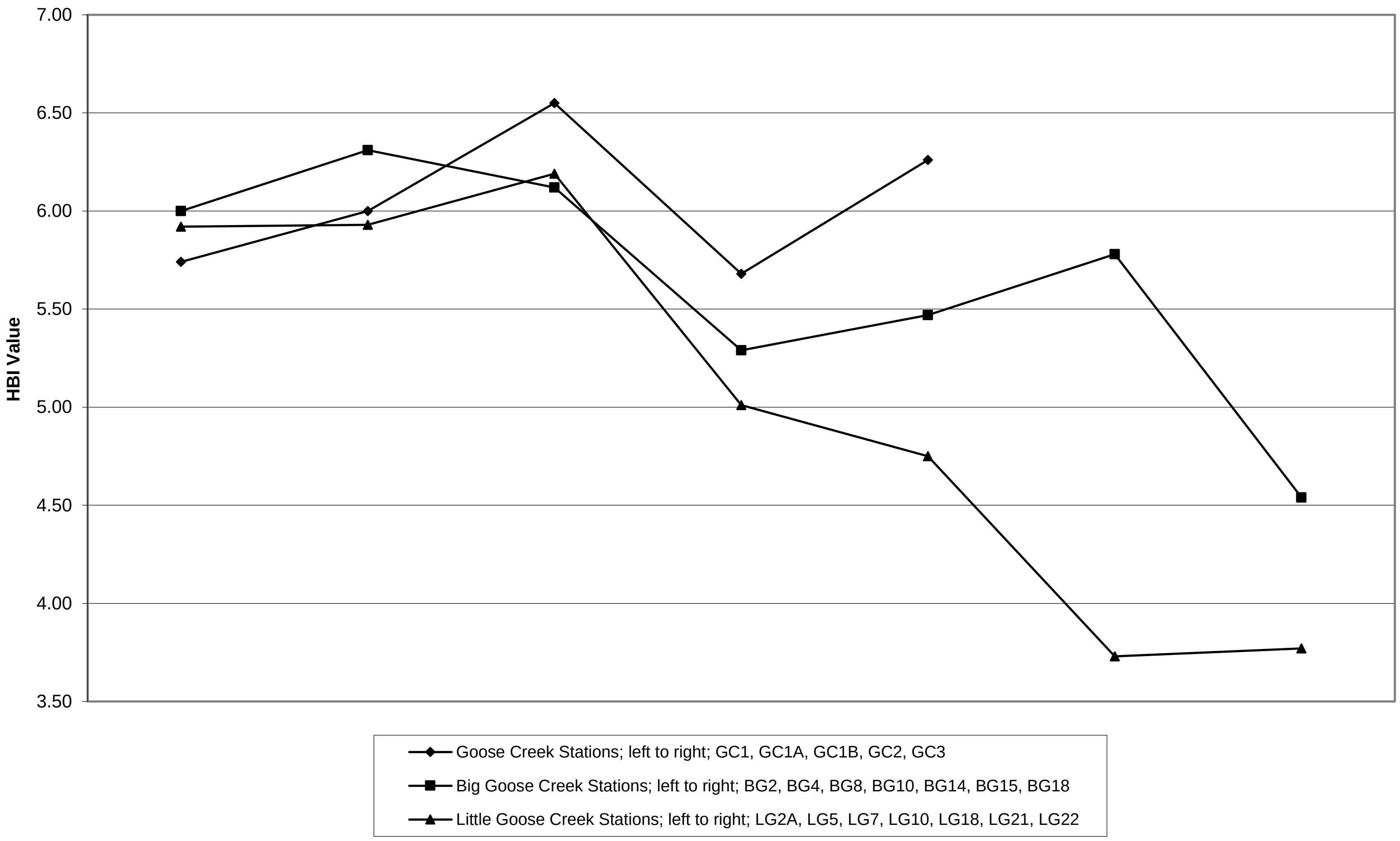


Figure 8-85. Relationship Between Mean HBI Values and WSII Biological Condition Scores for Goose Creek Watershed Stations, 2001 and 2002.

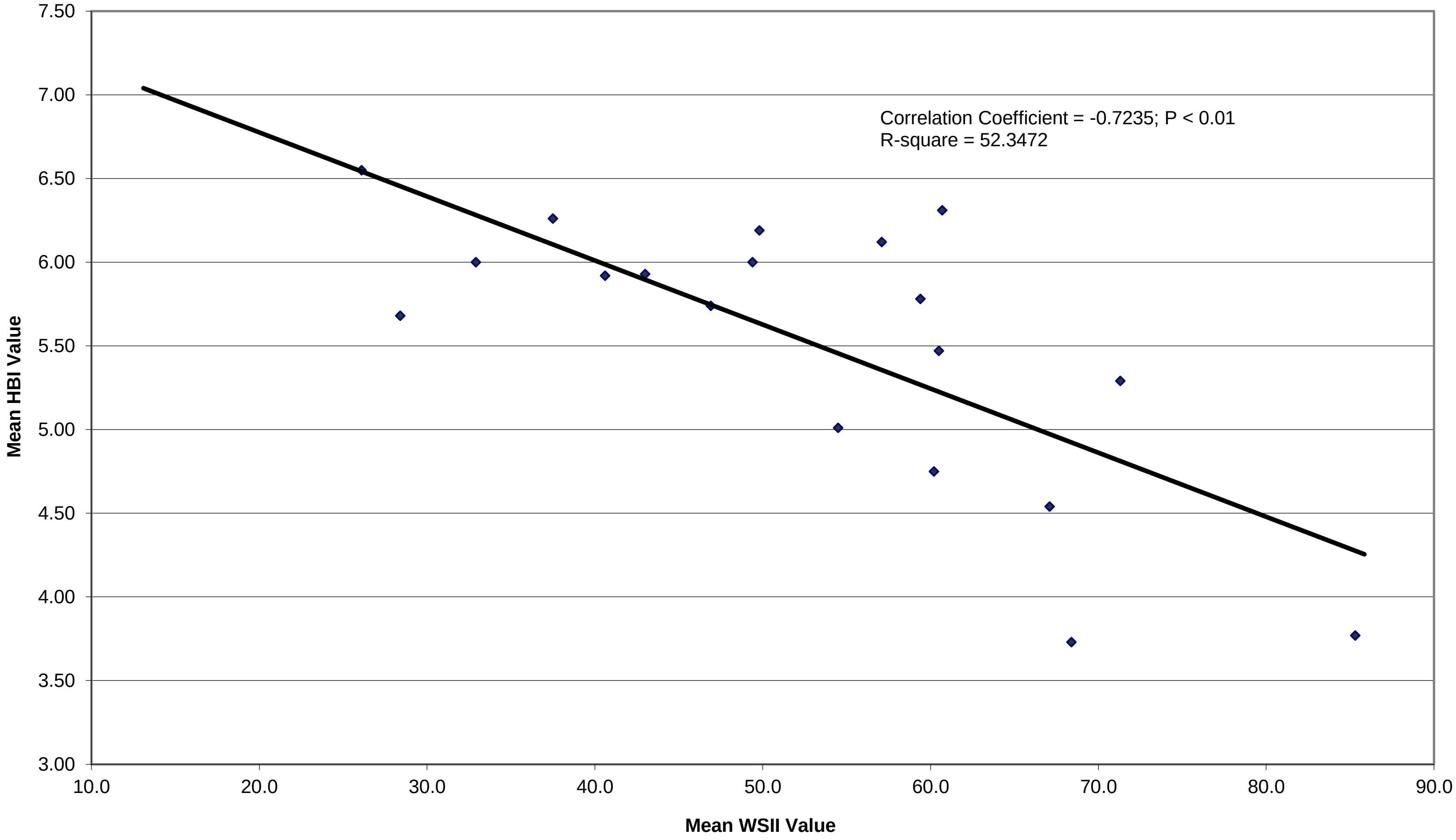


Figure 8-86. Mean Percent Oligochaeta (worms) for Goose Creek Watershed, 2001 and 2002.

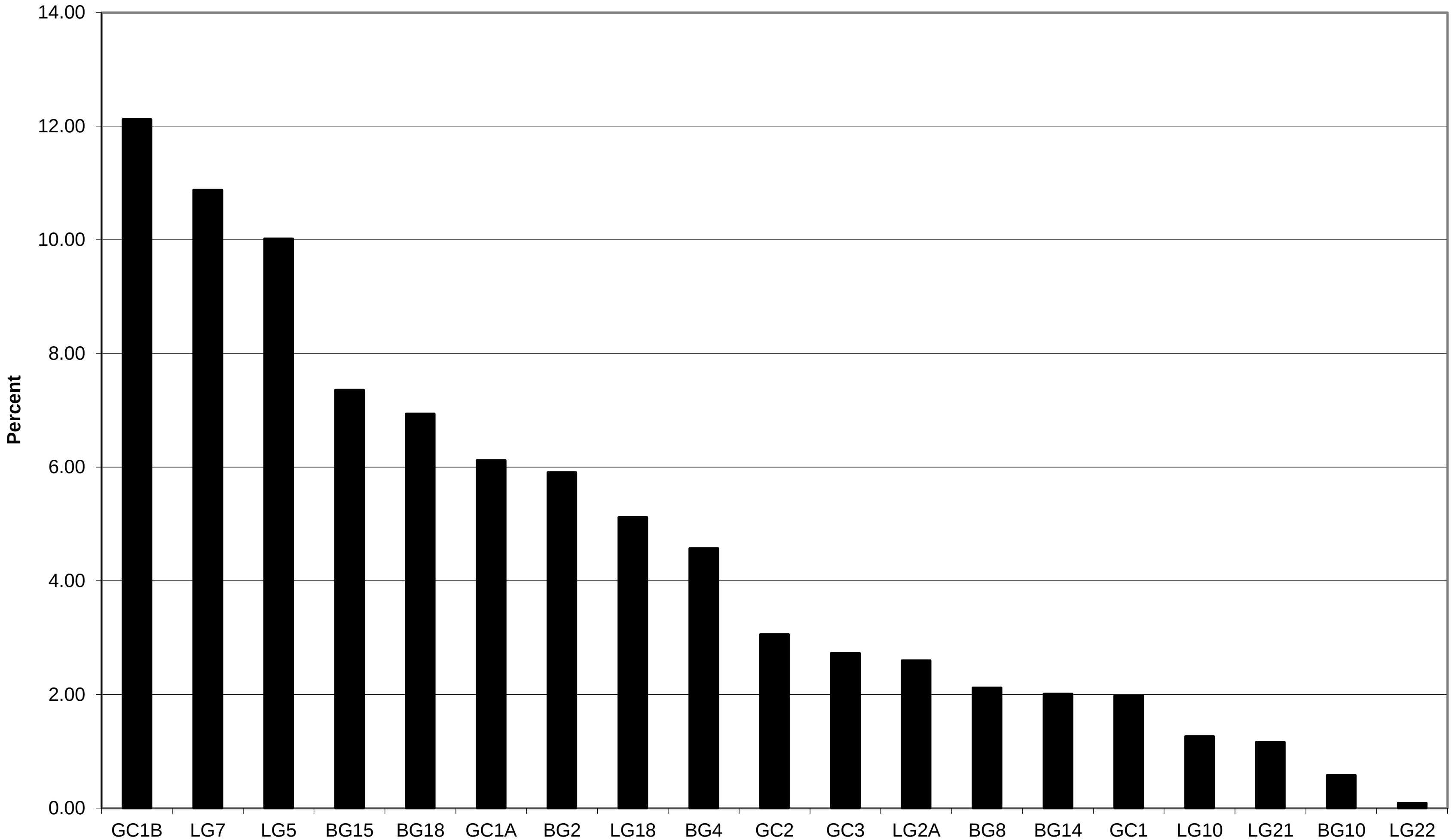


Figure 8-87. Mean Total Taxa and Mean Total EPT Taxa at Big Goose Creek Stations, 2001 and 2002.

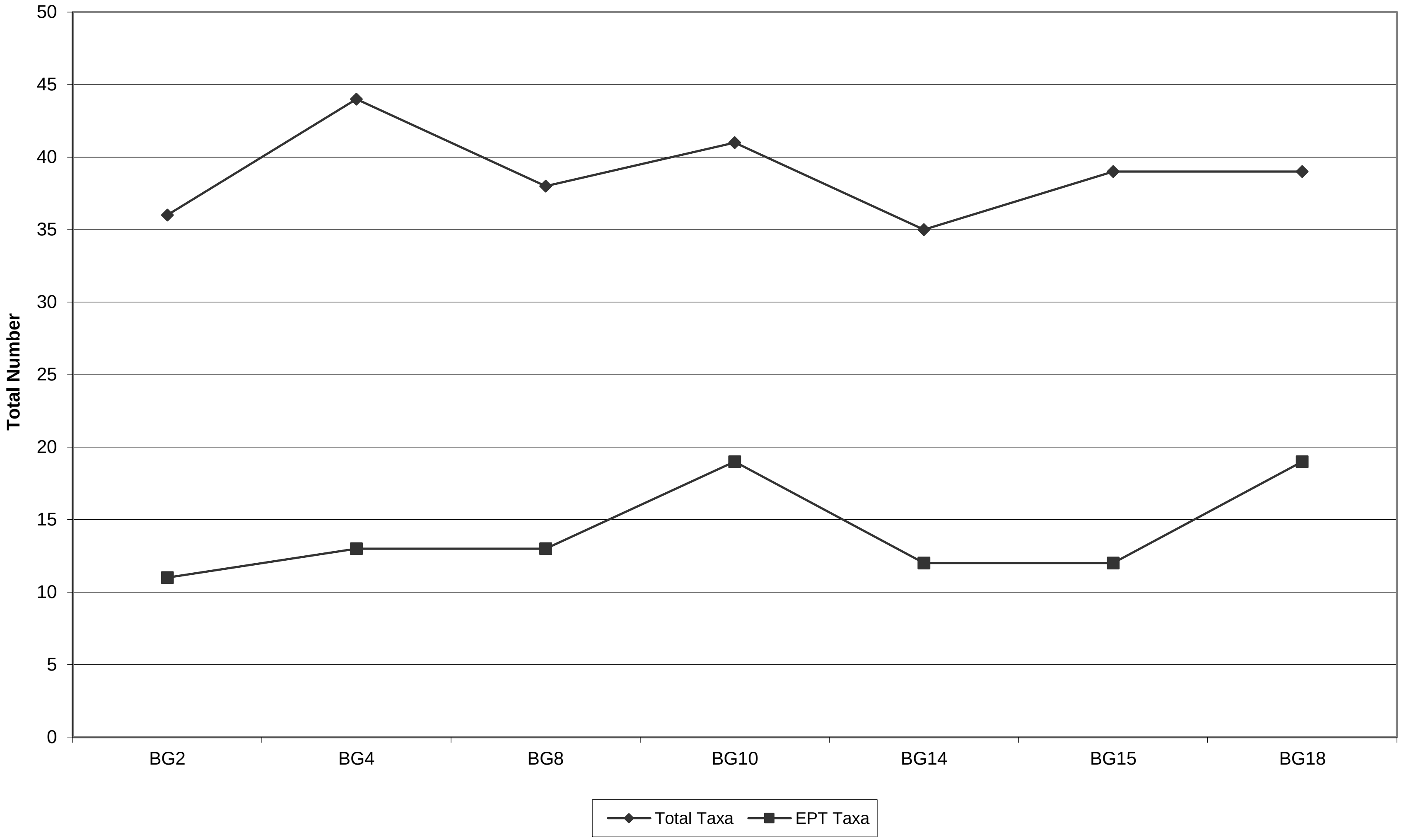


Figure 8-88. Mean % Scrapers, % Shredders, and % Multivoltine Taxa at Big Goose Creek Stations, 2001 and 2002.

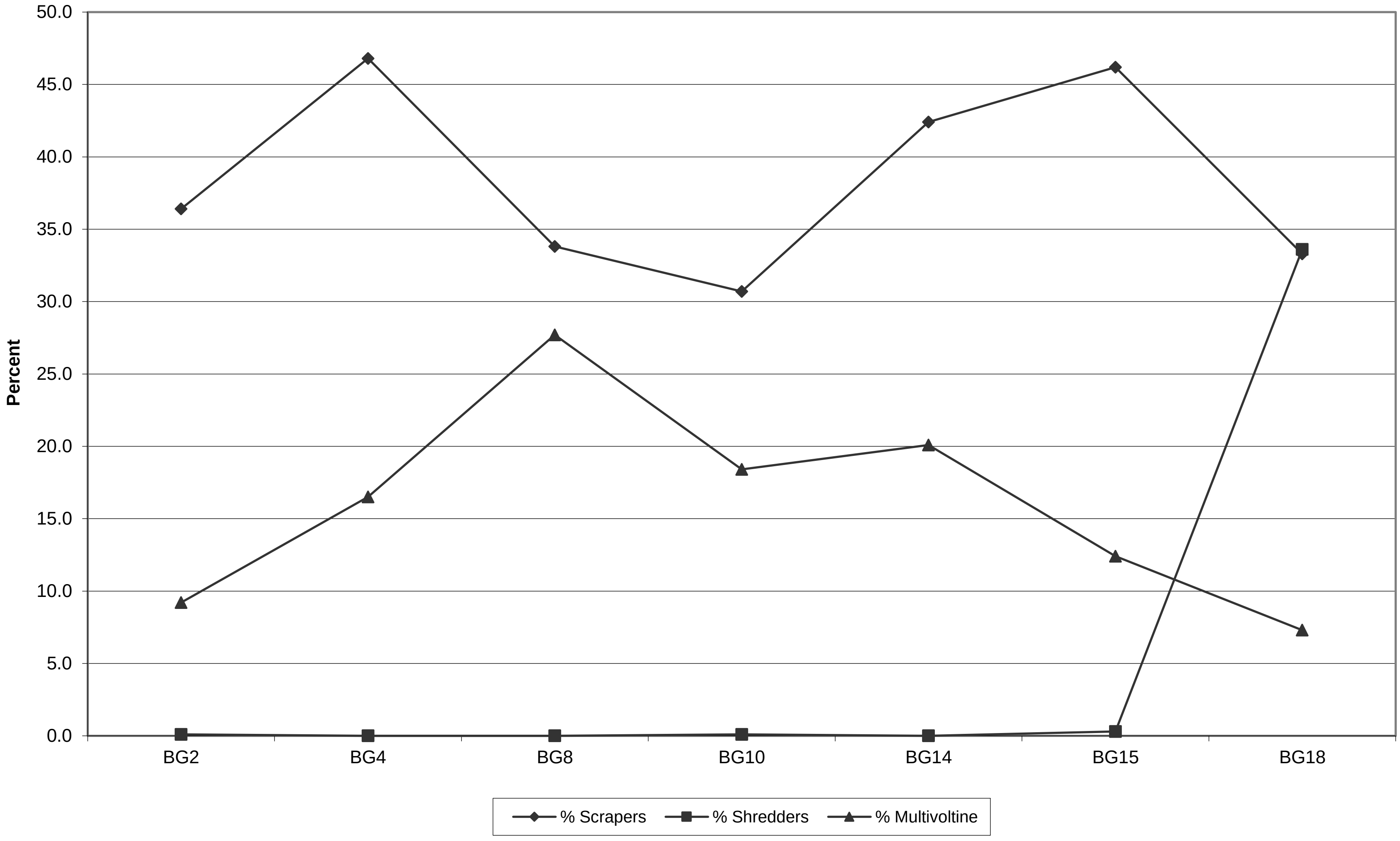


Figure 8-89. Mean Total Taxa and Mean Total EPT Taxa at Little Goose Creek Stations, 2001 and 2002.

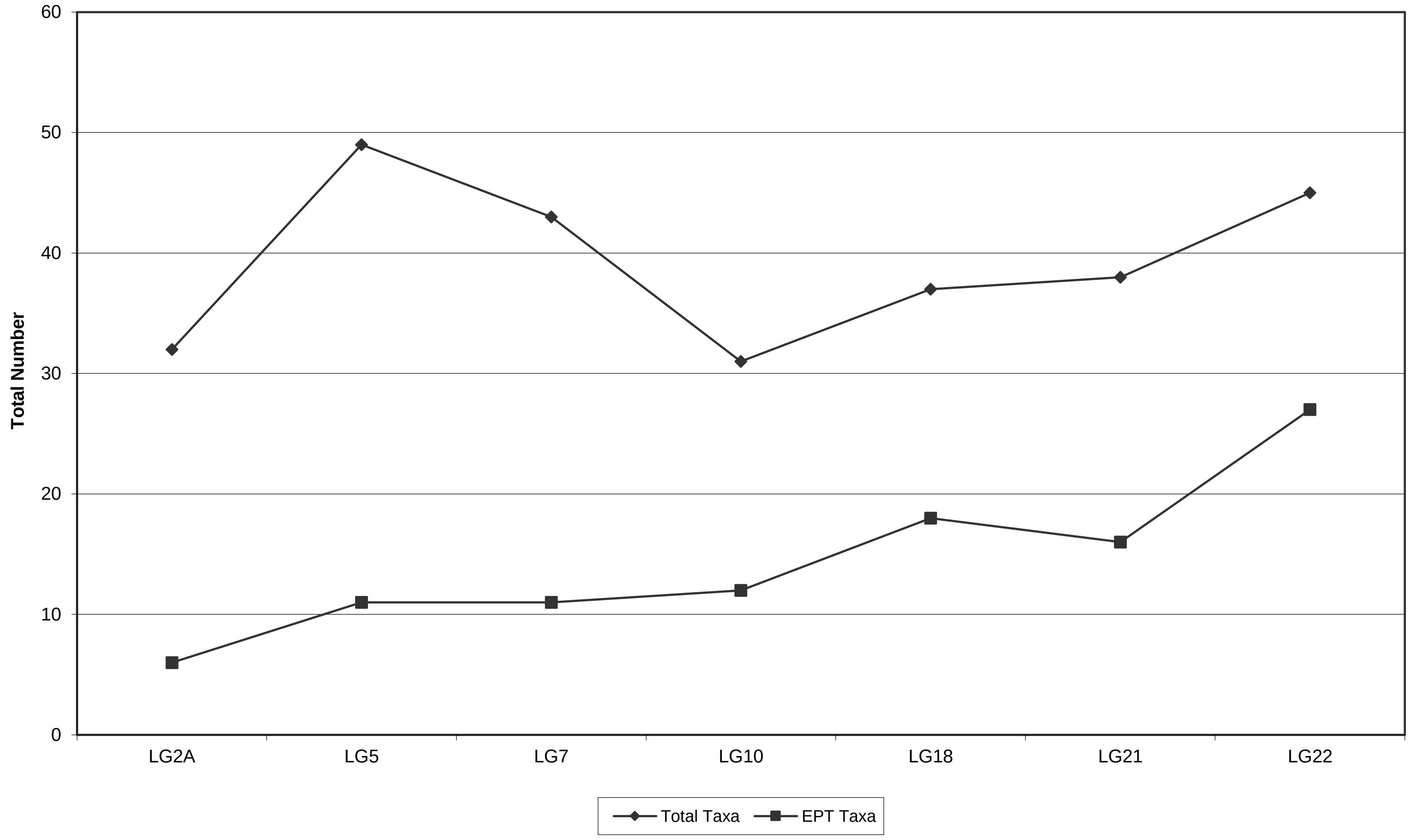


Figure 8-90. Mean % Scrapers, % Shredders, and % Multivoltine Taxa at Little Goose Creek Stations, 2001 and 2002.

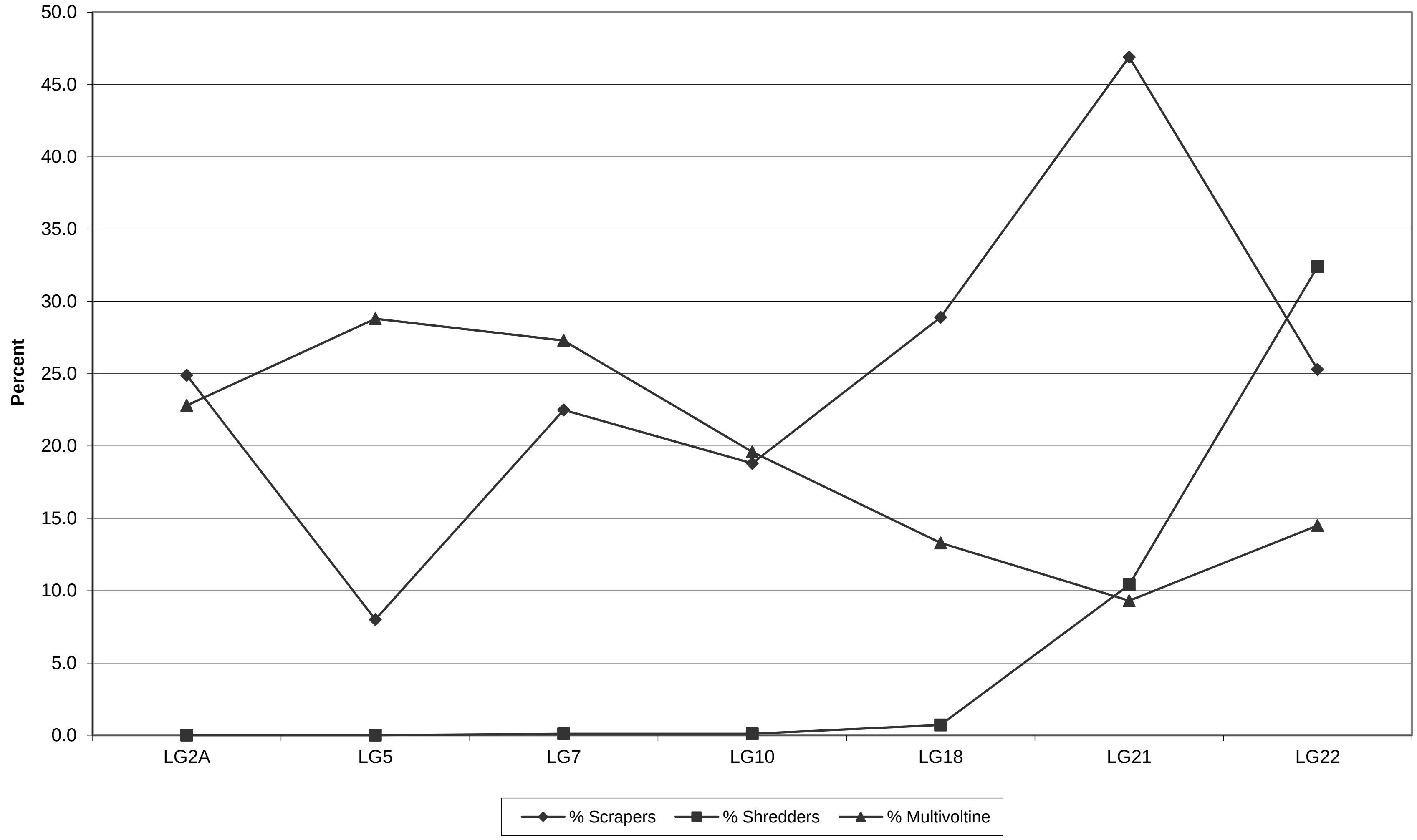


Figure 8-91. Total Habitat Assessment Scores at Goose Creek Stations, 2001 and 2002.

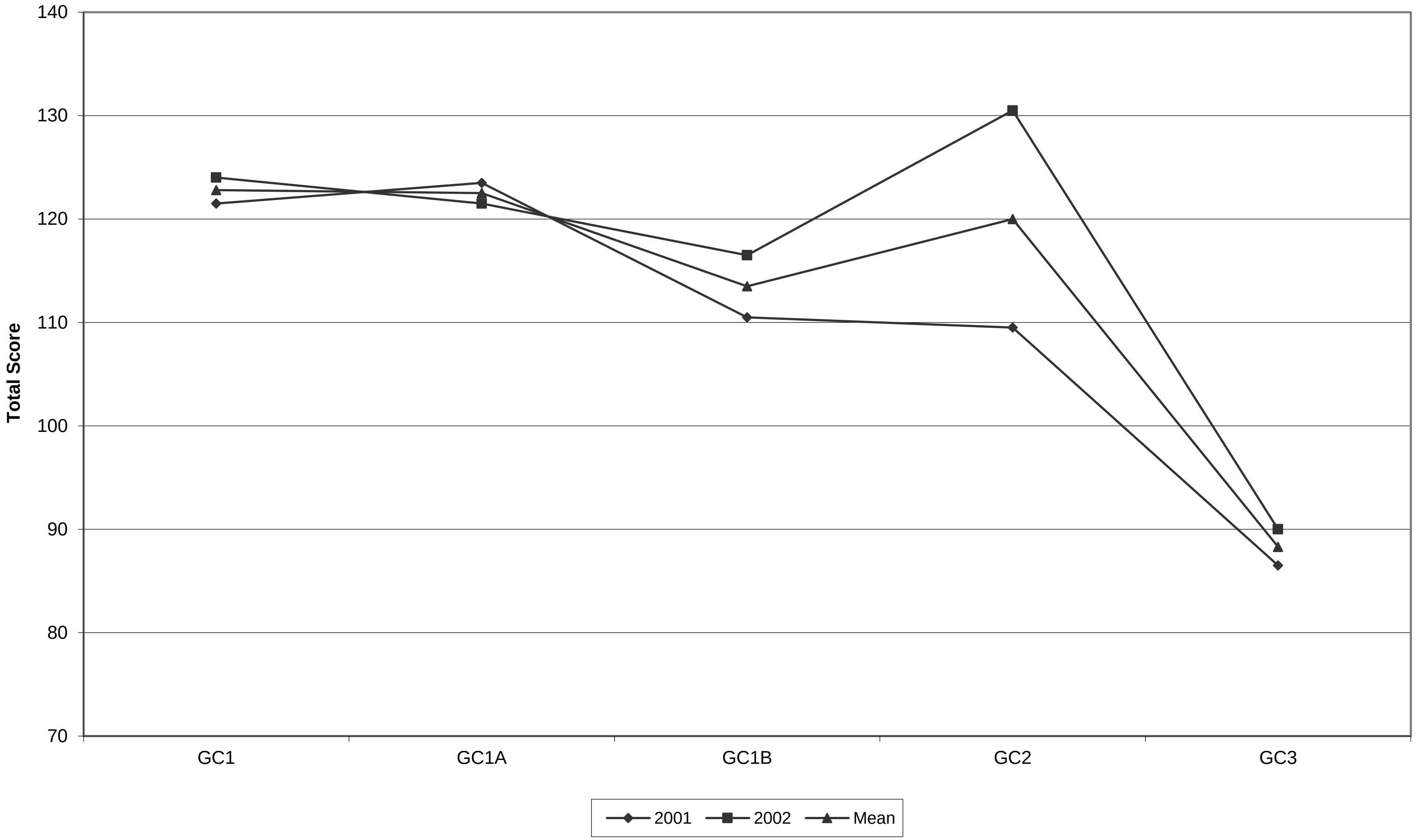


Figure 8-92. Total Habitat Assessment Scores at Big Goose Creek Stations, 2001 and 2002.

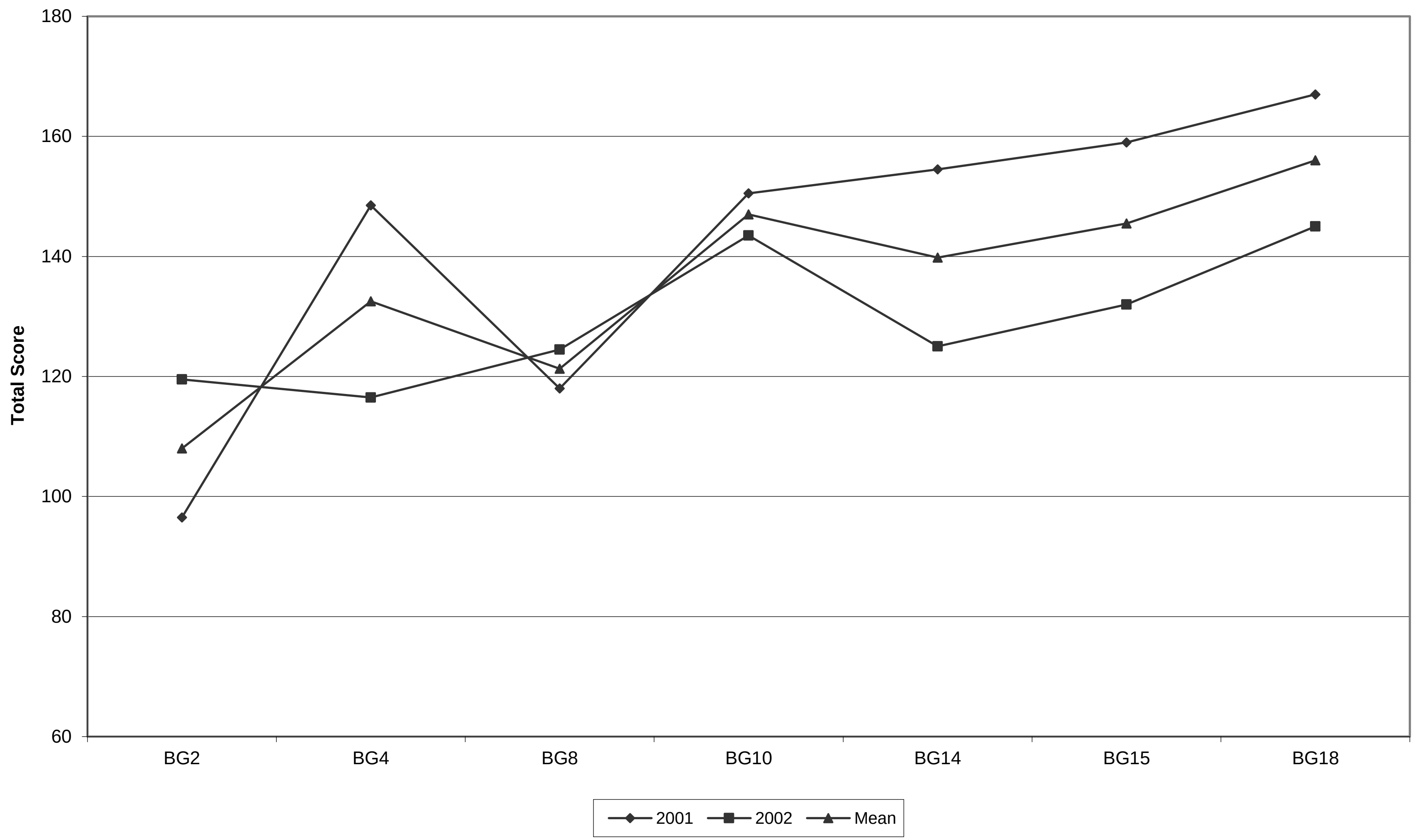


Figure 8-93. Total Habitat Assessment Scores at Little Goose Creek Stations, 2001 and 2002.

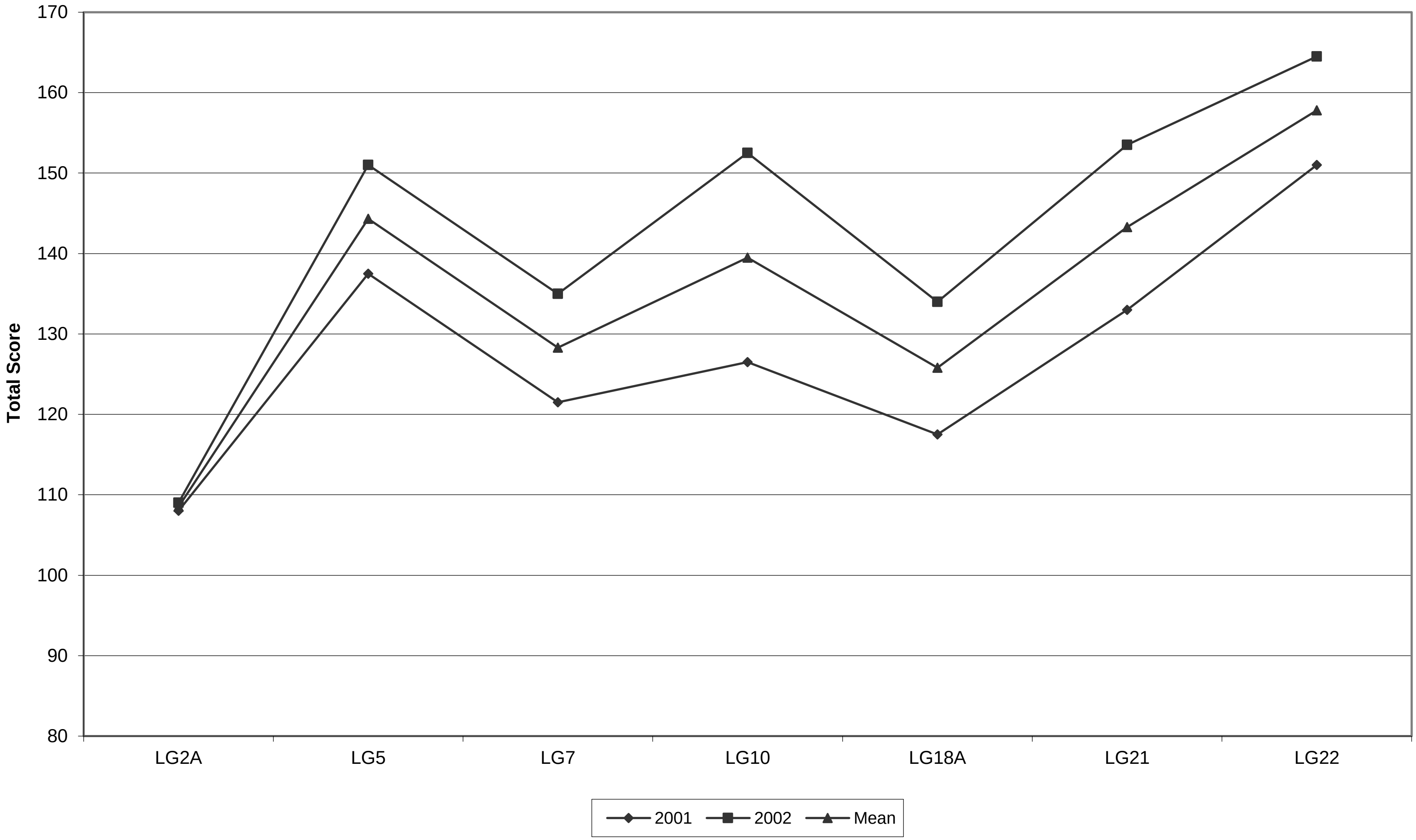


Figure 8-94. Mean Total Habitat Assessment Scores at Goose Creek Watershed Monitoring Stations, 2001 and 2002.

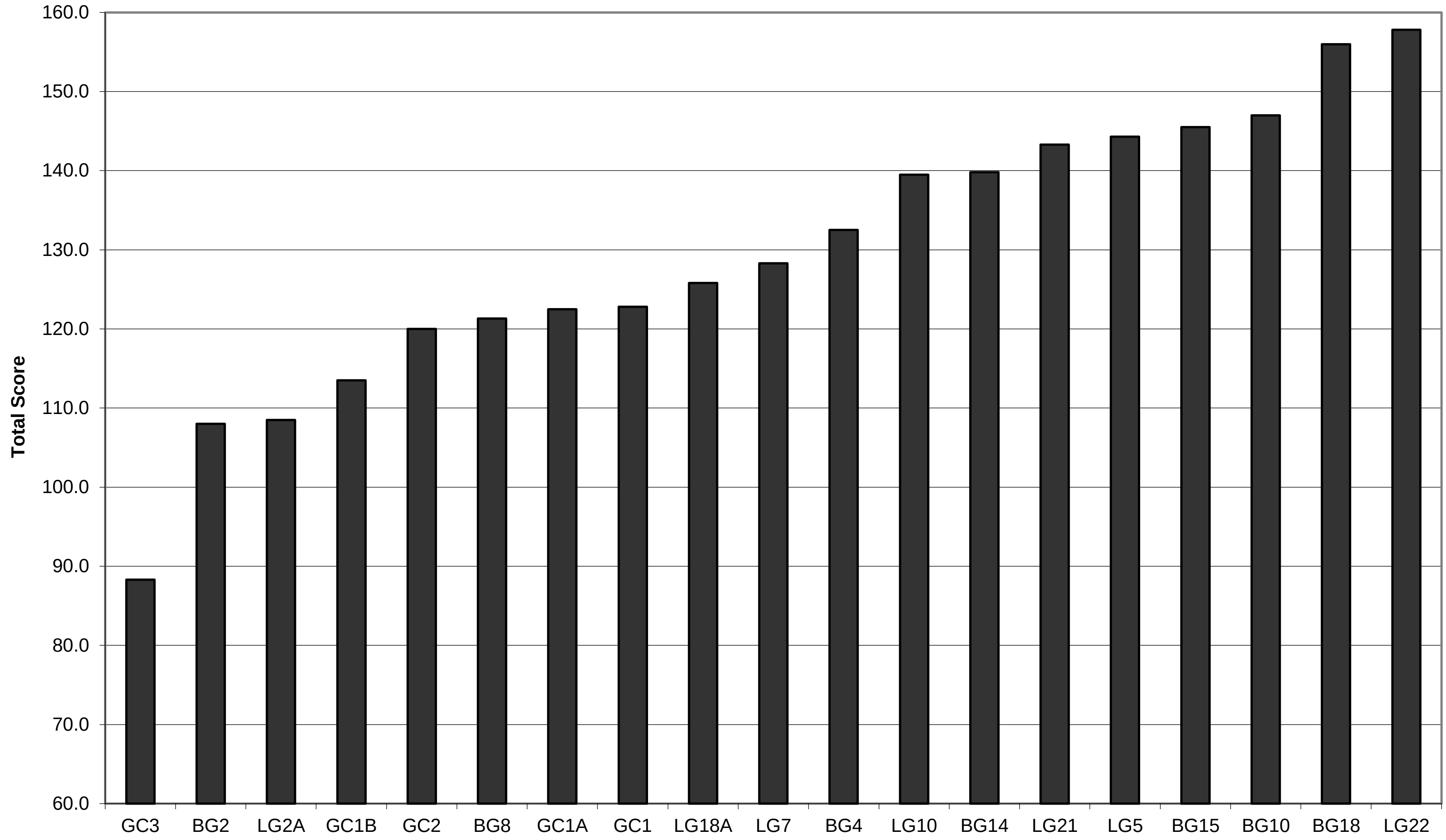


Figure 8-95. Embeddedness (silt cover) at Goose Creek Stations, 2001 and 2002.

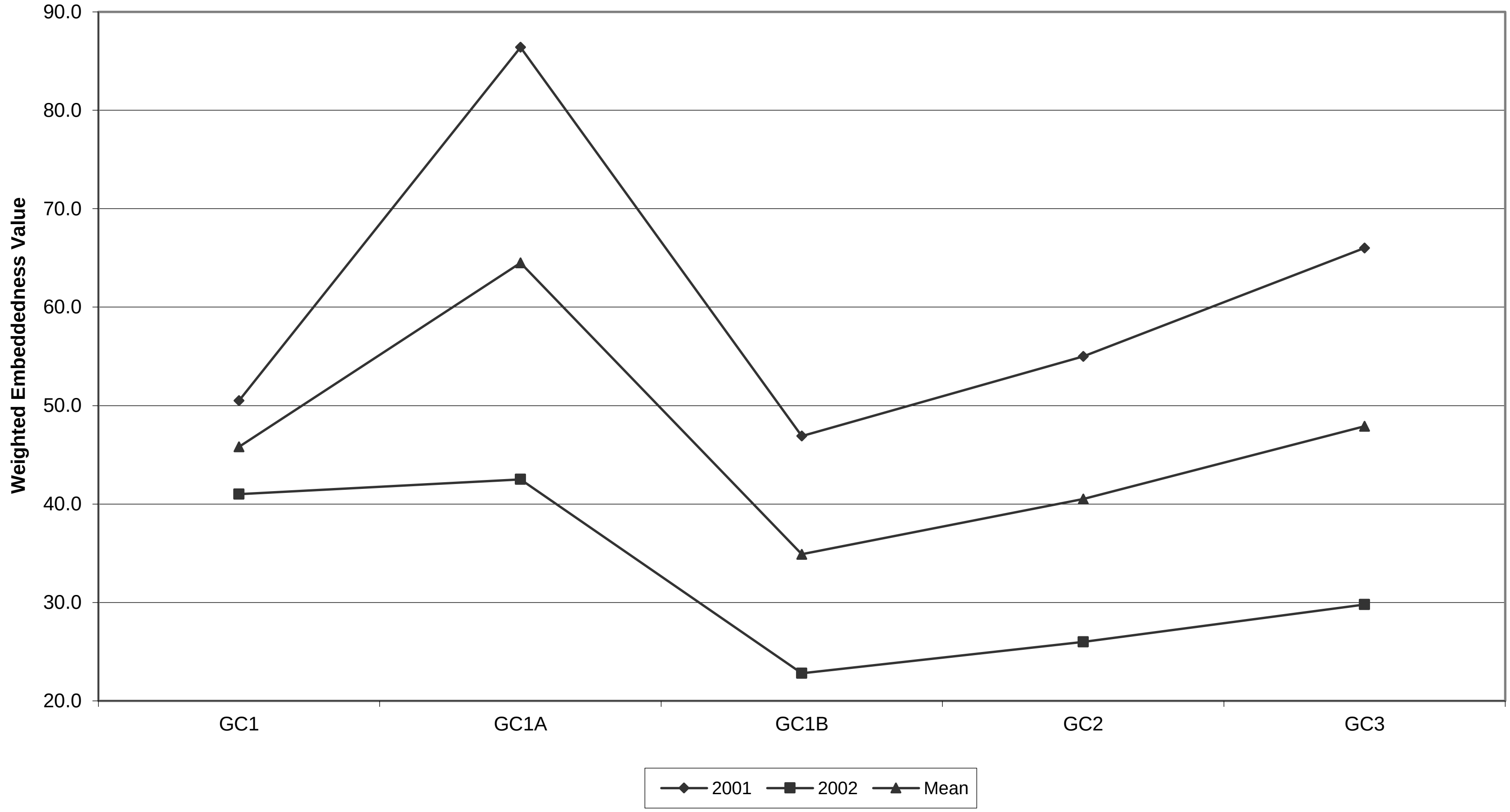


Figure 8-96. Embeddedness (silt cover) at Big Goose Creek Stations, 2001 and 2002.

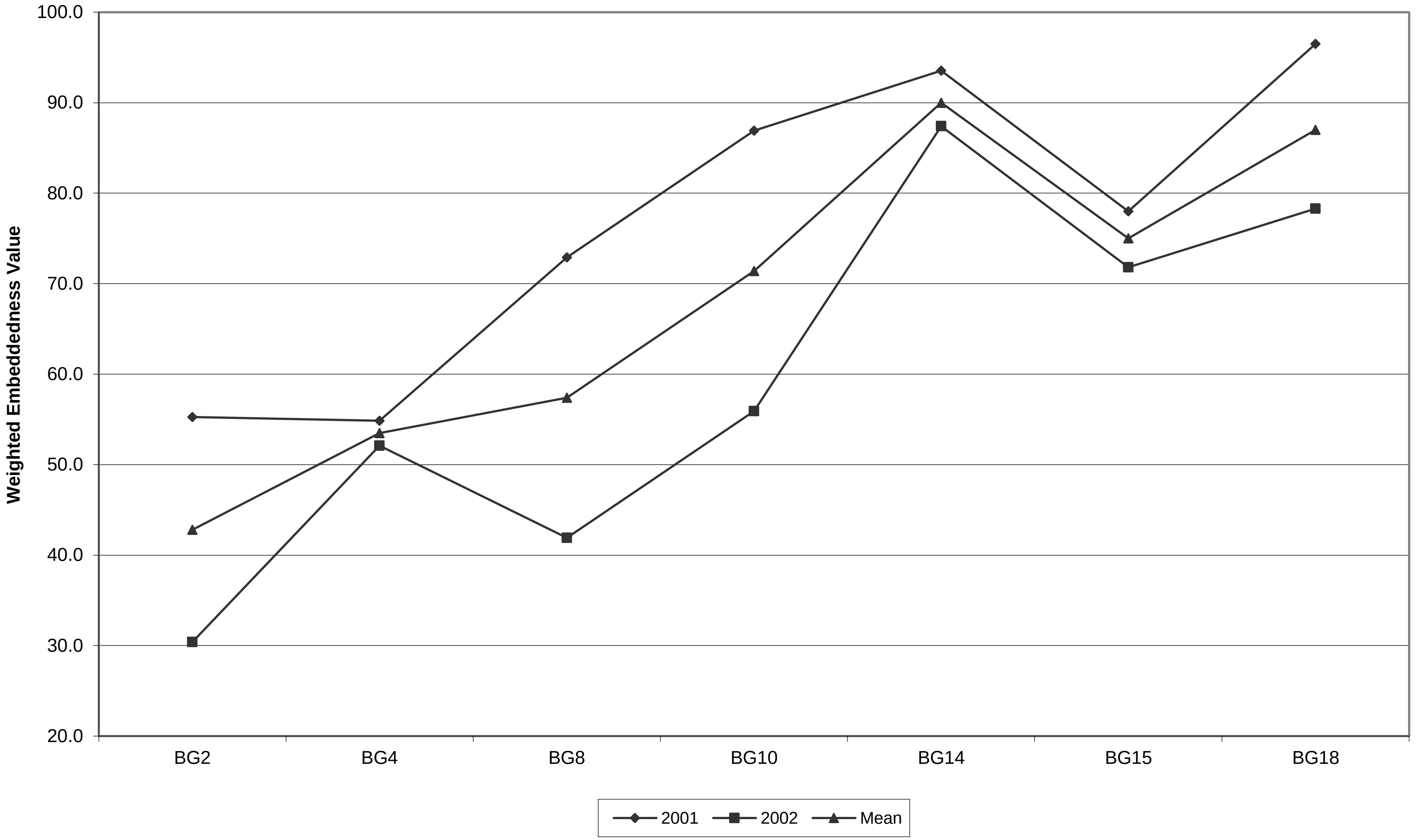


Figure 8-97. Embeddedness (silt cover) at Little Goose Creek Stations, 2001 and 2002.

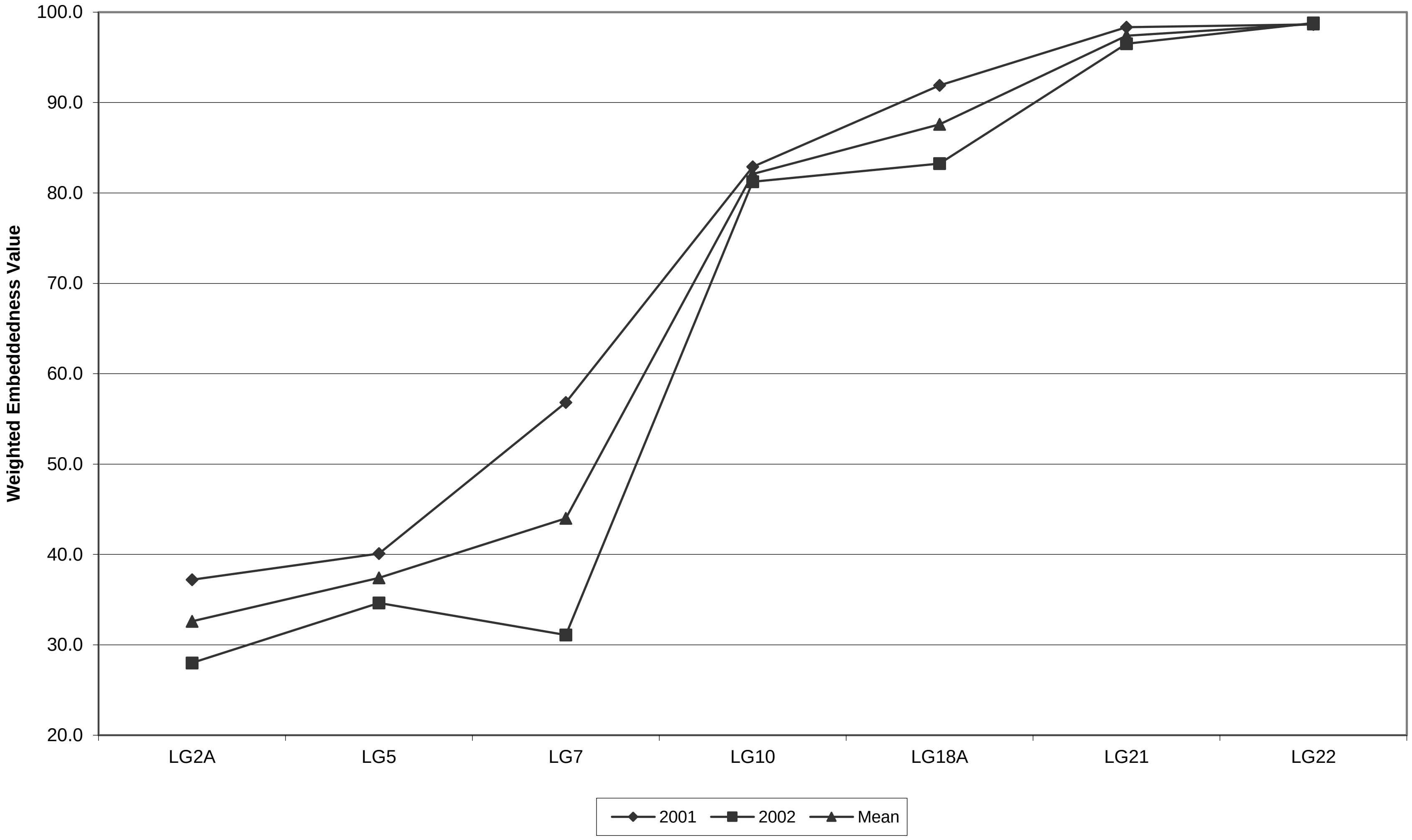


Figure 8-98. Mean Embeddedness (silt cover) Values at Goose Creek Watershed Stations, 2001 and 2002.

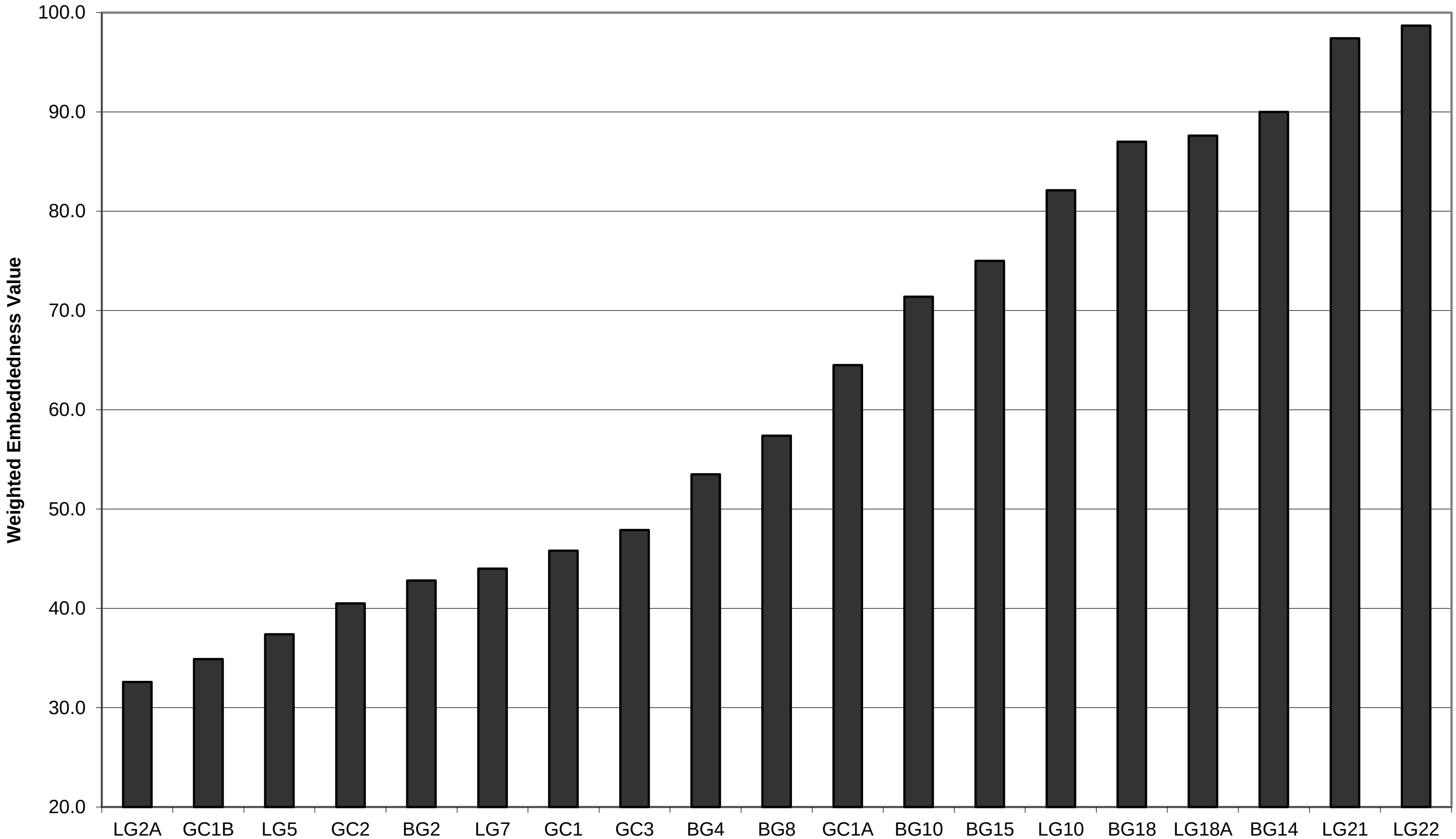


Figure 8-99. Relationship Between Mean Total Habitat Score and Mean WSII Biological Condition Score for Goose Creek Watershed Stations, 2001 and 2002.

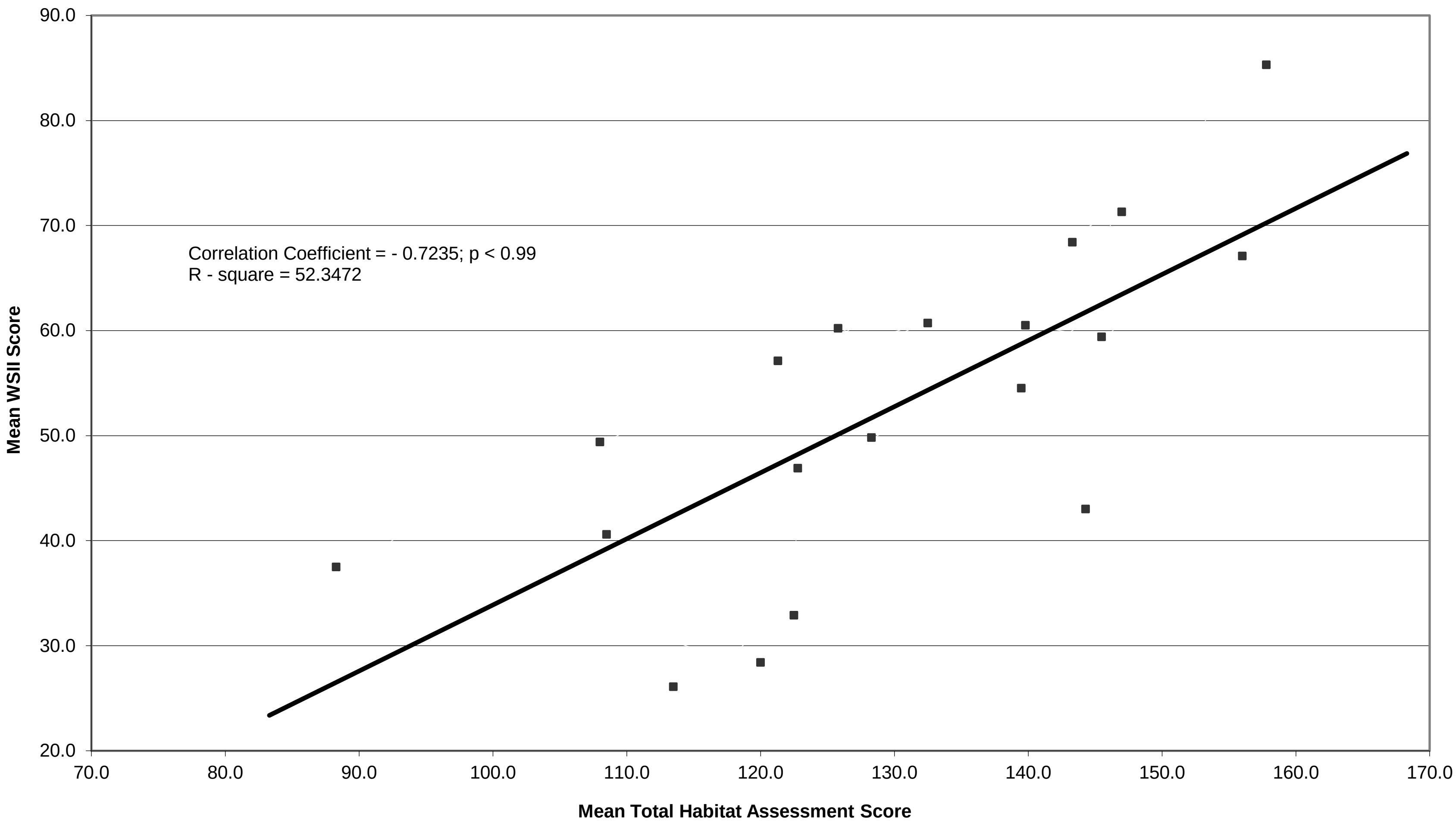


Figure 8-100. Picture of Crushed Ice Bath that was used as a QA Check to Determine if the Temperature Loggers were Performing Within Acceptable Limits. Loggers were Submerged into the Ice Bath and the Bucket was Placed in a Refrigerator During the Test.

Figure 8-101. An Example of Low Streams Flows Induced by Seasonal Dewatering and the Regional Drought. Photograph Taken Looking Upstream from Big Goose Creek Site BG15 Toward the Rapid Creek Confluence, August 2002. Measured Discharge for the day was 2.2 cfs.

Figure 8-102. An Example of Turbid Sackett Creek Stream Water Entering and Mixing with Low Turbidity Little Goose Creek Stream Water. Photograph Taken Looking East Across Little Goose Creek at the Sackett Creek Confluence.

Figure 8-103. Goose Creek stations GC1 (top) and GC3 (bottom). Photos taken September 19, 2002.

Figure 8-104. Big Goose Creek stations BG2 (top) and BG18 (bottom). Photo at BG2 taken September 10, 2001; BG18 taken September 17, 2002.

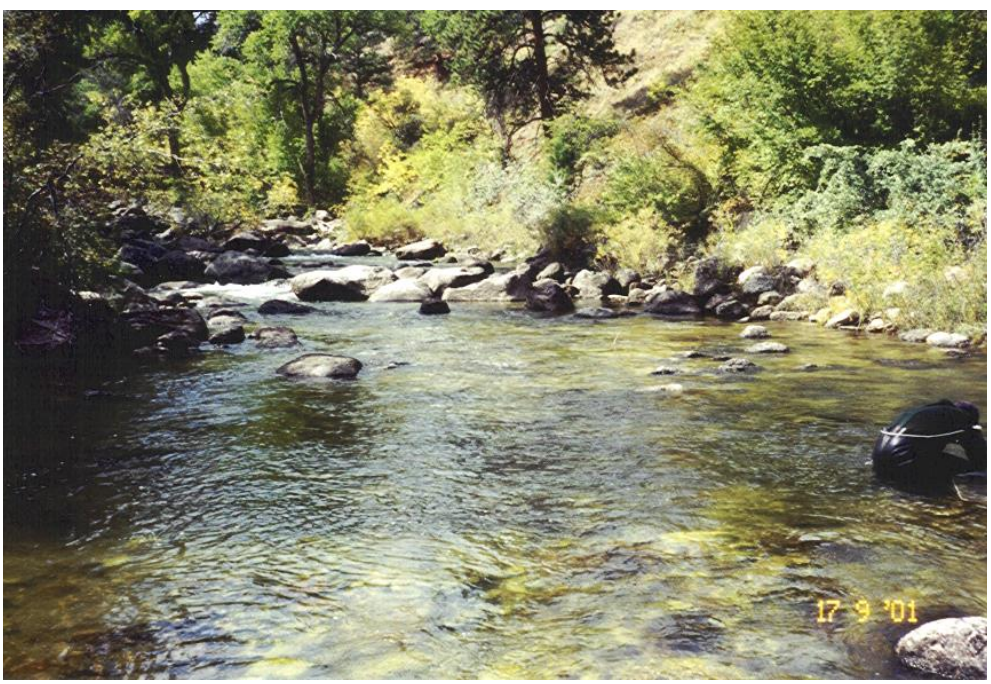
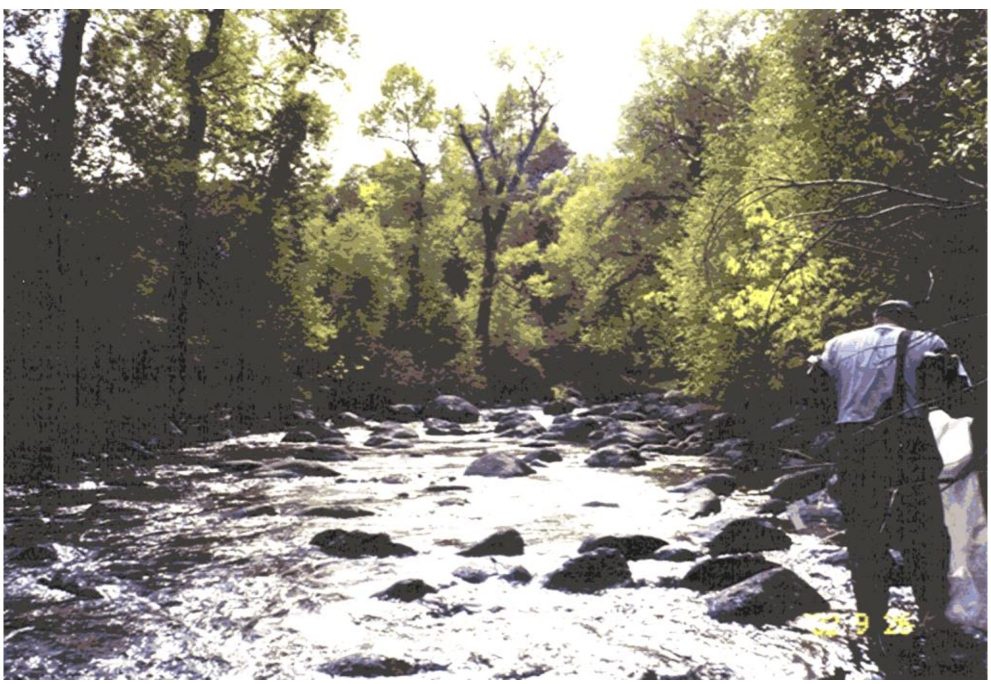


Figure 8-105. Little Goose Creek stations LG5 (top) and LG22 (bottom). Photo at LG5 taken September 17, 2002; LG22 taken September 26, 2002.



9. CUMULATIVE EFFECTS AND PLANNING PRIORITIZATION

The GCWA identified pollutants affecting Goose Creek, Big Goose Creek, Little Goose Creek and primary tributaries. There were no significant pollutants identified from point source discharge, therefore the majority of pollutants affecting water bodies were from non-point sources. The assessment provided potential sources for pollutants and discussed land use associations with fecal coliform bacteria and certain water quality parameters. Sampling provided chemical, physical, biological, pesticide, herbicide, macroinvertebrate, and habitat data for the watershed at many "new" monitoring stations and at several historical stations sampled by various entities. Most of the watershed had never been sampled at this intensity prior to this assessment. Section 8 presented results and discussions by sampling parameter. Section 9 provides a cumulative overview of monitoring and assessment results. The evaluation of cumulative water quality effects at the watershed scale will assist in planning future watershed improvement activities.

9.1 GOOSE CREEK, BIG GOOSE CREEK, AND LITTLE GOOSE CREEK

Water quality within the three major waterbodies, Goose Creek, Big Goose Creek, and Little Goose Creek, generally improved from downstream to upstream with few exceptions. The water in Big Goose Creek and Little Goose Creek leaving the BHNF was of very high quality with rare occurrences of high fecal coliform concentrations. After leaving the mountain foothills, fecal coliform concentrations and water temperatures in Big Goose Creek and Little Goose Creek increased while traveling through the agricultural, rural, and suburban areas south and west of Sheridan, Wyoming. Land uses and population densities along these streams steadily increase toward Sheridan, which is reflected in changes to water quality. Water quality in lower Big Goose Creek, lower Little Goose Creek, and Goose Creek was of lesser quality. In contrast, water quality appeared to improve for several water quality parameters at the lowermost station (GC1) located near Acme, Wyoming. Monitoring stations with Wyoming water quality violations are listed in Tables 9-1 and 9-2. Comparisons of current WDEQ, GCWA, and USGS fecal coliform data to historical USGS data on lower Goose Creek indicate bacteria concentrations have declined significantly since the 1970's and early 1980's. This decline appears to correspond with the timing of facility upgrades made at the Sheridan WWTP in 1983 and 1984.

Goose Creek sites throughout Sheridan (GC2, GC3, GC5, and GC6) exceeded the fecal coliform standard on at least one occasion. The lowermost site, GC1, did not have a geometric mean that exceeded 200 CFU/100 mL during this assessment. Lower Big Goose Creek site BG1 through BG4 each exceeded the fecal coliform standard during the assessment while BG5 through BG18 (not including the tributary sites) had geometric means less than 200 CFU/100 mL. Little Goose Creek proper sites LG1 through LG4 and LG6 through LG12 also exceeded the fecal coliform standard. Sites LG5 and LG13 through LG22 (not including the tributary sites) never violated the standard during this assessment. Current and historical WDEQ and USGS fecal coliform monitoring generally revealed higher fecal coliform concentrations on Goose Creek, Big Goose Creek, and Little Goose Creek than those found during the 2001-2002 GCWA. During 1998 and 1999 monitoring, WDEQ found fecal coliform impairment on upper Goose Creek throughout Sheridan, on Big Goose Creek from its mouth to the canyon, and on Little Goose Creek from its mouth to the canyon. Lower fecal coliform concentrations found during the GCWA may be attributable to below normal discharge observed while collecting these samples. Sampling conducted during the Project suggested that higher bacteria populations are present within bed sediment that may be suspended during higher flows. Based upon the 2001-2002 GCWA fecal coliform monitoring, Appendix Map A-10 was created to show stream reaches within the Goose Creek known to be impaired for fecal coliform, NPS pollution.

Monitoring stations that were found during the assessment to exceed the fecal coliform standard also exceeded WDEQ's proposed *E. coli* standard of 126 CFU/100 mL for Full Body Contact recreational waters (WDEQ, 2002). Of the 19 sites monitored during August 2002, 10 stations exceeded the proposed *E. coli* standard and existing fecal coliform standard. However, of these 10 stations, Goose Creek site GC2 exceeded only the *E. coli* standard and BG1 exceeded only the fecal coliform standard. Paired fecal coliform and *E. coli* samples collected throughout the watershed during 2002 should provide sufficient baseline data for future references operating under the new regulations that use *E. coli* as the indicator of bacterial pathogens.

Water temperatures in Goose Creek, lower Big Goose Creek, and lower Little Goose Creek were often found to exceed the 20°C instream limit set forth in the Wyoming water quality standards. Instantaneous measurements with field meters occasionally recorded temperatures in excess of 20°C; however, the time at which these samples were taken often did not correspond to the actual daily high water temperatures. Continuous water temperature data collected at Goose Creek site GC1, Big Goose Creek sites BG2 and BG6, and Little Goose Creek site LG2 and LG8 showed routine daily exceedences of the maximum instream temperature standard from May until September. Moreover, each of these sites observed periods when water temperatures never cooled below 20°C. These continuous water temperature data, when evaluated with benthic macroinvertebrate data and historical fisheries data, suggest most of the lower reaches in the watershed are more accurately represented as warm-water fisheries. Continuous temperature data and 2001 – 2002 instantaneous temperature measurements suggest the entire length of Goose Creek, Big Goose Creek from its mouth to the canyon, and Little Goose Creek from its mouth to the canyon regularly exceed the water temperature standard. Appendix Map A-11 illustrates these reaches.

With the exception of three DO measurements, all other water quality parameters were found to meet Wyoming water quality standards. DO measurements less than 5.0 mg/L were taken at Goose Creek site GC1, Big Goose Creek site BG5, and Park Creek site BG13. However, these measurements only represented 0.14% of all GCWA dissolved oxygen samples taken and were taken at or near Project low discharges. In general, DO throughout the watershed was good to excellent.

Based on mean WSII scores derived from current and historical benthic macroinvertebrate sampling, the entire reach of Goose Creek from its headwaters in Sheridan at the confluence of Big Goose Creek and Little Goose Creek, to its confluence with the Tongue River, had either fair or poor biological condition. It should be noted however, that aquatic life use support in the Placheck Pit, a former surface coal mine pit constructed in the main Goose Creek channel, is unknown due to lack of sampling. Two rainbow trout, a cold water game fish species, were collected in gillnet samples from the Placheck Pit by WWRRI in 1977. The rainbow trout were probably stocked or transients from upstream Goose Creek or downstream Tongue River and were apparently able to survive in the cooler water temperature refuge afforded by the pit. Brown trout were collected in 62% of samples from Goose Creek and the 2 rainbow trout collected only from the Placheck Pit suggested the Pit may support cold water aquatic life use. It should also be noted that where Brown trout were collected in Goose Creek, they were never abundant and ranged from only 1 fish to 3 fish per sample. This observation indicated brown trout populations were marginal at Goose Creek sample stations.

Although biological condition based on benthic macroinvertebrate populations improved downstream of Sheridan between Goose Creek station GC1A and GC1, the lower biological condition scores indicated non-support of the narrative WDEQ water quality standard for aquatic life use for all of Goose Creek, with perhaps the exception of the Placheck Pit.

As indicated by mean WSII scores derived from current and historical benthic macroinvertebrate sampling, Big Goose Creek appears to support aquatic life use from station BG18 in the canyon on the T-T Ranch downstream to station BG4 located at Normative Services. It should be noted that although aquatic life use support occurs through the reach from station BG18 to BG4, water quality and habitat stressors appeared to negatively affect biological condition at stations BG15, BG14, BG8 and BG4, but not to the degree to result in non-attainment of aquatic life use. It was proposed that the reach from station BG18 to downstream station BG14 be described as fully supporting, but threatened for aquatic life use support; and the reach from station BG10 to downstream station BG4 be described as fully supporting, but threatened for aquatic life use support. Biological condition was reduced between station BG4 and BG2 in Sheridan indicating non-support of aquatic life use within this stream reach. Further, it is likely the stream reach from station BG2 to the confluence with Little Goose Creek in Sheridan did not support aquatic life use. Evaluation of information presented in Final Report Sections 3.3, 8.2 through 8.20, 8.22, 8.23 and 8.24 was combined with the biological condition data to support this conclusion.

Little Goose Creek appears to support aquatic life use from upstream station LG22 downstream to station LG10 based on WSII scores derived from current and historical benthic macroinvertebrate sampling. Biological condition at station LG10 indicated marginal aquatic life support during 2001 sampling, but non-support for samples collected in 1998 and 2002. Biological condition decreases and aquatic life use was not supported at each consecutive station downstream from station LG10 into Sheridan. This observation was supported by fisheries data in Section 8.23, which found a shift from cold water fish species to more non-game and warm water game species from the Highway 87 bridge downstream to the Woodland Park bridge near Little Goose Creek station LG7 for this Project. Biological condition continues to decline from station LG7 downstream to station LG2A in Sheridan and non-support of aquatic life use is indicated.

Additional evaluation of the biological condition data using the "weight of evidence" approach described in WDEQ (2002b) by incorporating chemical, physical, and biological data in addition to consideration of soils, geology, hydrology, climate, geomorphology, and stream succession, supported the finding that Little Goose Creek did not support aquatic life use from station LG10 downstream to station LG2A. It is probable the stream reach from station LG2A downstream to the Big Goose Creek confluence did not support aquatic life use. Further, the biological condition at station LG10 indicated full support for aquatic life, but there was a downward trend indicating potential non-support in the near future. It is recommended that the stream reach from station LG18 to downstream station LG10 be described as fully supporting, but threatened for aquatic life use support. Appendix Map A-12 illustrates the segments of Goose Creek, Big Goose Creek, and Little Goose Creek not meeting Wyoming's narrative standard for aquatic life use or identified as threatened.

As described in Section 8, discharges observed during the Project were significantly less than normal for the watershed as a result of the continuing drought affecting North-Central Wyoming. In summary, discharge during 2001 and 2002 was 31% and 29% of normal at USGS Station Number 06305700 (Goose Creek Near Acme), 44% and 57% of normal at USGS Station Number 06301500 (West Fork Big Goose Creek Near Big Horn, and 42% and 55% of normal at USGS Station Number 06303500 (Little Goose Creek in Canyon), respectively. Discharge quantities normally affect most water quality parameters, macroinvertebrate communities, fisheries production, and riparian habitat. Stream dewatering and irrigation return flows probably had a greater impact on overall water quality during 2001-2002 than during normal years due to the drought and increased demand for supplemental watering. However, stream dewatering has likely affected water quality in this watershed for several decades. Dewatering of streams within the watershed during the irrigation season is a complex issue due to competing interests for water resources. The balance of water use among municipalities, fisheries and recreation, and the demand for irrigation and survival of the agricultural community has proven to be a difficult issue to resolve.

9.2 PRIMARY TRIBUTARIES, THE COFFEEN AVENUE STORM DRAIN, AND THEIR CUMULATIVE EFFECTS ON WATER QUALITY

Water quality in the tributaries was generally of lesser quality than Goose Creek, Big Goose Creek, and Little Goose Creek. Each of the tributaries, except Beaver Creek, exceeded the fecal coliform standard during the assessment. However, Beaver Creek nearly exceeded the standard on several occasions and did exceed WDEQ's proposed *E. coli* standard of 126 CFU/100 mL during August 2002. Soldier Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek also exceeded the proposed *E. coli* standard during August 2002. *E. coli* samples were not collected from Park Creek during August 2002 because the stream was dry.

Soldier Creek had fecal coliform concentrations greater than 200 CFU/100 mL during each of the months of May and August, 2001 and 2002. Jackson Creek had fecal coliform geometric means greater than 200 CFU/100 mL during three months of the assessment. Park Creek, McCormick Creek, and Sackett Creek exceeded the fecal coliform standard during two months each. The fecal coliform standard was exceeded during one month only at Rapid Creek and Kruse Creek. Tributary segments impaired for fecal coliform bacteria are shown on Appendix Map A-10.

Continuous temperature data collected from Soldier Creek, Beaver Creek, and Jackson Creek during 2002 provided nearly identical results. Beaver Creek and Jackson Creek each exceeded 20°C during 45 days during 2002. Soldier Creek only exceeded the temperature standard during 34 days, however, the data logger was partially buried in stream sediment during much of June and these data were not included. Since daily average temperatures were nearly identical for these three streams during 2002, it is estimated that Park Creek, Rapid Creek, McCormick Creek, Kruse Creek, and Sackett Creek would have yielded similar results. The temperature impaired segments of Soldier Creek, Beaver Creek, and Jackson Creek are shown on Appendix Map A-11.

The Coffeen Avenue storm drain (site LG3) generally had very poor water quality. However, the volume of water from this storm drain entering Little Goose Creek was only about 35 gpm (0.08 cfs) on average. Conductivity, total sulfate, total chloride, total nitrate nitrogen, and total hardness were highest at this site during the GCWA. This storm drain also had fecal coliform geometric means greater than 1,100 CFU/100 mL during both August 2001 and August 2002. Although site LG3 was the only urban storm drain monitored during this assessment, historical data collected by WDEQ and others have shown that several other Sheridan storm drains discharge similar water quality and may collectively have an impact on local water quality.

None of the eight individual tributaries and one storm drain monitored during this Project appeared to have a significant impact on the water quality of Goose Creek, Big Goose Creek, and/or Little Goose Creek. Poorer tributary water quality was usually offset by their relatively low flow contributions and subsequent dilution into the larger streams. However, the combined effect of all tributary waters, storm drains, irrigation returns, and non-point sources of various pollutants did have a profound effect on the water quality of the main streams. Water quality in Big Goose Creek and Little Goose Creek steadily decreases towards Sheridan, and cannot be attributed solely to single sources.

9.3 WATERBODY RANKING AND PRIORITIZATION FOR RESTORATION

Each of the 46 GCWA monitoring stations was ranked from highest water quality to lowest water quality in Table 9-3. Ranks were based upon combined 2001 and 2002 parameter averages and were distributed with the number 1 indicating the best water quality and the number 46 being the poorest water quality. Each water quality parameter was allowed equal "weight" in the ranking (i.e. temperature was not considered more important than pH, etc.). BOD was not included in the ranking because approximately 96% of all Project samples were analyzed as non-detectable. *E. coli* was not included since only 19 of the 46 stations were monitored for this parameter. After each parameter was ranked, the scores were added in the Sum of Rank Scores column in Table 9-3. Figure 9-1 was then created from these Sum of Rank Scores to illustrate highest to lowest water quality by station. The Overall Water Quality Rank in Table 9-3 was then determined by ordering the Sum of Rank Scores.

Big Goose Creek site BG18 ranked highest followed by Little Goose Creek site LG22. These were the two uppermost sites monitored during the project and were located upstream from most (not all) residences and septic systems, grazing lands, urban areas, roads, irrigation diversions and returns, and other non-point sources. As expected, the stream segments within the lower reaches of the watershed and the tributaries generally ranked lower in water quality (see Table 9-3 and Figure 9-1). The Coffeen Avenue storm drain had the poorest water quality of any GCWA monitoring station. As shown in Figure 9-1, Rapid Creek had the highest water quality of the tributaries. Rapid Creek was followed by Sackett Creek, Beaver Creek, Kruse Creek, Jackson Creek, McCormick Creek, Park Creek, and finally Soldier Creek.

Biological condition and habitat assessment results for monitoring stations were ranked in a similar manner to the water quality ranking as shown in Table 9-4. Figures 8-80 and 8-94 were used to rank biological conditions and habitat assessments, respectively. Seventeen of the GCWA stations were used for water quality sampling, macroinvertebrate sampling, and habitat assessment and are scored from 1 being highest to 17 being lowest in Table 9-4. Sites used only for water quality monitoring or only for BURP monitoring are not included in this ranking table.

As shown in Table 9-4, water quality ranking, biological condition ranking, and habitat assessment ranking agreed favorably among most stations. This suggests that water quality monitoring or BURP monitoring alone could be used to generally describe the overall riparian health within the Goose Creeks watershed.

Ranking of the monitoring stations as provided in Table 9-3, Table 9-4, and Figure 9-1 was performed primarily for use in future watershed planning and BMP implementation efforts. Although future improvement projects will probably be completed on a voluntary basis, the ranking provided in this Section may be used as a tool to prioritize projects such that stream segments with lower water quality are given highest priority. Waterbodies with confirmed fecal coliform bacteria impairments should receive highest priority because they represent immediate public health and safety concerns. Improvements made in water quality will likely play a major role in the improvement of biological condition, fisheries, and stream habitat.

Improvement strategies should involve the entire watershed since water management practices appeared to be indirectly responsible for water temperature and narrative aquatic life use standard exceedences. Any role that water management played in fecal coliform bacteria standard exceedences was less clear. Improved water management by users in the upper watershed will improve water quality for users located lower in the watershed.

WDEQ standards should not be the sole means by which water quality is measured, or improvement strategies are planned. Existing standards may not adequately reflect the impacts of some parameters on overall ecosystem quality. Addressing cost-effective improvements for parameters complying with standards (i.e. turbidity, nutrients, DO, etc.) may often be essential for water quality maintenance and improvement. Furthermore, public expectations uncovered through a local planning process should provide direction at least equal to that provided by the regulatory standards.

9.4 RECOMMENDATIONS FOR FUTURE ASSESSMENTS

Future monitoring will likely be conducted to determine whether BMP implementation projects have a beneficial impact on water quality. Based on the observations of the 2001 and 2002 GCWA, the following recommendations are suggested for future water quality monitoring projects:

1. Continuous water temperature monitoring should be included in future monitoring efforts. Monitoring during the 2001 and 2002 assessment was conducted during a relatively severe drought. Future continuous temperature monitoring during "normal" or near-normal flow years may provide information that alters the stream reaches determined by the GCWA to violate the temperature standard. Additional continuous temperature monitoring sites on upper Big Goose Creek and upper Little Goose Creek may accurately define transition zones between cold-water fisheries and warm-water fisheries.

2. Fecal coliform and *E. coli* monitoring should be conducted to further identify their relationship within the watershed. Future fecal coliform monitoring will provide a link to historical trends in water quality; *E. coli* monitoring will be necessary to comply with proposed standards.

3. BURP monitoring should be included in future programs to assess narrative aquatic life use criteria. Several stations during the GCWA were identified as threatened and/or bordered between two rating categories (i.e. fair and good).

4. A water quality monitoring station even closer to the mouth of Goose Creek is recommended. During the 2001 and 2002 assessment, several data suggested Goose Creek water quality improved with increasing distance from Sheridan.

5. The date, location, and type of voluntary BMP implementation projects should be tracked to relate possible water quality and/or water resource improvements and potentially preclude any future needs for TMDL's.

6. Fish sampling in Goose Creek, Big Goose Creek, Little Goose Creek, and Soldier Creek would provide current data to better assess of the beneficial use for fish. Fishery data in the GCWA Project area collected since 1957 were useful, but inconsistent sampling methods did not provide a clear picture of current fish populations.

7. Increase the number of monitoring stations in Soldier Creek and certain tributaries to define segments with water quality problems. The entire length of Soldier Creek and other tributaries are currently listed as water quality impaired.

Table 9-1. Summary of Wyoming Water Quality Standard Violations on Goose Creek and Big Goose Creek During the 2001 – 2002 Goose Creek Watershed Assessment

Monitoring Station	Fecal Coliform	Temperature	Dissolved Oxygen	Narrative Aquatic Life Use[A]
GC1		X	X	X
GC1A				X
GC1B				X
GC2	X	X		X
GC3	X	X		X
GC4 – Soldier Creek	X	X		X[B]
GC5	X	X		
GC6	X	X		
BG1	X	X		
BG2	X	X		X
BG3	X	X		
BG4	X	X		X
BG5		X	X	
BG6		X		
BG7		X		
BG8		X		X[C]
BG9 – Beaver Creek		X		
BG10		X		
BG11		X		
BG12		X		
BG13 – Park Creek	X		X	
BG14		X		X[C]
BG15		X		X[C]
BG16 – Rapid Creek	X	X		
BG17		X		
BG18				

Notes:

A. Stream reaches exceeding the narrative aquatic life use standard or identified as threatened are illustrated on Appendix Map A-12.

B. Soldier Creek impairments for aquatic life use are based upon 1999 WDEQ monitoring.

C. Indicates threatened status for the narrative aquatic life use standard at this station.

Table 9-2. Summary of Wyoming Water Quality Standard Violations on Little Goose Creek During the 2001 – 2002 Goose Creek Watershed Assessment

Monitoring Station	Fecal Coliform	Temperature	Dissolved Oxygen	Narrative Aquatic Life Use[A]
LG1	X	X		
LG2	X	X		
LG2A				X
LG3 – Storm Drain	X	X		
LG4	X	X		
LG5		X		X
LG6	X	X		
LG7	X	X		X
LG8	X	X		
LG9 – McCormick Creek	X			
LG10	X	X		X[B]
LG11 – Kruse Creek	X	X		
LG12	X	X		
LG13		X		
LG14		X		
LG15		X		
LG16		X		
LG17 – Jackson Creek	X	X		
LG18		X		
LG18A				
LG19 – Sackett Creek	X			
LG20		X		
LG21		X		
LG22				

Notes:

A. Stream reaches exceeding the narrative aquatic life use standard or identified as threatened are illustrated on Appendix Map A-12.

B. Indicates threatened status for the narrative aquatic life use standard at this station.

Table 9-3. Final Project Water Quality Ranking as Organized by Station (stations are ranked from 1 – highest to 46 – lowest). Ranking Performed on Final Parameter Averages

Monitoring Station	Temperature	pH	Conductivity	DO	Fecal Coliform	Turbidity	Alkalinity	Chloride	Hardness	Ammonia	Nitrates	Phosphorus	Sulfate	TSS	Sum of Rank Scores	Overall Water Quality Rank
GC1	40	35	38	35	15	37	29	41	37	42	30	44	38	43	504	44
GC2	38	30	34	10	39	26	21	42	25	44	44	45	30	32	460	41
GC3	42	40	30	3	26	25	25	40	32	16	27	21	31	33	391	32
GC4-Soldier Cr	6	5	45	39	43	44	46	44	45	26	42	41	45	44	515	45
GC5	44	41	36	4	31	31	27	43	33	12	26	30	32	37	427	36
GC6	45	37	35	5	35	33	20	45	28	5	28	24	34	36	410	35
BG1	25	31	32	41	32	23	17	29	34	9	11	20	42	29	375	28
BG2	27	25	33	44	33	28	16	25	29	18	8	37	41	31	395	33
BG3	28	28	29	42	37	22	15	24	26	21	6	29	39	23	369	27
BG4	24	8	31	43	24	16	18	20	35	17	16	7	40	9	308	21
BG5	21	20	26	31	19	17	19	17	24	20	1	35	28	10	288	19
BG6	18	24	24	20	9	13	22	18	22	3	7	16	26	7	229	11
BG7	19	18	25	21	18	14	23	16	23	2	2	14	27	3	225	9
BG8	7	26	20	12	17	15	24	12	21	31	21	36	20	8	270	16
BG9-Beaver Cr	5	38	43	11	34	27	45	22	43	15	38	43	35	38	437	37
BG10	12	19	19	13	12	10	11	11	15	6	5	31	21	1	186	5
BG11	11	21	17	8	29	8	9	10	14	1	4	28	22	5	187	6
BG12	22	17	13	6	8	4	7	8	13	7	3	23	24	12	167	3
BG13-Park Cr	1	1	42	46	45	32	43	36	42	41	43	46	43	28	489	43
BG14	26	29	10	14	7	5	6	5	10	43	9	18	25	13	220	8
BG15	32	44	9	17	22	12	5	3	9	8	17	25	33	17	253	14
BG16-Rapid Cr	29	34	11	28	38	9	10	7	11	10	24	17	14	20	262	15
BG17	30	33	5	22	6	11	4	2	4	4	12	3	15	27	178	4
BG18	2	3	1	23	1	1	1	4	1	29	15	5	1	2	89	1

Table 9-3. (Continued)

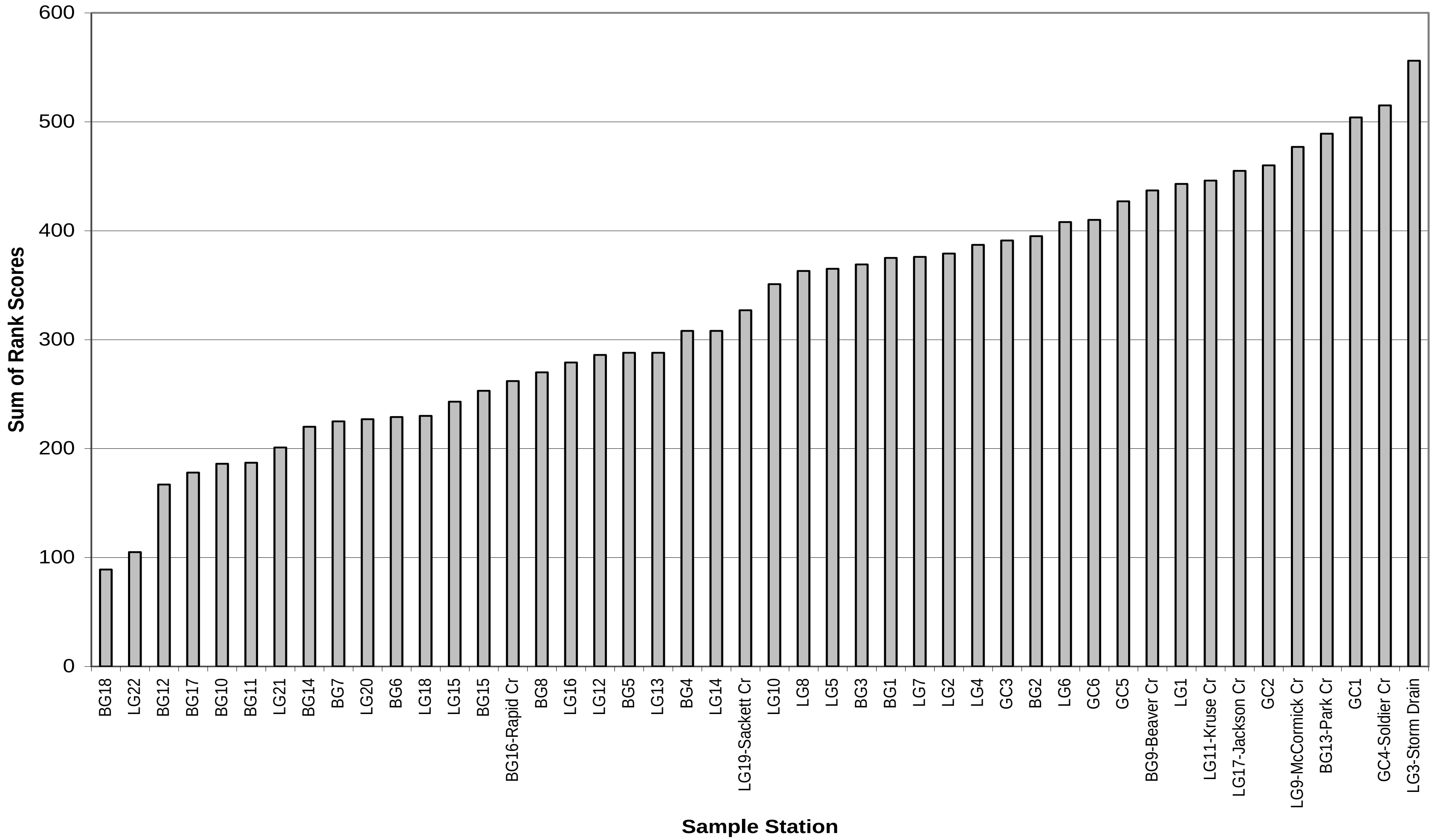
Monitoring Station	Temperature	pH	Conductivity	DO	Fecal Coliform	Turbidity	Alkalinity	Chloride	Hardness	Ammonia	Nitrates	Phosphorus	Sulfate	TSS	Sum of Rank Scores	Overall Water Quality Rank
LG1	8	32	40	33	41	35	37	39	41	40	25	11	37	24	443	38
LG2	9	16	41	34	27	34	39	38	40	28	13	9	36	15	379	30
LG3-Storm Drain	46	4	46	36	44	40	34	46	46	45	46	42	46	35	556	46
LG4	14	23	39	26	23	38	38	35	39	22	10	26	29	25	387	31
LG5	13	13	37	37	11	36	41	33	38	37	14	6	23	26	365	26
LG6	17	9	28	38	36	42	40	26	36	46	23	10	16	41	408	34
LG7	15	7	27	40	46	41	33	31	31	13	19	15	19	39	376	29
LG8	10	12	22	19	28	39	36	30	27	24	36	33	17	30	363	25
LG9-McCormick Cr	3	15	44	16	40	43	44	37	44	30	37	40	44	40	477	42
LG10	20	11	18	18	25	30	32	32	19	32	40	27	13	34	351	24
LG11-Kruse Cr	39	27	23	29	30	45	35	23	20	35	45	39	11	45	446	39
LG12	16	6	16	24	20	18	31	34	17	36	32	8	12	16	286	18
LG13	23	22	14	9	5	19	30	27	16	19	41	34	10	19	288	20
LG14	43	43	12	1	10	21	26	28	18	33	22	22	18	11	308	22
LG15	33	45	8	2	13	20	14	15	8	23	29	4	7	22	243	13
LG16	35	46	7	7	14	29	13	14	7	34	33	13	6	21	279	17
LG17-Jackson Cr	31	10	21	45	42	46	42	19	30	38	39	38	8	46	455	40
LG18	37	42	6	15	4	7	12	13	6	25	35	19	5	4	230	12
LG19-Sackett Cr	34	14	15	30	21	24	28	21	12	14	31	32	9	42	327	23
LG20	36	39	4	25	3	3	8	9	5	39	34	12	4	6	227	10
LG21	41	36	3	32	2	6	3	6	3	27	20	2	2	18	201	7
LG22	4	2	2	27	16	2	2	1	2	11	18	1	3	14	105	2

Table 9-4. Comparison of Ranking Scores for GCWA Stations Monitored for Water Quality, Biological Condition, and Habitat Assessment (Stations are ranked from 1 – highest to 17 – lowest)

Monitoring Station	Water Quality Rank[3]	Biological Condition Rank[3]	Habitat Assessment Rank[3]	Sum of Rank Scores	Overall Rank
GC1	17	13	12	42	13
GC2	16	17	14	47	16.5
GC3	14	16	17	47	16.5
BG2	15	12	16	43	14.5
BG4	9	5	9	23	7
BG8	8	9	13	30	10.5
BG10	3	2	3	8	3
BG14	5	6	7	18	5
BG15	7	8	4	19	6
BG18	1	4	2	7	2
LG2/LG2A[1]	13	15	15	43	14.5
LG5	11	14	5	30	10.5
LG7	12	11	10	33	12
LG10	10	10	8	28	9
LG18/LG18A[2]	6	7	11	24	8
LG21	4	3	6	13	4
LG22	2	1	1	4	1

Notes:
1. LG2 was a water quality monitoring station, LG2A was a BURP monitoring station located upstream from LG2.
2. LG18 was a water quality monitoring station, LG18A was a BURP monitoring station located upstream from LG18.
3. Water quality ranks are from Table 9-3, Biological Condition Ranks are from Figure 8-80, and Habitat Assessment Ranks are from Figure 8-94.

Figure 9-1. **Histogram of the Sum of Rank Scores Provided in Table 9-3.**



10. WATERSHED PLANNING

Once a stream is identified as impaired by WDEQ, it is subject to regulatory intervention. In Wyoming, WDEQ encourages locally-led planning and improvement activities. WDEQ assigns a low priority for TMDL development on waterbodies with an active local process for improvements in place. A locally-led planning process uses voluntary, incentive-based measures, developed and applied locally to make improvements.

In 1996, the WACD, NRCS, and the Wyoming Department of Agriculture (WDA) developed a process for watershed planning. In 2002 WDEQ, WACD, NRCS, and WDA met to discuss Wyoming's local watershed planning efforts and the States obligation to EPA for addressing waterbodies with listed impairments. To ensure accountability for these efforts, they outlined a schedule for completing Watershed Management Plans (WMP) in a June 7, 2002 letter sent to all Conservation Districts. The letter proposed that WMP's be finalized within six years of the stream listing. Therefore, because Big Goose Creek and Little Goose Creek were placed on Table A of the Wyoming 303(d) List during 1998, the Goose Creeks WMP must be finalized during 2004. Goose Creek, Beaver Creek, Jackson Creek, Kruse Creek, Park Creek, Rapid Creek, Sackett Creek, and Soldier Creek were later added to the 303(d) List during 2000. The June 7, 2002 letter also provided an outline for preparing WMP's. The WMP's should, at a minimum, contain the following:

1. *Executive Summary* – With goals which at a minimum must be to meet the designated uses for the waterbody.
2. *Introduction* – Including a resource description, why the plan is being developed, the planning authority of Districts, and the public participation process.
3. *Watershed Assessment and Concerns* – Including historical and current water quality data in comparison with WDEQ standards.
4. *Watershed Improvement Actions and Recommendations* – Identify potential BMP's to implement, information and education, etc.
5. *Action Register/Milestone Table* – Including dates for reaching planned action items (a who, what, when, and how of action items).
6. *Monitoring and Evaluation* – Chemical, physical, and biological data (water quality data, riparian condition, etc.) and informative (education of public, the public's acceptance and participation) methods of tracking progress towards meeting goals and action items.
7. *Appendices* or any reference documents needed in support of or explanation of the plan.

As mentioned in outline item number 2 above, Conservation Districts have a responsibility to assist in watershed planning activities. Under Wyoming Statute, 11-16-103 Legislative declarations and policy, SCCD is required to "provide for the conservation of the soil, and soil and water resources of this state, and for the control and prevention of soil erosion and for flood prevention or the conservation, development, utilization, and disposal of water, and thereby to stabilize ranching and farming operations, to preserve natural resources, protect the tax base, control floods, prevent impairment of dams and reservoirs, preserve wildlife, protect public lands, and protect and promote the health, safety and general welfare of the people of this state." Wyoming Statute 11-16-122 (b) further charges the Conservation Districts to "conduct surveys, investigations and research and disseminate information relating to…..the conservation, development, utilization and disposal of water…..in cooperation with the government of this state or its agencies…..(v)," to "develop comprehensive plans for …..conservation of soil and water resources…..[that] specify in detail the act, procedures, performances, and avoidances necessary or desirable to carry out the plans (xvi)," and to "make public the plans and information and bring them to the attention of owners and occupiers of the land within the district (xvii)."

In order to be successful, the planning process and the plan itself must include all environmental, social, and economic considerations and must be landowner/stakeholder driven with voluntary, incentive-based programs. A well-planned process generally consists of two broad components:

1. A Descriptive component describes local land use issues, water quality concerns, the current condition of the watershed, community objectives and goals (including customs and cultures), and other specific local concerns.
2. A Prescriptive component then identifies broad treatment programs and alternatives using available technical, financial, and educational resources.

In June 2003, the SCCD received Clean Water Act 319 federal funding to initiate local watershed planning and implementation to address water quality impairments identified within the Goose Creek watershed, should the residents choose to move in that direction. The process will be facilitated by the SCCD, but the plan itself will be developed by the watershed residents.

To develop and implement a Goose Creeks WMP, a steering committee will be formed and should include representatives from the major interests on the watershed. Membership may include officials from the local towns (Sheridan, Big Horn, etc.), Sheridan County officials, ditch companies, subdivisions, recreation interests, wildlife interests, agricultural interests, etc. Most importantly, landowners within the watershed must become involved with the Goose Creek planning and implementation strategies. Landowners have the primary ability and responsibility to make changes within the watershed that protect local natural resources.

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