1. INTRODUCTION

1.1 Project Background

Big and Little Goose Creeks originate in the Big Horn Mountains west of Sheridan, Wyoming and pass through the Bighorn 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 (see Appendix Map A-1). 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.

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. Results of the WDEQ sampling revealed elevated fecal coliform bacteria concentrations on Goose Creek, Big Goose Creek, and Little Goose Creek that exceeded Wyoming water quality standards. Exceedences of these standards resulted in a non-attainment of the designated use for Recreation and Human Consumption. These exceedences 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 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 designated uses applicable to these waterbodies (e.g. protection and propagation of fish and wildlife, scenic value, human health-fish consumption, 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. To address these impairments in lieu of the development of a TMDL, 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 served on this committee. In July 2000, the GCDAG received $195,443.51 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 $134,062.61 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 designated uses applicable to each waterbody and define temporal (seasonal) and spatial (among sample stations) changes in water quality to identify impaired segments. Completion of the GCWA would be the technical basis for the watershed planning and mitigation efforts.

During August 2002, SCCD submitted a request for Clean Water Act Section 319 funding to WDEQ to initiate Goose Creek watershed planning and implementation. SCCD received funding in 2003 to administer and guide a public Goose Creek watershed planning process, develop a watershed plan, implement remediation projects, develop a progress register, and conduct interim and follow-up water quality monitoring.

Watershed planning was initiated during a November 2003 public meeting and soon after the Goose Creek Watershed Planning Committee (GCWPC) was formed to guide the process. The GCWPC consisted of about 20 landowners, watershed residents, SCCD, Natural Resources Conservation Service (NRCS), WDEQ, Sheridan County officials, City of Sheridan officials, and the Sheridan County Planning Commission. This planning process included monthly planning meetings to identify watershed concerns and to plan and prioritize efforts to improve water quality. By December 2004, the GCWPC had finalized the Goose Creek Watershed Management Plan (SCCD, 2004). SCCD received notification that WDEQ had formally approved the plan in April 2005, and to finalize the initial planning document, it was filed with the Sheridan County Clerk on May 17th, 2005.

Currently, the GCWPC is meeting on a quarterly basis to implement the items detailed in the watershed plan. Watershed improvement projects continue to be implemented, with much more activity planned for the near future.

1.2 Previous Assessments

During April 2001, SCCD, under the direction of the GCDAG, initiated the monitoring program, which included collecting pH, water temperature, conductivity, dissolved oxygen, total residual chlorine, fecal coliform, turbidity, alkalinity, biochemical oxygen demand, chloride, total hardness, sulfate, ammonia, nitrate nitrogen, total 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, and 18 on Little Goose Creek. In addition, each of the eight tributaries was monitored at a single, lower station located near its mouth. Fecal coliform and turbidity samples were collected five times during the months of 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 in October.

Year 2002 monitoring was similar to the previous year's monitoring with a few exceptions. BOD samples were not taken during 2002 because of their high cost and that 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. In addition, 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.

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 (SCCD, 2003~~e~~). 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 on Goose Creek 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 in 1983 and 1984.

Goose Creek sites throughout Sheridan exceeded the fecal coliform standard on at least one occasion. The lowermost site did not have a geometric mean that exceeded 200 CFU/100 mL during the assessment. The lower Big Goose Creek sites to approximately 4 miles west of Sheridan each exceeded the fecal coliform standard during the assessment while the upper sites had geometric means less than 200 CFU/100 mL. The lower Little Goose Creek sites to the County Road 60 bridge also exceeded the fecal coliform standard. The upper Little Goose Creek sites never violated the standard during this assessment. Soldier Creek, Park Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, Sackett Creek, and the Coffeen Avenue storm drain also exceeded the fecal coliform standard during the 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 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 following stream substrate raking suggested that higher bacteria populations are present within bed sediment, which may be re-suspended during higher flows.

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 from Goose Creek, lower Big Goose Creek, and Little Goose Creek showed routine daily exceedences of the maximum instream temperature standard from May until September. Continuous water temperature data and 2001 – 2002 instantaneous water 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.

Evaluation of 2001, 2002, and historic macroinvertebrate data suggested that Goose Creek was not meeting its designated use for aquatic life from the Plachek Pit upstream to the confluence of Big and Little Goose Creeks. Lower Big Goose Creek and lower Little Goose Creek were also determined not to meet their aquatic life designated uses.

1.3 Project Implementation

To date, ten Animal Feeding Operation (AFO) improvement projects have been completed or are in progress within the watershed. Six voluntary septic system improvement projects have been completed, and three more are planned or under contract. A 27-acre riparian buffer project has also been implemented on Jackson Creek. During the summer of 2004, the City of Sheridan implemented a storm drain stenciling program to warn local residents about dumping materials into City storm drains. These projects are shown on the Progress Register Map (see Appendix Map A-2).

Public information and education efforts for the Goose Creek watershed have been on-going; however, with the recently developed Watershed Management Plan, these efforts will become a higher priority in order to carry out plan directives. To date, articles in the Sheridan Press have described the local water quality impairments, the watershed assessment, and the public planning process. SCCD assisted the Department of Health and WDEQ in posting signs along the creeks to warn residents of the potential pathogens in highly used areas. A public meeting was held at Sheridan College to describe the assessment findings, watershed planning options, and implementation possibilities during November 2003. In addition, public workshops to discuss AFO's with local landowners have been held in January 2001, February 2002, and April 2003. A septic system and pathogen workshop was hosted by SCCD and the Soil and Water Conservation Society during January 2005. A second septic system workshop was hosted by SCCD during February 2006. A contest for developing a logo to represent the watershed project was initiated in January 2005 with an after school arts program for 6th graders. Additional project awareness has been achieved through SCCD newsletters, local radio interviews, and state and local public presentations.

2. DESCRIPTION OF THE PROJECT AREA

The majority of surface waters forming Goose Creek originate in the Bighorn 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 Bighorn Mountains and join in downtown Sheridan, Wyoming. Goose Creek then meanders north before entering the Tongue River near Acme, Wyoming. Several smaller tributaries were also monitored during this project and include Soldier Creek, Beaver Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek.

The Goose Creek watershed has an approximate drainage area of 415 square miles and is identified by hydrologic unit code (HUC) 10090100-010. Appendix Map A-1 provides a view of the watershed identifying local communities, highways, and landmarks. Lands owned and operated by private landowners, the State of Wyoming, the Bureau of Land Management (BLM), and the United States Forest Service (USFS) are found within the project area.

After leaving the Bighorn Mountains, the predominant geology along the Goose Creek, Big Goose Creek, and Little Goose Creek channels is alluvium and colluvium comprised of clay, silt, sand, and gravel (USGS, 1985). Soils along these lower areas of Goose Creek, Big Goose Creek, and Little Goose Creek as described by the 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.

Land uses are many and varied within the watershed. Above the BHNF boundary, land uses include, but are not limited to, wildlife habitat, recreation, seasonal cattle grazing, and timber. Below the forest boundary, land uses on private lands are primarily agricultural although housing growth in the area has resulted in an increasing number of semi-rural subdivisions. Agricultural uses are primarily grazing on the upper range lands areas with the lower, flatter areas along the creeks generally being used for irrigated haylands and for winter cattle grazing and feeding. The density of rural housing generally increases from the mountain foothills downstream to Sheridan. North of Sheridan, agriculture again becomes the dominant land use. During recent years, this northern area of the watershed has also been used for the development of coal-bed methane production.

Since the area was settled in the late 1800’s, a significant amount of change has been imposed on the stream channel systems within the project area. Miles of irrigation ditches and trans-basin diversions have been created. Several reservoirs have been built on the BHNF for domestic and irrigation uses. Throughout Sheridan, much of Goose Creek, Big Goose Creek, and Little Goose Creek have been placed into straightened channels for flood control. Goose Creek, near the Tongue River confluence, has been extensively channelized as part of coal mine reclamation.

3. STREAM CLASSIFICATIONS AND LISTINGS

3.1 STREAM CLASSIFICATIONS AND BENEFICIAL USES

During June 2001, WDEQ revised the Wyoming Surface Water Classification List to include more specific subdivisions for designating beneficial uses on surface waters (WDEQ, 2001). 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.

3.2 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. 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 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.

4. HISTORIC AND CURRENT DATA

Historic data for the purposes of this project are defined as data greater than five years old from the start of this project. Historic data for the project area have been previously summarized in the Goose Creek Watershed Assessment 2001-2002 Final Report (SCCD, 2003). The Final Report is a comprehensive compilation of known water quality data for the watershed and contains historic and current data through 2002. These data were collected by SCCD, government agencies, and various other sources and are provided in tabular form in the Appendices to the Final Report.

A summary of current water quality data collected by the USGS, and not provided in the 2001-2002 Final Report, is provided in Appendix B. Data for USGS Station Numbers 06305700 (Goose Creek Near Acme), 06305500 (Goose Creek Below Sheridan), and 06304500 (Little Goose Creek at Sheridan) are included as Appendix Tables B-23 through B-25. For these stations, only data similar in scope to the parameters collected by SCCD during 2005 for this project are shown. Please note that the USGS did collect water quality samples for additional parameters, but they are not included in this report.

5. MONITORING DESIGN

5.1 MONITORING PARAMETERS

This 2005 monitoring project was designed specifically to determine if changes had occurred in fecal coliform bacteria concentrations since the implementation of local improvement projects. *Escherichia coli* (*E. coli*) was added to the parameter list with the expectation of WDEQ changing the Wyoming pathogen indicator standard from fecal coliform to *E. coli*. By monitoring *E. coli* and fecal coliform concurrently, future correlations between these indicators can be determined which will be useful when comparing historic fecal coliform levels to current and future *E. coli* levels.

Water quality monitoring during 2005 included the following parameters: water temperature, pH, conductivity, dissolved oxygen, discharge, turbidity, fecal coliform, and *E. coli*. Continuous water temperature data loggers were used to monitor temperature at seven stations on Goose Creek, Big Goose Creek, and Little Goose Creek during 2003. BURP monitoring, to include macroinvertebrate sampling and habitat assessments, was also performed at all six stations.

5.2 SITE DESCRIPTIONS

The 18 monitoring stations utilized during 2005 were located at the same locations as during the previous 2001-2002 assessment. However, the number of stations was limited from 46 as used in the previous assessment to 18 during 2005 to conduct follow-up water quality monitoring. Two stations were located on Goose Creek, four were located on Big Goose Creek, five were located on Little Goose Creek, and one site was located near the mouth of each of seven tributaries: Soldier Creek, Beaver Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek and Sackett Creek. Detailed site and watershed descriptions were provided in the Final Report and in the 2005 Sampling and Analysis Plan (SCCD, 2005). Tables 5-1 and 5-2 provide these site descriptions for the 2005 monitoring program.

Table 5-1. 2005 Monitoring Site Descriptions

Site	Type(s) of Monitoring Performed	Water Quality Sample Site Description	Benthic Macroinvertebrate Sample Site Description
GC1	Continuous Temperature, Water Quality, and BURP	Located on Goose Creek approximately 75 yards downstream of HWY 339 bridge crossing at USGS Station No. 06305700 (approximately 2 miles south of Acme).	Base of riffle located on Goose Creek approximately 300 yards upstream from the HWY 339 bridge crossing.
GC2	Water Quality, and BURP	Located on Goose Creek approximately 200 yards downstream of Sheridan WWTP.	Riffle is located about 200 yards downstream from Sheridan WWTP discharge.
GC4	Water Quality	Located on Soldier Creek approximately 10 yards downstream from Dana Avenue bridge.	
BG2	Continuous Temperature, Water Quality, and BURP	Located on Big Goose Creek approximately 100 yards downstream from the footbridge at the intersection of Works and Elk Street.	Located on Big Goose Creek at first riffle upstream from the footbridge at Works and Elk Street.

Site	Type(s) of Monitoring Performed	Water Quality Sample Site Description	Benthic Macroinvertebrate Sample Site Description
BG6	Continuous Temperature, Water Quality	Located on Big Goose Creek at the west end of the Paulson Youth Camp.	
BG9	Water Quality	Located on Beaver Creek 25 yards upstream from the Big Goose Creek confluence.	
BG10	Water Quality, and BURP	Located on Big Goose Creek approximately 40 yards upstream from the County Road 87 bridge crossing.	Located at riffle near first bend upstream from County Road 87 bridge crossing.
BG16	Water Quality	Located on Rapid Creek approximately 150 yards upstream from the Big Goose Creek confluence.	
BG18	Continuous Temperature, Water Quality	Located near the mouth of Big Goose Canyon at USGS Station No. 06302000. The Alliance Ditch intake is about 50 yards downstream.	
LG2	Continuous Temperature, Water Quality, and BURP	Located on Little Goose Creek approximately 30 yards upstream from the concrete flood channel in downtown Sheridan.	LG2A - Riffle is located near first bend downstream (100-150 yards) from Coffeen Avenue bridge crossing.
LG5	Water Quality	Located on Little Goose Creek approximately 100 yards upstream from the Brundage Lane bridge crossing.	
LG8	Continuous Temperature, Water Quality	Located on Little Goose Creek approximately ¼ mile downstream from McCormick Creek near the Cox Valley Road.	
LG9	Water Quality	Located on McCormick Creek approximately 20 yards upstream from the Little Goose Creek confluence.	
LG10	BURP		Located at first riffle below the Kruse Creek confluence.
LG11	Water Quality	Located on Kruse Creek about 100 yards upstream from the Little Goose Creek confluence.	
LG13	Water Quality	Located on Little Goose Creek approximately 20 yards upstream from the County Road 60 bridge crossing at Knode Ranch subdivision.	
LG17	Water Quality	Located on Jackson Creek near the Little Goose Creek confluence.	
LG19	Water Quality	Located on Sackett Creek 10 yards upstream from the Little Goose Creek confluence.	
LG22	Continuous Temperature, Water Quality	Located on Little Goose Creek above the County Road 77 bridge crossing. Same location as USGS Station No. 06303700.	

Additional site description information and land use information are provided in Table 5-2. Latitude and longitude for each site were recorded by Global Positioning System (GPS).

Table 5-2. Additional Site Information and Land Use

Site	Latitude / Longitude	Elevation (feet)	Land Use(s)
GC1	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.
GC2	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.
GC4	44°49.198' / 106°57.719'	3,705	Downer Addition is the main land use in lower watershed.
BG2	44°47.751' / 106°58.164'	3,745	Predominantly urban / residential.
BG6	44°46.384’ / 107°02.755'	3,890	Recreational (youth camp), cattle grazing, and haylands.
BG9	44°45.579' / 44°45.579'	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.
BG10	44°45.778' / 107°04.501	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.
BG16	44°43.752' / 107°08.667'	4,160	Cattle grazing, irrigated haylands, and wildlife habitat.
BG18	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.
LG2	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.
LG5	44°46.391' / 106°57.029'	3,775	Located just upstream from Sheridan, uses are mainly wildlife habitat, irrigated haylands, and rural residential.
LG8	44°43.185' / 106°57.068'	3,895	Small acreage properties with livestock grazing, wildlife habitat, and irrigated haylands.
LG9	44°43.110' / 106°57.229	3,905	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.
LG10	44°42.749' / 106°57.229	3,915	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.
LG11	44°42.615' / 106°57.444'	3,915	Small acreage properties with cattle grazing and irrigated haylands.
LG13	44°42.149' / 106°58.104'	3,940	Large subdivisions with small acreage lots, wildlife habitat, and haylands.
LG17	44°41.357' / 106°59.121	4,020	Small acreage properties with cattle grazing and irrigated haylands.
LG19	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.
LG22	44°37.239' / 107°02.290'	4,533	Ranch buildings, cattle grazing, and wildlife habitat. The BHNF boundary is approximately 3 miles upstream.

5.3 MONITORING SCHEDULE

The 2005 monitoring schedule was designed to include the geometric mean of 5 monthly bacteria samples in May and August which correspond to seasonal high and low flows. These months were also directly comparable to sampling periods used during the 2001-2002 assessment which were April, May, August, and October. May and August also had the highest rate of exceeding the pathogen indicator standard. Therefore, May and August were selected and 5 sampling events were conducted during each month in 2005. Continuous temperature data loggers were used to measure instream temperatures from April 1, 2005 through November 8, 2005. BURP monitoring was performed at all six stations during September 2005. The 2005 monitoring schedule followed the SAP schedule with few exceptions.

5.4 SAMPLING AND ANALYSIS METHODS

Water quality samples, discharge measurements, and BURP monitoring were collected by the methods described in the SAP. Instrument calibration, equipment maintenance, and documentation were performed following the SAP requirements. Water quality and macroinvertebrate samples were obtained from representative sample riffles.

Continuous temperature data were collected by anchoring the data loggers near the bottom of pools to simulate the water temperatures of trout habitat. Except for site GC1, discharge measurements at all sites were collected with the use of calibrated staff gauges. USGS Station No. 06305700 is located about 200 yards downstream from site GC1; mean daily discharge data from this station were used for GC1 discharge data. The remaining staff gauge calibrations were performed by measuring instantaneous discharge with a Marsh-McBirney 2000 current meter. Turbidity, fecal coliform and E. coli samples were hand delivered to Inter-Mountain Laboratories (IML) in Sheridan, Wyoming for analysis. Macroinvertebrate samples were analyzed by Aquatic Biology Associates, Inc. (ABA) in Corvallis, Oregon. Analytical methods utilized are provided in Table 5-3.

Table 5-3. Standard Field and Laboratory Methods

Parameter	Units	Method / Reference[1]	Location of Analyses	Preservative	Holding Time
Temperature	°C	grab/EPA 1983 170.1	On-site	n/a	n/a
Temperature	°C	continuous recorder	On-site	n/a	n/a
pH	SU	grab/EPA 1983 150.1	On-site	n/a	n/a
Conductivity	µmhos/cm	grab/EPA 1983 120.1	On-site	n/a	n/a
Dissolved Oxygen	mg/l	grab/EPA 1983 360.1	On-site	n/a	n/a
Turbidity	NTU	grab/EPA 1983 180.1	IML[2]	Ice; at or below 4BC	48 hours
Fecal Coliform	col/100 ml	grab/SM 9221E[4]	IML[2]	Ice; at or below 4BC	6 hours
E. coli	col/100 ml	grab/SM 9222G[4]	IML[2]	Ice; at or below 4BC	6 hours
Flow	cfs	Calibrated staff gauge	On-site	n/a	n/a
Flow	cfs	Mid-Section Method	On-site	n/a	n/a
Macroinvertebrates	Metrics	King 1993	ABA[3]	formalin	n/a
Habitat (Reach level)	n/a	King 1993	On-site	n/a	n/a

[1]Method references for laboratory analyses were provided by the contract laboratories and defined in their SOPs.
[2]IML refers to Inter-Mountain Laboratories in Sheridan, Wyoming.
[3]ABA refers to Aquatic Biology Associates, Inc. in Corvallis, Oregon.
[4]SM refers to Eaton et. al., 1995. Standard Methods for the examination of water and wastewater. Washington, D.C.

6. QUALITY ASSURANCE / QUALITY CONTROL

6.1 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). 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 Quality Assurance Project Plan (QAPP) is the SCCD document used to guide QA/QC procedures for water quality assessments and was used to develop QA/QC practices that were implemented throughout this project (SCCD, 2003a). 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. 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.

6.2 TRAINING

Personnel involved in the 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 Program Specialist 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 when conducting the macroinvertebrate sampling and habitat assessments. These personnel were trained by the Program Specialist prior to sampling and were under direct supervision by the Program Specialist during sampling.

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

6.3.1 COLLECTION, PRESERVATION, AND ANALYSIS

Accepted referenced methods for the collection, preservation, and analysis of samples were described in Section 5.4 and listed in Table 5-3 of this report.

6.3.2 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 Chain of Custody (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 with an isopropyl alcohol and formaldehyde mixture, placed in a cooler, and transported to the SCCD office in Sheridan. A project specific macroinvertebrate COC form was completed. After all macroinvertebrate samples were collected, samples and COC forms were shipped by United Parcel Service to ABA. ABA then 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.

6.4 CALIBRATION AND PROPER OPERATION OF FIELD EQUIPMENT

The project SAP outlined requirements for calibration and maintenance of field equipment. 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 and pH 10 buffer solutions. The Hanna 8733 conductivity meter was calibrated using a 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 for the proper elevation with the probe placed in the moist calibration chamber before each sampling event. Calibration of each meter was documented on the appropriate calibration log.

Equipment maintenance, to include battery replacement and monthly replacement of the DO meter membrane cap, were performed according to requirements set forth in the project SAP and manufacturer's instructions. All maintenance activities were documented on the maintenance log.

The Marsh-McBirney flow meter was factory calibrated and did not require field calibration. Onset Tidbit data loggers, used for continuous temperature monitoring, were factory calibrated and designed to be completely encapsulated. These loggers were considered disposable; when the enclosed battery is depleted, it cannot be replaced. Factory calibration of the loggers was checked by utilizing the manufacturers "crushed-ice test" to ensure the loggers were performing accurately. Results of the crushed-ice tests are described in Section 6.5.9.

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

6.5 SUMMARY OF QA/QC RESULTS

This section provides a QA/QC summary of the requirements set forth in the Project SAP. Data Quality Objectives (DQO's) are qualitative and quantitative specifications used by water quality monitoring programs 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.

6.5.1 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. 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. All parameters met precision DQO's for the project and are provided in Table 6-1.

Table 6-1. Precision of 2005 Monitoring Data

Parameter	Precision (% - RPD)	DQO (%)
Water Temperature	0.6	10
pH	0.3	5
Conductivity	1.0	10
Dissolved Oxygen	0.5	20
Turbidity	7.8	10
Fecal Coliform	27.9	50
E. coli	32.0	50
Total Abundance	4.1	50
Total Taxa	0.0	15
Intra-Crew Habitat Assessments	2.5	15

6.5.2 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. There are no current laboratory methods to determine the accuracy of biological samples. Therefore, the accuracy of fecal coliform and *E. coli* samples could not be determined.

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.

6.5.3 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 results for the project are provided in Table 6-2; all parameters except discharge data met the completeness DQO's set forth in the SAP for this project. This was due to the extraordinarily high spring flows during May which prevented stage readings and therefore prevented discharge estimates for the following reasons:

- stream stages were sufficient to submerge many staff gauges for an extensive period of time;
- flood flows and floating debris destroyed or removed staff gauges; and
- staff gauges which did allow recording of flood stages could not be used to estimate discharge because these flood stages were well outside of the calibrated range of the gauge.

Table 6-2. Completeness of 2005 Monitoring Data

Parameter	Completeness (%)	DQO (%)
Water Temperature	100	95
pH	100	95
Conductivity	100	95
Dissolved Oxygen	100	95
Discharge	77.2	95
Turbidity	100	95
Fecal Coliform	100	95
E. coli	100	95
Macroinvertebrates	100	95
Habitat Assessments	100	95
Stage-Discharge Relationships	100	95

6.5.4 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 within the 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.

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.

6.5.5 TRIP BLANKS

Trip blanks were prepared to determine whether samples might be contaminated by the sample container, preservative, or during transport and storage conditions. Fecal coliform, *E. coli*, and turbidity trip blanks were utilized during every sampling event. These trip blanks were prepared by the analytical laboratory, Inter-Mountain Laboratories (IML), immediately prior to sampling. IML prepared trip blanks by filling preserved bottles with laboratory de-ionized water. No trip blanks used during the project contained detectable levels of fecal coliform or *E. coli*. However, trip blanks on May 31, 2005 and August 24, 2005 were analyzed as having 0.1 and 0.4 NTU turbidity, respectively. These results were discussed with IML personnel and were thought to potentially be the result of having contaminated bottles prior to trip blank preparation. However, the low detection levels do not indicate the data is not of significant value.

6.5.6 DUPLICATES

The project SAP required that duplicate chemical, physical, biological, and habitat samples be obtained for at least 10% of all field samples. Duplicate water quality samples were obtained by collecting consecutive water quality and duplicate samples from a representative stream riffle. Duplicate macroinvertebrate samples were collected by two field samplers, each equipped with a Surber net, collecting samples simultaneously adjacent to one another. Duplicate habitat assessments were performed by two field samplers performing independent assessments without communication at the same site and same time. Table 6-3 provides a summary of duplicates taken during the project.

Table 6-3. Summary of 2005 Duplicates

Parameter	No. of Samples	No. of Duplicates	% Duplicated	DQO (%)
Water Quality Samples	180	18	10.0	10
Macroinvertebrate Samples	6	1	16.7	10
Habitat Assessments	6	1	16.7	10

6.5.7 STAGE-DISCHARGE RELATIONSHIPS

Stage-discharge relationships were required to be established for at least 95% of the monitoring sites by the project SAP. The SAP also recommended that these relationships be established such that when regressions of stage height and discharge are performed, the correlation coefficient (R^2 value) be 0.95 or greater. Table 6-4 provides a summary of the stage-discharge relationships for monitoring stations during 2005.

Table 6-4. Summary of R^2 Values for 2005 Stage-Discharge Relationships

Station	Actual R^2 Value	DQO Minimum R^2 Value
GC1	* NA	0.95
GC2	0.9860	0.95
GC4	0.9998	0.95
BG2	0.9995	0.95
BG6	0.9957	0.95
BG9	0.9934	0.95
BG10	0.9955	0.95
BG16	0.9807	0.95
BG18	1.0000	0.95
LG2	0.9838	0.95
LG5	0.9925	0.95
LG8	0.9967	0.95
LG9	0.9976	0.95
LG11	0.9661	0.95
LG13	0.9997	0.95
LG17	0.9998	0.95
LG19	0.9740	0.95
LG22	0.9926	0.95

* GC1 site staff gauge was not calibrated by SCCD, USGS mean daily discharge data for Station No. 06305700 were used.

6.5.8 SAMPLE HOLDING TIMES

All IML prepared laboratory data sheets were reviewed to ensure that turbidity, fecal coliform, and *E. coli* samples were analyzed within their required holding times. This review found that all of these samples were indeed analyzed before their holding times had expired. All water quality field samples were analyzed on-site immediately following sample collection. Benthic macroinvertebrate samples were preserved immediately following sample collection; there is no holding time for benthic macroinvertebrate samples.

6.5.9 CONTINUOUS TEMPERATURE DATA LOGGERS

The continuous temperature data loggers used at stations GC1, BG2, BG6, BG18, LG2, LG8, and LG22 during the 2005 monitoring project were Onset Tidbit Model #TBI32-05+37 temperature loggers. These loggers are factory calibrated, encapsulated devices that cannot be re-calibrated. Onset suggests these loggers should maintain their accuracy unless they have been utilized outside their range of intended use (-20°C to 50°C). These data loggers have not been used outside of this range and therefore, should still be recording accurate water temperatures.

To test a data logger’s accuracy, Onset recommends performing a crushed ice test. The manufacturer’s instructions for this test were adhered to and were followed accordingly.

A seven pound bag of crushed ice was emptied into a 2.5 gallon bucket. Distilled water was then added to just below the level of the ice. The mixture was then stirred and the seven data loggers were submerged in the ice bath. Immediately afterwards, the bucket was then placed in a refrigerator to minimize temperature gradients. According to Onset, if the ice bath was prepared properly and if the loggers have maintained their accuracy, the loggers should read the temperature of the ice bath as 0°C ±0.23°C.

On November 18, 2005, the crushed ice test was performed on the data loggers used at stations GC1, BG2, BG6, BG18, LG2, LG8, and LG22. A data table of the test results is provided below in Table 6-5. These results show the data logger's environmental response as they were transferred to the crushed ice bath mixture. Each data logger cooled to near 0°C; however, the loggers used at GC1 and LG22 stabilized at -0.42°C and at -0.24°C, respectively. These values are slightly outside the range of 0°C ±0.23°C that Onset predicted. This could be due to temperature variations in the ice bath and/or refrigerator or the loggers may be slightly out of calibration. Nonetheless, SCCD feels these data loggers have provided valuable and sufficiently accurate continuous temperature data that should be included in this project.

Table 6-5. Summary of November 18, 2005 Crushed Ice Test

Serial #	415509	415508	415507	415505	415506	415513	415512
Time	BG6	GC1	BG2	LG8	LG2	BG18	LG22
11:00:00	3.51	2.78	2.98	2.98	3.51	3.34	3.25
11:02:30	1.13	0.71	0.77	0.77	0.96	0.97	0.87
11:05:00	0.33	0.06	0.12	0.12	0.16	0.17	0.23
11:07:30	0.01	-0.26	-0.03	-0.03	0	0.01	-0.08
11:10:00	0.01	-0.26	-0.03	-0.03	-0.16	-0.14	-0.08
11:12:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:15:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:17:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:20:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:22:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:25:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:27:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:30:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:32:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:35:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:37:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:40:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:42:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:45:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:47:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:50:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:52:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:55:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
11:57:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
12:00:00	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24
12:02:30	-0.15	-0.42	-0.19	-0.19	-0.16	-0.14	-0.24

6.6 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 report. A total of 41 discharge measurements were rejected from use in this report for the reasons stated in Section 6.5.3.

6.7 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 on file in the SCCD office. Photographs and photograph descriptions are organized by station and maintained on file in the SCCD office.

Water quality and supporting QA/QC data were received in hard copy format from IML. Hard copies of these data are maintained on file in the SCCD office. 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 in Sheridan, Wyoming.

6.8 DATABASE AND DATA REDUCTION

6.8.1 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 constructed. All computer data entries were checked for possible mistakes made during data entry. If a mistake was suspected, the original field or laboratory data sheet was re-examined and the data entry corrected.

6.8.2 DATA REDUCTION

After data validation and database construction, data were statistically summarized for the following calculations which are provided in Appendix B:

- Number of samples;
- Maximum;
- Minimum;

- Median;
- Mean;
- Geometric mean;
- 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.

6.9 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.

6.10 DATA REPORTING

Data collected by SCCD for this project are presented in tabular, narrative, and graphical formats throughout this report. This report will be submitted to WDEQ, EPA, and other interested parties as necessary. Copies of this report will be available through the SCCD office and compact disks containing the Microsoft Excel®, Microsoft Word®, and Arc Map 8.3® files used to construct this document will also be available.

7. DISCUSSION OF RESULTS

Water quality data collected during the 2005 monitoring project have been summarized in Appendix Tables B-2 through B-19. Appendix Table B-1 explains the codes, units, and abbreviations used in the Appendix B data tables. Appendix Table B-20 provides statistical summaries for each monitoring parameter at all sites.

7.1 2005 WATER QUALITY DATA AND CURRENT USGS DATA

Water quality data were collected from April through October at all 18 sites. Results of this monitoring were generally similar to the data collected during the 2001-2002 assessment. All specific conductivity, pH, dissolved oxygen, and turbidity results were within Wyoming Water Quality Standards during the project. Turbidity values were considered normal for the watershed with occasional high values occurring during late-spring, early-summer precipitation and snow melt run-off events.

Instantaneous temperature measurements were recorded above the maximum 20°C instream temperature standard at GC1, LG8, LG11, and LG13. However, these exceedences were infrequent and occurred only once per site at each of the four stations. Instantaneous temperature measurements collected during 2005 did not necessarily represent daily minimum, maximum, or average water temperatures. In addition, sampling was usually conducted at GC sites during early morning, at BG sites during mid- to late morning, and LG sites during late morning to early afternoon. As a result, sites on Little Goose Creek (and its tributaries) were generally sampled when water and air temperatures were relatively warmer.

Current data collected by the USGS at Stations 06305700 (Goose Creek near Acme), 06305500 (Goose Creek below Sheridan), and 06304500 (Little Goose Creek at Sheridan) have been summarized in Appendix Table B-23 through B-25; these data represent samples collected after preparation of the 2001-2002 Goose Creek Watershed Assessment Final Report. Not all sample parameters measured by the USGS have been included in this table—only those similar to the 2005 SCCD monitoring program.

7.2 FECAL COLIFORM AND *E. COLI*

During 2005, five fecal coliform and *E. coli* samples were obtained from each of the 18 monitoring stations during each of the months of May and August. The individual sampling results are provided in Appendix Tables B-2 through B-19. The geometric means of these monthly bacteria data are provided in Appendix Tables B-21 and B-22 which also provide results from the 2001-2002 assessment for comparison. At the time of completing this monitoring report, fecal coliform bacteria remained the indicator for pathogens for comparison to Wyoming Water Quality Standards. However, it is likely that *E. coli* may become the indicator for pathogens in the future.

As shown in Appendix Table B-21, the number of comparable sites exceeding the fecal coliform standard was higher in 2005 than during 2001 and 2002 for both May and

August. The number of comparable sites exceeding WDEQ's proposed standards for an *E.coli* indicator also increased during August 2005 (Appendix Table B-22). The increased bacterial concentrations during May 2005 are likely attributable to an above average spring run-off condition which was largely the result of 5.5 inches of precipitation falling within a six day period from May 8-13, 2005 (as recorded by the National Weather Service at the Sheridan County Airport). The National Weather Service (NWS) also reported 6.87 inches for Big Horn, WY and 7.72 inches for Story, WY during this same period. This precipitation event resulted in local streamflows at or above the bankfull stage for an extended period. Appendix Figure B-9 shows the mean daily discharge data recorded for this event by the USGS at Station No. 06305700 – Goose Creek near Acme, WY.

This was a significant precipitation event and is thought to have increased bacteria concentrations in two ways. The first being bacterial inputs from cattle, wildlife, possibly human, and other sources were transported from upland areas and deposited into the streams via overland run-off. An event of this scale places many surface contaminants, not only bacteria, into the local waterways and thereby increases their concentrations regardless of the increased streamflow. Bacteria concentrations are also thought to increase by a second method during increased streamflows. Deeper, faster moving water within the stream channels themselves tend to scour and suspend sediment that has been previously deposited on the channel bottom. These bed sediments have been found to contain elevated levels of bacteria. SCCD has observed up to a three fold increase in bacteria concentrations when the bed sediments are disturbed and suspended (SCCD, 2003). In addition, rangeland studies in Idaho have shown that *E. coli* concentrations can be 2 to 760 times greater in bottom sediment than in the water column (Stephenson and Rychert, 1982).

When analyzing the May bacteria data, the effect of this precipitation event is readily apparent. Bacteria levels were generally low before the event (May 4), increased sharply during the event (May 9), and then concentrations generally decreased for the remainder of the month (May 17, 26, and 31) as streamflows began to subside and stream channels were cleansed of sediment. The geometric means for the month of May could have been even higher if a May 12 sampled event was not rescheduled (to May 31) due to flooding. Flows in many local streams peaked during the afternoon of May 11.

The reasons for the increased bacteria concentrations during the month of August 2005 are not as readily apparent. The August 2005 levels were higher than those found during 2001 and 2002 when steamflows were much lower; however, the 2005 concentrations are similar to data collected by WDEQ during 1998 and 1999 when streamflows were at or above normal flows. Regardless of the possible hydrologic effects on bacteria concentrations, the data show that, in general, the same general stream reaches were found to be impaired during 2005 as those found during previous monitoring efforts.

7.3 CONTINUOUS WATER TEMPERATURE DATA

Monitoring stations at sites GC1, BG2, BG6, BG18, LG2, LG8, and LG22 were used to continuously monitor water temperature from April 1, 2005 through November 8, 2005. Temperature was also monitored at these same sites on a continuous basis during 2001 and 2002. Data loggers were positioned in relatively deep river waters and programmed to measure water temperature at 15 minute intervals. Continuous water temperature data observed by these data loggers are provided in Appendix Figures B-1 through B-7. Daily and seasonal temperature variations are shown within these figures.

The data logger initially deployed at site LG2 was lost during the high spring streamflows and a second logger was deployed at this site on June 10, 2005 (see Appendix Figure B-5). As streamflows receded after spring run-off, the data loggers at sites BG6 and LG8 were beached on the adjacent streambanks. All data suspected of being directly influenced by air temperature rather than water temperatures during these periods were deleted (see Appendix Figures B-3 and B-6).

In general, water temperatures were cooler in 2005 than during 2001 and 2002. Table 7-1 provides general water temperature statistics for the three years of monitoring. The number of days in which the maximum instream water temperatures exceeded 20°C was fewer at all sites during 2005. The maximum daily water temperatures recorded for each season was also generally lower in 2005.

Table 7-1. Continuous Water Temperature Data Summaries for 2001, 2002 and 2005

Site	Number of days when water temperatures exceeded 20°C			Maximum daily temperature recorded (°C)		
	2001	2002	2005	2001	2002	2005
GC1	103	93	59	30.17	30.36	27.96
BG2	92	76	47	29.88	29.14	26.86
BG6	100	90	46*	30.52	31.67	28.73
BG18	0	0	0	19.74	18.93	19.11
LG2	110	88	55*	29.93	29.21	29.88
LG8	90	63	25*	27.29	27.65	25.44
LG22	2	0	0	20.62	18.51	18.88

*Site had period during 2005 when data were not collected (logger lost or beached on streambank).

The lower stream temperatures during 2005 are likely due in large part to the increased streamflows observed during 2005. Table 7-2 demonstrates this point, lower temperatures are generally associated with higher streamflows and vice versa. As shown in Table 7-2, the 2005 monitoring season began with low streamflows and relatively higher stream temperatures. This trend changed significantly with the heavy precipitation event during mid-May previously described in Section 7.2. April 2005 had the lowest monthly average streamflow of the three years, but the remainder of 2005 held the highest monthly averages due to a very wet spring. Appendix B-8 shows means daily water temperatures at site GC1 during 2001, 2002, and 2005. In addition, Appendix Figure B-9 provides a graphical comparison of mean daily discharge data for 2001, 2002, 2005, and average daily flows for USGS Station No. 06305700.

Table 7-2. Summary of Mean Monthly Continuous Water Temperature Data and Discharge Data at site GC1 (discharge data from USGS Station 06305700)

Month	Mean Monthly Temperature (°C)			Mean Monthly Discharge (cfs)		
	2001	2002	2005	2001	2002	2005
April	9.5	8.1	9.9	89.9	71.7	40.9
May	16.1	13.5	9.6	52.4	70.6	650.5
June	19.8	18.5	13.8	39.2	125.4	668.9
July	24.8	24.2	21.5	9.5	15.8	142.3
August	23.0	19.5	19.6	38.6	22.4	61.7
September	17.0	16.0	15.5	28.0	39.1	60.2
October	8.8	7.0	8.9	41.6	44.1	92.4

7.4 HYDROLOGICAL AND METEOROLOGICAL DATA

As shown by the data in Table 7-3, average monthly air temperatures during 2005 were generally closer to the 30 year average as compared with years 2001 and 2002. May, June, July, and September had cooler air temperatures in 2005 than either 2001 or 2002. This trend resulted in similar results for water temperatures; May, June, July, and September also had cooler water temperatures at site GC1 during 2005. A comparison of mean daily air temperatures at the Sheridan County Airport is provided in Appendix Figure B-10.

Table 7-3. Summary of Mean Monthly Air Temperatures (°F) for the Sheridan County Airport (data from the National Weather Service)

Month	2001	2002	2005	Normal
April	45.6	40.7	42.2	43.9
May	55.3	50.3	49.2	52.5
June	62.9	64.3	61.8	61.6
July	74.0	75.1	71.7	68.8
August	73.1	65.3	66.6	68.2
September	61.2	58.4	58.0	57.1
October	45.1	38.3	46.0	45.1
Season Average	59.6	56.0	56.5	56.7

Appendix Figure B-11 shows cumulative precipitation data collected by the National Weather Service at the Sheridan County Airport. Precipitation for the April 1, 2005 through October 31, 2005 monitoring period was 16.27 inches. Normal precipitation for this same period averages 10.85 inches. This above normal precipitation resulted in an above average streamflow for April through October at USGS Station 06305700 – Goose Creek near Acme. Average discharge for this period is 209.2 cfs whereas 2005 discharge for this same period was 243.2 cfs.

7.5 BENTHIC MACROINVERTEBRATES

7.5.1 SAMPLING IN 2004 AND 2005

The historic and current benthic macroinvertebrate data collected in the Goose Creek watershed through 2002 were presented and discussed in the *Goose Creek Watershed Assessment 2001-2002*, *Final Report* (SCCD, 2003). This report presents the results of benthic macroinvertebrate sampling conducted by WDEQ in 2004 and SCCD in 2005 in the Goose Creek watershed. No benthic macroinvertebrate samples were collected in the Goose Creek watershed during 2003.

Benthic macroinvertebrate sampling occurred at a reduced number of sample stations when compared to the number of water quality sample stations discussed in Section 7.1 through Section 7.3. A total of seven benthic macroinvertebrate samples were collected by SCCD in 2005 from six stations. During 2001 and 2002, a total of twenty-one samples were collected each year by SCCD from nineteen stations (SCCD, 2003). The reduced number of sample stations and samples collected during 2005 precluded a complete evaluation of the benthic macroinvertebrate communities and the comparison of biological condition when compared to the results from the benthic macroinvertebrate sampling program conducted during 2001 and 2002.

During 2005, SCCD collected a total of three benthic macroinvertebrate samples from two Goose Creek stations (station GC1 and station GC2), two samples were collected from two Big Goose Creek stations (station BG2 and station BG10) and two samples were collected from two Little Goose Creek stations (station LG2A and station LG10). Included in the total number of samples was a duplicate sample collected at station GC1. 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.

WDEQ collected ten benthic macroinvertebrate samples at nine stations in the Goose Creek watershed during 2004. WDEQ benthic macroinvertebrate sampling occurred in and near Sheridan as part of the Goose Creeks storm water project. The purpose of the storm water project was to identify and assess significant potential water quality problems related to storm water discharges within the Goose Creek watershed, identify sources of pollutants in storm water runoff, and assess the impacts of storm water runoff on receiving waters (WDEQ, 2005). WDEQ collected a total of four benthic macroinvertebrate samples from three Goose Creek stations (station GC1A, station GC3 and a new station identified as Goose Creek @ 5th Street), two samples from two Big Goose Creek stations (station BG2 and a new station identified as Big Goose Creek @ Kendrick Park) and four samples were collected from four Little Goose Creek stations (station LG2A, station LG5 and two new stations identified as Little Goose Creek @ Loucks Street and Little Goose Creek @ Emerson Park). Included in the total number of samples was a duplicate sample collected at the Big Goose Creek @ 5th Street station. The duplicate sample was used for construction of taxa lists and for general discussion of macroinvertebrate results. The duplicate sample was not used for the determination of biological condition.

With the exception of the four new WDEQ benthic macroinvertebrate sampling stations assessed in 2004, all samples were collected at stations previously established in the Goose Creek watershed. The site descriptive information for the four new WDEQ benthic macroinvertebrate sampling stations is presented in Table 7-4. Field benthic macroinvertebrate sampling methods employed by SCCD in 2005 were the same as those used for sampling in 2001 and 2002 (see Section 6.5.3 *in* the *Goose Creek Watershed Assessment 2001-2002, Final Report* (SCCD, 2003)). WDEQ benthic macroinvertebrate sampling methods were identical to those used by SCCD resulting in comparable benthic macroinvertebrate data. Benthic macroinvertebrate samples collected by SCCD were analysed by Aquatic Biology Associates, Inc. in Corvallis, OR and benthic macroinvertebrate samples collected by WDEQ were analysed by Rhithron Associates, Inc. in Missoula, MT.

7.5.2 BENTHIC INVERTEBRATE TAXA

Taxa lists for Goose Creek benthic macroinvertebrate samples collected in 2004 and 2005 are presented in Appendix C, Tables C-1 through C-7. The list of metrics for each Goose Creek sample is presented in Appendix D, Tables D-1 and D-2. The taxa lists for Big Goose Creek benthic macroinvertebrate samples are presented in Appendix C, Tables C-8 through C-11. The list of metrics for each sample is presented in Appendix D, Tables D-2 and D-3. The taxa lists for Little Goose Creek benthic macroinvertebrate samples are presented in Appendix C, Tables C-12 through C-17. The list of metrics for each sample is presented in Appendix D, Tables D-3, D-4 and D-5.

A total of 192 benthic macroinvertebrate taxa have been identified since 2001 from a total of 59 samples collected during the Project (Appendix C, Table C-18). All taxa have been previously identified from north-central Wyoming streams and rivers with the exception of the mayfly genera *Asioplax* and *Mccaffertium*, the cranefly genera *Pseudolimnophila* and *Erioptera*, the crayfish genus *Orconectes*, and the soldier fly genus *Caloparyphus*. No threatened or endangered benthic macroinvertebrate taxa or fish species (incidentally captured during macroinvertebrate sampling) were identified. The widespread occurrence of the freshwater shrimp genus *Gammarus* and the freshwater shrimp species *Hyalella azteca* (commonly used in laboratory toxicity tests) in the Goose Creek watershed indicated that water in Goose Creek, Big Goose Creek and Little Goose Creek contained no toxic substances in sufficient concentration to prevent the establishment and survival of these organisms.

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 and the new WDEQ Little Goose Creek @ Emerson Park station. The mayfly genus *Mccafertium* (family Heptageniidae – flatheaded mayflies) was formerly a subgenus of *Stenonema*, but was recently elevated to generic status from the genus *Stenonema*. The occurrence of *Mccafertium* likely represents the change in taxonomic nomenclature and not the occurrence of a new mayfly genus in the Goose Creek watershed since *Stenonema* has been previously identified at Goose Creek station GC3 and Big Goose Creek stations BG8 and BG10.

The cranefly genera *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 the most upstream Big Goose Creek foothill station BG18 and *Erioptera* was found only at Little Goose Creek station LG5.

The crayfish genus *Orconectes* is common throughout the United States (Pennak, 1989), but normal riffle and run stream sampling methods employed during this Project probably underestimate its distribution in the Goose Creeks watershed as well as other Wyoming streams and rivers. *Orconectes* was found at Little Goose Creek station LG7, the new WDEQ Little Goose Creek @ Loucks Street station and Big Goose Creek station BG10.

The soldier fly genus *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.

Of note was the apparent new occurrence of the midge fly genus *Zavrelimyia* in the Goose Creek watershed. *Zavrelimyia* was reported from four (N = 4) samples collected by WDEQ in 2004. Among over 950 samples collected from north-central Wyoming streams, *Zavrelimyia* has previously been reported only from Little Sourdough Creek, a cold-water mountain stream in the Bighorn National Forest in Johnson County at an elevation of 7,500 feet (King, 2006). Fittkau and Roback (1983) report that larvae of *Zavrelimyia* are, with few exceptions, cold-stenothermic (prefer stable cold-water habitats) and inhabit sandy or detritus rich sediments of lentic habitats of stream sections close to springs. The occurrence of this taxon in streams in the lower Goose Creek watershed at sample stations in and near Sheridan suggested a shift from warm-water stream habitat to a more stable cool-water stream habitat. However, there were no significant changes in water quality, water temperature and physical habitat, or changes in other cool-water benthic taxa identified from other samples collected in and near Sheridan to suggest a shift in water temperature or habitat. It is possible that *Zavrelimyia* was confused with the taxonomically similar midge fly genus *Pentaneura*, which is common in lower elevation, warmer water north-central Wyoming streams. *Pentaneura* occurred in 41% of benthic macroinvertebrate samples collected in the Goose Creek watershed (Appendix C, Table C-18) and was not identified in the 2004 WDEQ samples. Until the identification of *Zavrelimyia* can be verified, a question mark has been placed next to it in the Appendix C taxa lists for the 2004 WDEQ samples.

Turbellaria flatworms were most common in the Goose Creek watershed and occurred in 95% of the total samples collected (Appendix C, Table C-18). The mayfly genus

Tricorythodes occurred in 93% of samples and oligochaete worms occurred in 92% of samples. The riffle beetle *Microcylloepus* (88%), the mayfly *Fallceon quilleri* (86%), the midge fly genera *Cricotopus* (88%) and *Rheotanytarsus* (85%), Acari (water mites) (85%) and the caddisfly *Helicopsyche borealis* (86%) were common and occurred in over 80% of the total samples collected. No other taxa occurred in over 80% of the total benthic macroinvertebrate samples.

The Diptera family Chironomidae had the greatest number of taxa in the Project area (N = 48 midge taxa), followed by the order Ephemeroptera (N = 30 mayfly taxa), the order Trichoptera (N = 29 caddisfly taxa), the class Oligochaeta (N = 13 worm taxa), the order Plecoptera (N = 12 stonefly taxa), the Diptera family Tipulidae (N = 10 cranefly taxa) and the Coleopteran family Elmidae (N = 8 riffle beetle taxa) (Appendix C, Table C-18).

7.5.3 BIOLOGICAL CONDITION

Biological condition was determined by comparison of the benthic macroinvertebrate community sampled to the Wyoming Stream Integrity Index (WSII) developed by Jessup and Stribling (2002). The WSII is based on the analysis of monitoring data collected by WDEQ from 1993 through 1999 from multiple reference and non-reference quality streams statewide. The biological criteria for the WSII are presented in Table 7-5. The WSII compares metric values for the sample benthic macroinvertebrate community to optimal benthic macroinvertebrate metric values from combined reference (least impacted) sample stations (Table 7-6). 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 7-5). Biological condition ratings of Very Good or Good indicate full support for aquatic life use and ratings of fair, poor, or very poor indicate 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.

Biological condition scores for benthic macroinvertebrate samples collected in 2004 by WDEQ and in 2005 by SCCD are presented in Table 7.7. Biological condition scores for benthic macroinvertebrate samples collected since 2001 are illustrated in Figure 7-1 (Goose Creek), Figure 7-2 (Big Goose Creek) and Figure 7-3 (Little Goose Creek).

<u>Goose Creek Biological Condition</u>

Biological condition was fair at Goose Creek stations GC1, GC1A, GC2 and GC3 sampled during 2004 and 2005 (Figure 7-1). The biological condition was poor at the new benthic macroinvertebrate monitoring station identified as Goose Creek @ 5th Street sampled by WDEQ in 2004 (Table 7-7). A general improvement in biological condition was observed since 2001 at Goose Creek stations GC1, GC1A, GC2 and GC3. In 2001, station GC2, GC3 and station GC1A exhibited poor biological condition, but each improved to fair biological condition during 2004 or 2005. The greatest improvement in biological condition since 2001 occurred at station GC2 located downstream of the Sheridan WWTF (Figure 7-1).

Big Goose Creek Biological Condition

Biological condition was fair at Big Goose Creek station BG2 and good at Big Goose Creek station BG10 during 2004 and 2005 (Figure 7-2). Biological condition was fair at the new benthic macroinvertebrate monitoring station identified as Big Goose Creek @ Kendrick Park sampled by WDEQ in 2004 (Table 7-7). In contrast to the general improvement in biological condition observed at most Goose Creek stations since 2001, biological condition declined at the two Big Goose Creek stations sampled. The decline in biological condition at station BG10 was due primarily to a reduction in the number of Ephemeroptera (mayfly) taxa, reduction in the number of Plecoptera (stonefly) taxa, reduction in % scrapers (a functional feeding group) and increases in the % non-insects and BCI CTQa (Appendix Table D-3). The decline in biological condition at station BG2 was due primarily to a reduction in the total number of taxa, reduction in the number of Ephemeroptera taxa, reduction in % scrapers, and a reduction in the total number of scraper taxa (Appendix Table D-2 and Appendix Table D-3).

Little Goose Creek Biological Condition

Biological condition improved from fair to good since 2001 at station LG5 (Figure 7-3). In contrast, biological condition decreased from good to fair since 2001 at station LG10. Biological condition has been fair at station LG2A since 2001 with only minor fluctuations in biological condition over the years. Biological condition was fair at the two new benthic macroinvertebrate monitoring stations identified as Little Goose Creek @ Loucks Street and Little Goose Creek @ Emerson Park sampled by WDEQ in 2004 (Table 7-7).

The increase in biological condition at station LG5 since 2001 was due primarily to an increase in the total number of Trichoptera (caddisfly) taxa and % scraper composition, and to a decrease in the % non-insect composition and BCI CTQa (Appendix D, Tables D-4 and D-5). The decrease in biological condition at station LG10 was due primarily to a reduction in the number of Plecoptera (stonefly) taxa, % scrapers (a functional feeding group) and the number of semi-voltine (long-lived) taxa, and to an increase in the % non-insect composition (Appendix D, Table D-5). A change in stream substrate at station LG10 was probably related to the reduction in biological condition during 2005. Sand comprised over 28 percent of the stream substrate during 2005 compared to 15 percent sand and 7 percent sand during 2001 and 2002, respectively (Appendix E, Table E-2). The increase in sand appeared to be related to a significant disturbance upstream of station LG10 that released large quantities of sand into the stream.

7.5.4 DISCUSSION OF BIOLOGICAL CONDITION

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 (see Table 7-8 *from* Table 3, Page 18 *in* WDEQ, 2002) 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 (see the *Goose Creek Watershed Assessment 2001-2002, Final Report* (SCCD, 2003) for this information).

Goose Creek

Based on the WSII scores and determination of biological condition from the WDEQ and SCCD benthic macroinvertebrate samples collected in 2004 and 2005, Goose Creek continues to exhibit fair biological condition. The general improvement in biological condition since 2001 observed at Goose Creek stations GC1, GC1A, GC2 and GC3 was notable. Continued sampling should be conducted at all Goose Creek stations to determine if the improvement in biological condition continues. However, it should be noted that although biological condition appeared to improve at Goose Creek stations, the generally low biological condition scores continued to indicate non-support of the narrative WDEQ water quality standard for aquatic life use. Planning and implementation of remedial measures to restore full aquatic life use support in Goose Creek should continue.

Big Goose Creek

It was not possible to determine change in benthic macroinvertebrate communities through the entire length of Big Goose Creek within the Project area because only two stations (BG2 and BG10) of the total seven benthic macroinvertebrate stations established in 2001 were sampled during 2004 and 2005. Based only on the limited sampling since 2002, biological condition has declined in Big Goose Creek since biological condition declined at stations BG2 and BG10 since 2002. Whether biological condition has declined at the other Big Goose Creek stations since 2002 is unknown since they were not sampled.

SCCD (2003) summarized historic and current benthic macroinvertebrate data collected at Big Goose Creek stations through 2002 and found that Big Goose Creek appeared to fully support aquatic life use from station BG18 in the canyon on the T-T Ranch downstream to station BG4 located at Normative Services. It was noted, however, that although full aquatic life use support occurred through the reach from station BG18 to downstream station 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 was likely the stream reach from station BG2 to the confluence with Little Goose Creek in Sheridan did not support aquatic life use.

Although sampling conducted in 2004 and 2005 found continued full support for aquatic life use at station BG10, located approximately 40 yards upstream of the County Road 87 bridge crossing, there was a downward trend in biological condition since 2002 suggesting that this station may not meet aquatic life use should the downward trend continue in the future (Figure 7-2). Should station BG10 not meet aquatic life use, the reach from station BG10 downstream to the confluence with Little Goose Creek in Sheridan would not support aquatic life use. Consequently, approximately 4 to 5 additional stream miles would be added to the Big Goose Creek reach not supporting aquatic life use. Continued sampling should be conducted at all Big Goose Creek stations to track changes in biological condition with special consideration toward monitoring the apparent downward trend in biological condition noted in the mid- to lower reaches of Big Goose Creek. Planning and implementation of remedial measures to restore full aquatic life use support in Big Goose Creek should continue.

Little Goose Creek

Change in the benthic macroinvertebrate communities through the entire length of Little Goose Creek within the Project area could not be determined because only three stations (LG2A (sampled by SCCD), LG5 (sampled by WDEQ) and LG10 (sampled by SCCD)) out of the total seven benthic macroinvertebrate stations established in 2001 were sampled during 2004 and 2005. Based on the limited sampling since 2002, biological condition has remained fair in the lower stream reach in Sheridan at station LG2A, increased to good biological condition at station LG5 located just upstream of the Sheridan city limits, and declined to fair biological condition at station LG10 located just upstream of the Highway 87 bridge crossing. Additional benthic macroinvertebrate sampling by WDEQ in 2004 at two new stations in Sheridan found only fair biological condition. Whether biological condition has improved or declined at the other Little Goose Creek stations since 2002 is unknown since they were not sampled.

SCCD (2003) summarized historic and current benthic macroinvertebrate data collected at Little Goose Creek stations through 2002 and found that Little Goose Creek appeared to fully support aquatic life use from the most upstream station LG22 (in the Little Goose Creek canyon) downstream to station LG10 located about 100 yards upstream of the Highway 87 bridge. Sampling by SCCD in 2005 indicated that aquatic life use was no longer fully supported at station LG10. Biological condition at station LG10 indicated marginal aquatic life support during 2001 sampling, but non-support for samples collected in 1998, 2002 and 2005. SCCD (2003) reported that 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 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 (see Section 8.23 *in* SCCD, 2003). Biological condition continued to decline from station LG7 downstream to station LG2A in Sheridan and non-support of aquatic life use was indicated.

Sampling in 2005 found a reduction in biological condition and non-support of aquatic life use at station LG10. The reason for the decline in biological condition is unknown, but may be related to the large increase of sand deposited on the streambed from a source upstream of the sample station. The percent contribution of sand at station LG10 increased from 7 percent in 2002 to over 28 percent in 2005 (Appendix E, Table E-2). Field observations indicated that significant precipitation in May 2005 washed out a small pond upstream of station LG10. The pond berm, apparently comprised of sand and gravel, was breeched and appeared to release sand into the stream system. If this localized source was the primary cause for the observed decline in biological condition at station LG10, the benthic macroinvertebrate community and biological condition should recover as the next spring flow flushes the stream channel and removes the sand. Continued monitoring is recommended at this station.

The increase in biological condition at station LG5 since 2001 was notable. Although there has been some residential development near this station since 2001-2002, land management practices have changed over the years allowing development of a more stable riparian zone resulting in the apparent improvement of biological condition. The apparent success of these land management practices should be more closely evaluated and considered for application at other stream segments in the Goose Creek watershed since their implementation has apparently enhanced biological condition.

Continued sampling should be conducted at all Little Goose Creek stations to track changes in biological condition with special consideration toward monitoring the apparent downward trend in biological condition noted at station LG10 as well as the upward trend in biological condition observed at station LG5. Planning and implementation of remedial measures to restore full aquatic life use support in Little Goose Creek should continue.

7.6 HABITAT

The historic and current habitat data collected in the Goose Creek watershed through 2002 were presented and discussed in the *Goose Creek Watershed Assessment 2001-2002, Final Report* (SCCD, 2003). This report presents the results of habitat assessments conducted by SCCD in the Goose Creek watershed. No comparable habitat assessments were conducted by WDEQ in conjunction with their Sheridan stormwater monitoring project conducted in 2004. No habitat assessments were conducted in the Goose Creek watershed during 2003.

Habitat assessments were conducted at the same stations sampled by SCCD for benthic macroinvertebrates in 2005 following methods described in SCCD (2003). A total of six habitat assessments were conducted by SCCD from six stations. During 2001 and 2002, a total of nineteen habitat assessments were conducted each year by SCCD from nineteen stations (SCCD, 2003). The reduced number of stations assessed during 2005 prevented a comparison of stream habitat at the thirteen other stations established on Goose Creek, Big Goose Creek, and Little Goose Creek since these stations were not assessed for habitat.

During 2005, SCCD conducted two habitat assessments at two Goose Creek stations (station GC1 and station GC2), two habitat assessments were conducted at two Big Goose Creek stations (station BG2 and station BG10) and two habitat assessments were conducted at two Little Goose Creek stations (station LG2A and station LG10).

The habitat assessments were conducted annually in September. Habitat assessments were generally conducted on sampling dates within $\pm$ two (2) weeks of one another each year. Results from the habitat assessments are presented in Appendix E, Tables E-1 and E-2. Because the habitat assessments were qualitative, SCCD used caution by providing a conservative interpretation of data. Although several elements of the habitat assessments were subjective, the habitat data when combined with photo points, may identify general habitat quality change among sample stations, between sample stations over time, and identify differences in habitat components such as stream channel and riparian zone characteristics, substrate composition and silt deposition.

There was no large change in habitat at Goose Creek stations GC1 or GC2 since 2002. The total habitat score at station GC1 changed little between years ranging from a total score of 121.5 in 2001 to a total score of 124 in 2002 (Appendix E, Table E-1). Stream substrate composition at station GC1 and station GC2 generally improved since 2001 with an increase in % cobble and % coarse gravel, and a decrease in sand. A mixture of substrate of different sizes was present and provided good microhabitat for the establishment and maintenance of a diverse benthic macroinvertebrate community which serves as a food source for fish. The amount of fine silt covering cobble and gravel (the weighted embeddedness value) decreased at station GC1 since 2001, but increased at station GC2 since 2001.

Habitat quality at Big Goose Creek station BG2 declined slightly from 2002 to 2005 (Appendix E, Table E-1). The habitat quality at station BG10 declined from 2001 to 2002, and from 2002 to 2005. The composition of stream substrate was similar at station BG2 from 2001-2002 to 2005 with the exception of a large increase in sand from 2002 (9 percent sand) to 2005 (22 percent sand). Sand and silt are detrimental to trout egg survival and the maintenance of healthy benthic macroinvertebrate populations that provide food for trout. The increase in the percent contribution of sand at station BG2 indicated an unknown disruption within the watershed upstream of this station that contributed sand to the stream bed. There were no large changes in stream substrate composition at station BG10 from 2001-2002 to 2005. Cobble dominated the substrate and comprised from 75 percent of the substrate in 2001 to over 90 percent of the substrate in 2002 (Appendix E, Table E-2).

Habitat quality remained low at Little Goose Creek station LG2A during 2005 (Appendix E, Table E-2). The lower habitat score (102.5) at station LG2A was due primarily to channelization of Little Goose Creek in Sheridan that reduced undercut banks, reduced the number of pools and instream cover for fish, and a good riparian zone. The channelization was artificially constricted for flood control and isolated the stream from the normal floodplain affecting the dynamics of stream flow and disrupting stream habitat at and downstream from the immediate channelized reaches. The habitat quality at station LG2A ranked 2^{nd} lowest among all stations assessed in the Goose Creeks watershed during 2001-2002 (SCCD, 2003). Cobble dominated the stream substrate during 2005 and comprised over 59 percent of the substrate. Sand comprised 20 percent of the stream substrate which was considered relatively high. The weighted embeddedness (silt covering cobble and gravel) value remained low during 2005 indicating the presence of silt cover on the majority of cobble and gravel. The low weighted embeddedness value of 39.9 at station LG2A indicated that about 80 percent of the surface of cobble and gravel were covered by silt.

There were no large changes in habitat at Little Goose Creek station LG10 during 2005. However, the percent contribution of sand at station LG10 increased from 7 percent in 2002 to over 28 percent in 2005 (Appendix E, Table E-2). The large increase in sand appeared to be related to the decline in biological condition at this station as noted in Section 7.5.3. Continued habitat monitoring is recommended at this station.

Good stream habitat is critical for the establishment and maintenance of good fishery, benthic macroinvertebrate populations and other aquatic life. Habitat quality is directly related to biological condition at streams in the Goose Creek watershed (see Figure 8-99 in *Goose Creek Watershed Assessment 2001-2002, Final Report* (SCCD, 2003)). The relationship between habitat quality and biological condition was strong and significant (Correlation Coefficient = 0.7235; $p<0.99$). This relationship is important because improvement in habitat quality in the absence of effects 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 resultant non-support of aquatic life use may be improved by enhancing habitat quality. Habitat quality can be improved at minimal cost often by minor changes 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 and maintained over time.

Table 7-4. Monitoring site descriptions for new benthic macroinvertebrate stations established by WDEQ in 2004 in the Goose Creek Watershed (from Goose Creeks Storm Water Report in WDEQ, 2005).

Site	Description	Latitude / Longitude	Elevation (feet)	Local Land Use(s)	Additional Information
NGP0183	Located on Goose Creek in Sheridan just upstream of 5th Street Bridge. New station established in 2004 by WDEQ.	44°48'23.33' / 106°57'34.40'	3,717	Primarily residential / urban with influences from urban drainage basins. Extensive historic channelization and no canopy cover over stream.	Located near Goose Creek Watershed Project water quality station GC6. Water quality station GC6 and NGP0183 are the first monitoring stations on Goose Creek downstream of the confluence of Little Goose Creek and Big Goose Creek.
NGP0180	Located on Big Goose Creek in Sheridan near the north east corner of Kendrick Park. New station established in 2004 by WDEQ.	44°48'03.83' / 106°57'47.62	3,743	Primarily residential / urban with few apparent influences from urban and rural drainage basins. Moderate historic channelization and little canopy cover over stream.	Located near Goose Creek Watershed Project water quality station BG1. Station BG1 and NGP0180 are the most downstream monitoring stations on Big Goose Creek.
NGP0182	Located on Little Goose Creek in Sheridan within Emerson Park. New station established in 2004 by WDEQ.	44°46'56.19' / 106°57'03.27	3,759	City park with some rural residential development. One urban storm drain outfall ((Q-Line) influences stream. Much of stream un-channelized with heavy canopy cover over stream.	Located between Goose Creek Watershed Project stations LG4 and LG5. Station NGP0182 is the first station after Little Goose Creek enters Sheridan city limits
NGP0181	Located on Little Goose Creek in Sheridan near the intersection of Loucks Street and Canby Street. New station established in 2004 by WDEQ.	44°47'50.99' / 106°56'48.76	3,734	Residential land use. Several urban storm drain outfalls influence stream. Extensive historic channelization and no canopy cover over stream.	Located upstream of Goose Creek Watershed Project water quality station LG2.

Table 7-5. Assessment rating criteria for benthic macroinvertebrate communities based on the Wyoming Stream Integrity Index (WSII; from Jessup and Stribling, 2002) Northwestern Great Plains ecoregion of Wyoming.

Rating of Biological Condition (Aquatic Life Use Support)	WSII (% of Reference) Northwestern Great Plains
Very Good (Full Support)	>77.5
Good (Full Support)	55.0 - 77.5
Fair (Non - Support)	36.7 - 54.9
Poor (Non - Support)	18.3 - 36.6
Very Poor (Non - Support)	<18.3

Table 7-6. Wyoming Stream Integrity Index (WSII) biological condition scoring criteria for benthic macroinvertebrate communities developed for Northwestern Great Plains ecoregion streams (from Jessup and Stribling, 2002)

Macroinvertebrate Metric	Northwestern Great Plains (5^{th} or 95^{th} %ile)
Total Taxa	45
Ephemeroptera taxa	9
Plecoptera taxa	5
Trichoptera taxa	10
% Plecoptera	13
% Trichoptera (w/o Hydropsychidae)	31.3
% Non-insects	0.5
% scrapers	31.8
BCI CTQa	62.6
Semi-Voltine Taxa	7

Table 7-7. Biological condition score and rating based on the Wyoming Stream Integrity Index (WSII; from Jessup and Stribling, 2002) for benthic macroinvertebrate stations sampled in 2004 and 2005 in the Goose Creek watershed.

Sampling Station and Year	Sampling Group	WSII Score	WSII Rating
Goose Creek GC1 (2005)	SCCD	48.3	Fair
Goose Creek GC1A (2004)	WDEQ	38.7	Fair
Goose Creek GC2 (2005)	SCCD	39.1	Fair
Goose Creek GC3 (2004)	WDEQ	45.9	Fair
Goose Creek @ 5th St. (2004)	WDEQ	35.4	Poor
Big Goose Creek BG2 (2004)	WDEQ	48.9	Fair
Big Goose Creek BG2 (2005)	SCCD	40.4	Fair
Big Goose Cr. @ Kendrick Pk. (2004)	WDEQ	48.0	Fair
Big Goose Creek BG10 (2005)	SCCD	55.6	Good
Little Goose Creek LG2A (2004)	WDEQ	40.1	Fair
Little Goose Creek LG2A (2005)	SCCD	42.6	Fair
Little Goose Creek @ Loucks St. (2004)	WDEQ	38.9	Fair
Little Goose Creek @ Emerson Pk. (2004)	WDEQ	37.0	Fair
Little Goose Creek LG5 (2004)	WDEQ	63.8	Good
Little Goose Creek LG10 (2005)	SCCD	43.3	Fair

Table 7-8. Aquatic Life Use support, Narrative Water Quality Standards (from WDEQ, 2002).

	FULL SUPPORT			PARTIAL SUPPORT	NON-SUPPORT
	Full Support	**Full Support**	**Threatened**		
Biological Data	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.

Figure 7-1. Biological condition at Goose Creek stations sampled from 2001 through 2005.

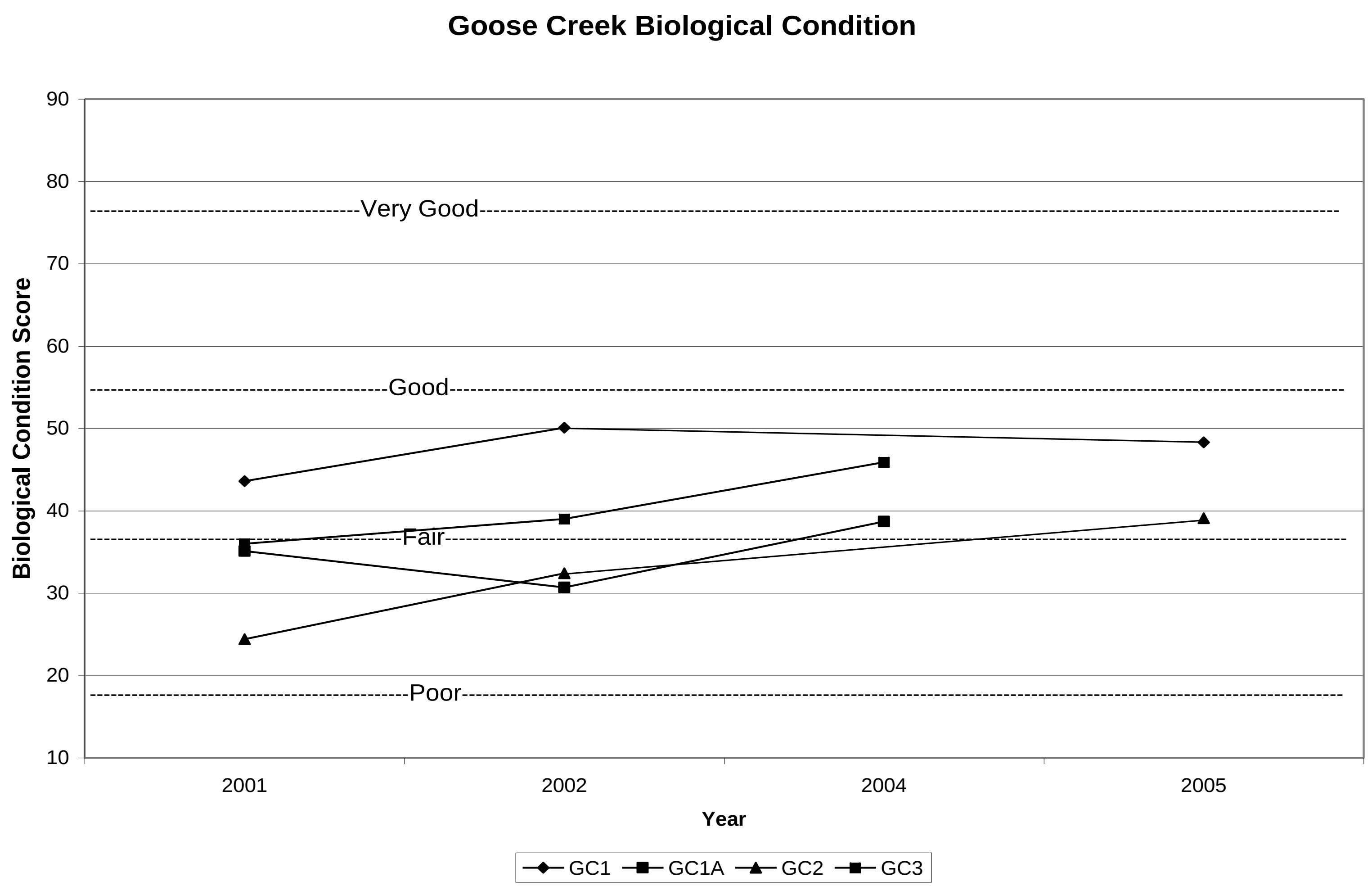


Figure 7-2. Biological condition at Big Goose Creek stations sampled from 2001 through 2005.

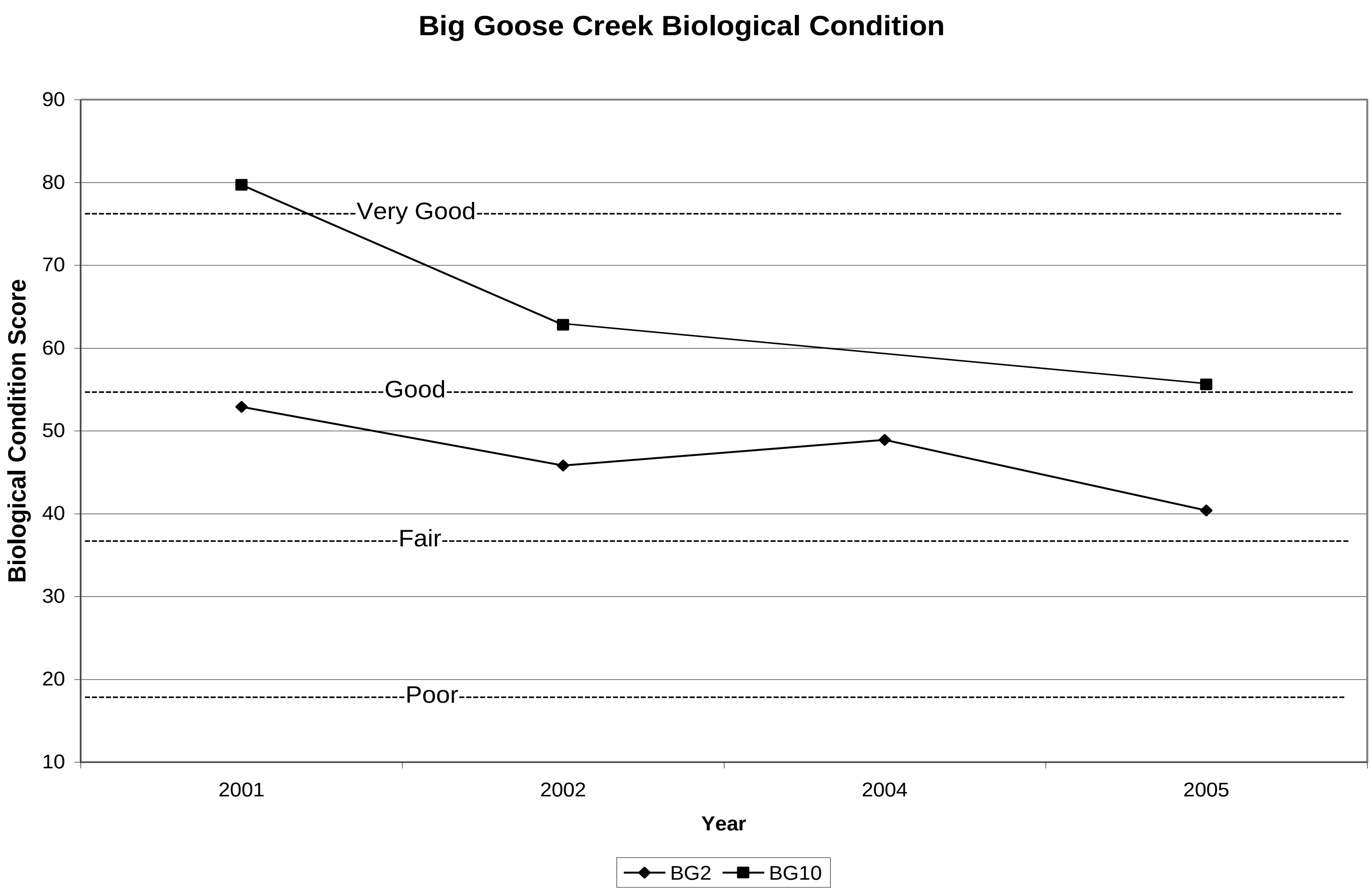
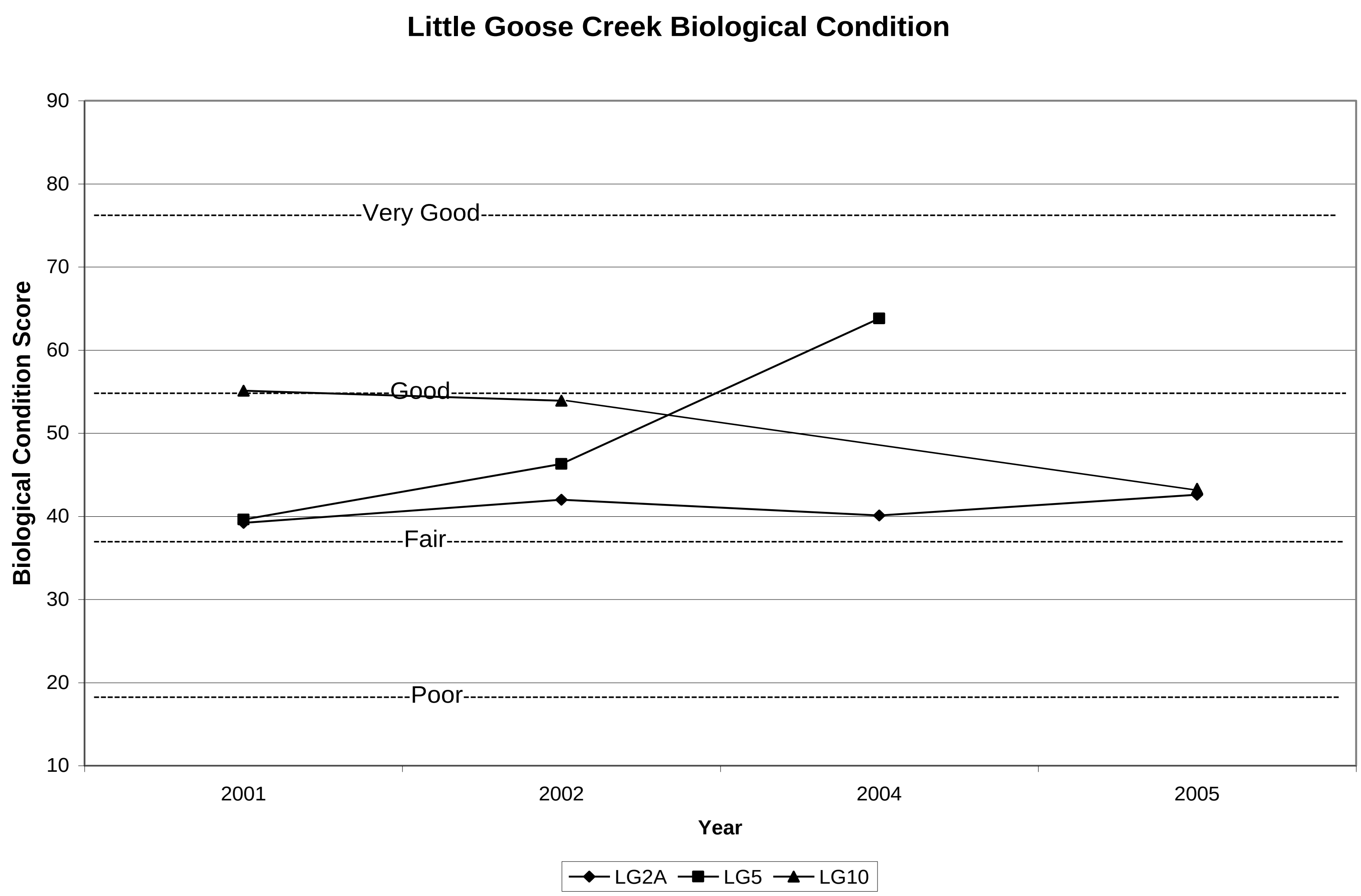


Figure 7-3. Biological condition at Little Goose Creek stations sampled from 2001 through 2005.



8. CONCLUSIONS AND RECOMMENDATIONS

Attempts to determine if improvements in overall water quality have been achieved are often difficult, especially when comparing water quality data that has been collected during seasons varying significantly in hydrological and meteorological conditions. Water quality data collected by SCCD on the Goose Creek watershed were generally obtained during below normal flow conditions during 2001 and 2002, and during higher than normal flow conditions during 2005. Although normal flow conditions cannot be anticipated nor expected during monitoring, these varying conditions do make water quality comparisons more difficult.

Fecal coliform and *E. coli* bacteria concentrations are known to vary due to a number of different water quality and water quantity factors. During the past several years of monitoring on the Goose Creek and upper Tongue River watersheds, SCCD has observed the greatest variations in bacteria concentrations during and shortly after heavy precipitation and/or snow melt run-off events. As described in Section 7, the 5.5 inch precipitation event which occurred during May 8 – 13, 2005 had a significant effect on local streamflows and water quality. This precipitation event not only produced short-term flooding in localized areas near Sheridan, but also saturated alluvial soils in riparian areas and created significant snow storage on the Big Horn Mountains. This additional soil and "bank" storage allowed local streamflows to maintain average to above average stages for the remainder of the monitoring season.

The wet spring experienced on the watershed during 2005 produced higher bacteria concentrations, in general, than those observed during the 2001 – 2002 assessment. The extremes in short and long-term weather conditions during these three years of monitoring on the watershed have produced bacteria data that are not directly comparable between years as a result of these hydrologic effects. Nonetheless, exceedences in bacteria standards have occurred on essentially the same stream reaches year after year and indicate that the water quality impairments continue to exist, regardless of hydrologic conditions.

Although the concentrations of bacteria have not exhibited measurable declines at this time, there are initial indicators of positive trends for the improvement of benthic macroinvertebrate communities and support of aquatic life use at some stations.

Biological condition based on the evaluation of the stream benthic macroinvertebrate communities have improved at most Goose Creek stations since the 2001 – 2002 assessment. Should the trend in the improvement of biological condition continue in the future, the attainment of full support of aquatic life use is possible. However, although biological condition has shown improvement, at this time, the entire reach of Goose Creek does not support the narrative WDEQ water quality standard for aquatic life use.

In contrast to the improvement shown in biological condition at the Goose Creek stations, the biological condition at the two Big Goose Creek stations sampled in 2005 declined since 2002. Both stations have exhibited a downward trend in biological condition since 2001. The biological condition at the Little Goose Creek station sampled in Sheridan (LG2A) has remained nearly the same since 2001. Effects from historic channelization associated with the Sheridan flood control project will likely limit improvement in biological condition in the future since management options are limited. The biological condition at the Little Goose Creek station located just upstream of the Sheridan city limits (station LG5) has improved each year since 2001 such that this station and stream reach, now fully support the narrative WDEQ water quality standard for aquatic life use. The improvement in biological condition appeared to be related to change in land management practices allowing the development of a more stable riparian zone resulting in the apparent improvement of biological condition. The apparent success of these land management practices should be more closely evaluated and considered for application at other stream segments in the Goose Creek watershed where biological condition is reduced or in decline. The middle reach of Little Goose Creek upstream of the Highway 87 bridge crossing showed a reduction in biological condition during 2005. The reduction in biological condition may have been related to a one-time large increase in sand deposited on the stream substrate that appeared to be linked to the mid-May precipitation event.

The positive effects on water quality improvements through the local watershed planning and implementation efforts are not readily measurable at this time. This local process of planning and project implementation is in the early phases of an anticipated long-term program. The watershed planning process has already begun to address and create widespread local awareness about several important resource issues, most notably the rural septic systems. The SCCD and GCWPC anticipate that voluntary, incentive based watershed planning and implementation efforts will be successful; however, it may require several years to actually measure these achievements. Nonetheless, each improvement project that has been implemented or is currently being implemented on the watershed certainly induces positive water quality changes, whether they are immediately apparent or not.

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