2009 GOOSE CREEK WATERSHED INTERIM MONITORING PROJECT

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

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

The WDEQ used historical 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 fecal coliform bacteria concentrations on Goose Creek, Big Goose Creek, and Little Goose Creek, and several tributaries that exceeded Wyoming water quality standards. Exceedences of these standards resulted in a non-attainment of the designated use for Recreation and Human Consumption.

In 2000, Wyoming's 303 (d) list of impaired waterbodies included fecal coliform bacteria impairments for Beaver Creek, Big Goose Creek, Goose Creek, Jackson Creek, Kruse Creek, Little Goose Creek, Park Creek, Rapid Creek, Sackett Creek, and Soldier Creek. To address these impairments the Goose Creek Drainages Advisory Group (GCDAG) was formed as a collaborative partnership among the Sheridan County Conservation District (SCCD), the Sheridan County Commission, and the City of Sheridan. In July 2000, the GCDAG received $195,444.51 in Federal Clean Water Act Section 319 funding, from the United States Environmental Protection Agency (USEPA). 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) initiated the Goose Creek Watershed Assessment (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 the fall of 2003 and concluded in December 2004 with the development of the Goose Creek Watershed Management Plan (SCCD, 2004). The planning process included monthly planning meetings that averaged about 20 landowners, watershed residents, SCCD, Natural Resources Conservation Service (NRCS), WDEQ, Sheridan County, and City of Sheridan. After finalizing the plan in December 2004, the plan was approved by WDEQ in April 2005 and filed with the Sheridan County Clerk.

The Goose Creek Watershed Plan included goals and objectives to address bacteria and other watershed issues identified by participants. The watershed committee also included recommendations and activities the group felt would achieve the objectives. Actions items included information and education activities such as an annual watershed newsletter and an informational booklet describing watershed issues and potential solutions. The Plan recommended continuation of local improvement programs offered by SCCD-NRCS to address bacteria and sediment contributions from livestock facilities, septic systems, eroding/unstable stream banks, and stormwater/run-off. Improvement programs are offered on a voluntary basis; information and education activities are important to encourage participation in local improvement efforts. Recognizing that measurable changes in water quality could take a long time, SCCD developed a local progress register that demonstrates the success of the local improvement effort in the short-term.

As part of the Goose Creek Watershed Plan, SCCD conducts interim water quality monitoring to observe changes in water quality over the long-term. Interim monitoring was completed in 2005 and was scheduled for 2008. Problems with funding and staffing resources delayed the 2008 monitoring until 2009. Interim monitoring is not as comprehensive as the 2001-2002 Assessment; interim monitoring evaluates trends in bacteria and sediment, along with benthic macroinvertebrates and habitat assessments at a limited number of stations.

In the summer of 2008, WDEQ decided to move forward with the development of a TMDL on the Goose Creek watershed. While the watershed plan addresses a broad set of water resource issues/needs, the TMDL was needed to provide a more quantitative, focused approach to address bacteria and sediment, which exceeded regulatory water quality standards. WDEQ contracted with SWCA to coordinate with SCCD, to complete the Goose Creek TMDLs. SCCD and the watershed committee will continue to work with WDEQ and SWCA to maintain a viable, local watershed improvement effort that also meets the requirements of the Clean Water Act.

1.2 PREVIOUS ASSESSMENTS

During April 2001, SCCD initiated the monitoring program, which included collecting pH, water temperature, conductivity, dissolved oxygen, total residual chlorine, fecal coliform, turbidity, alkalinity, biochemical oxygen demand, chloride, total hardness, sulfate, ammonia, nitrate nitrogen, total phosphorus, and total suspended solids samples. In total, 46 monitoring stations were sampled on Goose Creek, Big Goose Creek, Little Goose Creek, and 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 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). The water in Big Goose Creek and Little Goose Creek leaving the BNF 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 2001-2002 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 Assessment. 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 2001-2002 Assessment 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 20°C. 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.

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.

In 2005, water quality data were collected from 18 sites from April through October (Appendix A). Results of the 2005 monitoring were generally similar to data collected during the 2001-2002 Assessment (SCCD, 2006). The complete monitoring report was submitted to WDEQ in June 2006. The wet spring experienced on the watershed during 2005 produced higher bacteria concentrations, in general, than those observed during the 2001-2002 Assessment.

1.3 WATERSHED PLAN IMPLEMENTATION

To date, 27 improvements have been completed or are in progress on twelve livestock facilities, eleven septic systems, three streambanks and one irrigation diversion within the watershed. 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 documented on a Progress Register Map (Appendix A).

In 2003, 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. Additional public information and education efforts for the Goose Creek watershed have included:

- Development of a watershed logo by a local student;
- Distribution of an annual watershed newsletter to ~9500 residents;
- Distribution of a booklet summarizing watershed issues to ~2300 residents;
- Workshops on pathogens, animal feeding operations, and septic systems; and
- Various articles/news stories in the local paper, radio stations, and television broadcasts.

2. DESCRIPTION OF THE PROJECT AREA

The majority of surface waters forming Goose Creek originate in the Big Horn Mountains south and west of Sheridan, Wyoming with additional tributaries joining from the foothills and plains in the lower reaches of the watershed. The two main tributaries to Goose Creek, Big and Little Goose Creek, flow from the Big Horn Mountains and join in 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 (Appendix A).

The Goose Creek watershed has an approximate drainage area of 415 square miles and is identified by hydrologic unit code (HUC) 10090100-010. 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 Big Horn 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 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 (NRCS, 1986).

Land uses are many and varied within the watershed. Above the BNF 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 and small acreage developments. 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. In rural residential/small acreage areas, there are more horses and domestic animals other than cattle. 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 BNF 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 BENEFICIAL USES AND STREAM CLASSIFICATIONS

WDEQ is charged with implementing the policies of the Clean Water Act while also providing for the "highest possible water quality" for the designated uses on a waterbody (WDEQ, 2007). Depending on its classification, a waterbody is expected to be suitable for certain uses (Table 3-1).

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. . .Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies . . . (WDEQ, 2007).

In 2001, Class 2AB waters were protected for "primary contact recreation," although primary contact recreation was not specifically defined. In 2007, a definition was added for primary contact recreation although the use designation implies protection for both primary and secondary contact recreation. The difference between primary and secondary contact recreation is related to the potential of the activity to result in "ingestion of the water or immersion" (WDEQ, 2007). In neither case does the protection address the quantity of water; rather it ensures that the quality of water is "safe for human contact" (WDEQ, 2007).

Class 3B waters are

> tributary waters including adjacent wetlands that are not known to support 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, 2007).

Table 3-1. Surface Water Classes and Use Designations (WDEQ, 2007)

Class	Drinking Water[2]	Game Fish[3]	Non-Game Fish[3]	Fish Consumption[4]	Other Aquatic Life[5]	Recreation[6]	Wildlife[7]	Agriculture[8]	Industry[9]	Scenic Value[10]
1[1]	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	Yes	Yes	Yes	Yes	Yes
2AB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2A	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
2B	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2C	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2D	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3A	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3B	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3C	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4A	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4B	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4C	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes

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

[2]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.

[3]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 Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service with their appropriate jurisdictions.

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

[5]Aquatic life other than fish 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 Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service with their appropriate jurisdictions.

[6]Recreational use protection involves maintaining a level of water quality that is safe for human contact. It does not guarantee the availability of water for any recreational purpose. Both primary and secondary contact recreation are protected in Class 2AB waters.

[7]The wildlife use designation involves protection of water quality to a level that is safe for contact and consumption by avian and terrestrial wildlife species.

[8]For purposes of water pollution control, agricultural uses include irrigation or stock watering.

[9]Industrial use protection involves maintaining a level of water quality useful for industrial purposes.

[10]Scenic value 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.

Streams in the Goose Creek Watershed are classified as 2AB or 3B (Table 3-2) as provided in the June 21, 2001 Wyoming Surface Water Classification List (WDEQ, 2001). McCormick Creek is not included 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, 2007). The 2008 303(d) List of Waters Requiring TMDLs in Wyoming's 2008 305(b) Integrated State Water Quality Assessment Report identifies Beaver Creek and McCormick Creek as Class 2AB waterbodies.

Table 3-2. Goose Creek Watershed Stream Classifications and Beneficial Uses

Stream Classifications	Beneficial Uses: Class 2AB Waters	Beneficial Uses: Class 3B Waters
Goose Creek – 2AB	Drinking Water	
Soldier Creek – 2AB	Game Fish	
Big Goose Creek – 2AB	Non-game Fish	
Park Creek – 2AB	Fish Consumption	
Rapid Creek – 2AB	Other Aquatic Life	Other Aquatic Life
Little Goose Creek – 2AB	Recreation	Recreation
Kruse Creek – 2AB	Wildlife	Wildlife
Jackson Creek – 2AB	Agriculture	Agriculture
Sackett Creek – 2AB	Industry	Industry
Beaver Creek – 3B	Scenic Value	Scenic Value

3.2 STREAM LISTINGS

States are required to summarize water quality conditions in the state through Section 305 (b) of the Clean Water Act; this report is commonly known as the 305 (b) report. 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 Total Maximum Daily Load (TMDL) established to support their uses. A TMDL is the amount of a given pollutant a waterbody can receive and still meet water quality standards. WDEQ is required to develop TMDLs on waterbodies that do not meet water quality standards. While WDEQ supports and encourages local watershed planning efforts, they must also meet federal requirements for the development of TMDLs.

Wyoming's 305 (b) report and 303 (d) list is published every two years. The documents undergo a public comment period prior to being finalized. Chapter 1 of the Wyoming Water Quality Rules and Regulations (WDEQ, 2007) describes the surface water classes and uses that each class is to be able to meet. In addition, Chapter 1 outlines the water quality standards that must be achieved for a Wyoming waterbody to support its designated uses (WDEQ, 2007). If a waterbody exceeds narrative or numeric water quality standards, it is considered to be "impaired" or not meeting its designated uses. These waterbodies were included on the Wyoming 303 (d) list of Waters Requiring

TMDLs. In 2008, WDEQ combined Tables A and C into a single 303 (d) List of Waters Requiring TMDLs (WDEQ, 2008). Prior to 2008, the 303 (d) lists published by WDEQ were 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 1996, WDEQ included Big Goose Creek, Little Goose Creek, Soldier Creek, and Rapid Creek on the 303(d) list because of information suggesting the waters were not in full support of their designated uses (Table 3-3).

Table 3-3. Goose Creek Watershed 1996-1998 Listing Details

Waterbody	1996 Priority	1996 Impairments	1998 Listing
Big Goose Creek	High	silt, nutrients, habitat	Impaired-Recreation: fecal
Little Goose Creek	Medium	silt, nutrients, flow, habitat, pesticides, oil and grease, pathogens/bacteria, chlorine, ammonia, suspended sediment/turbidity	Impaired-Recreation: fecal
Soldier Creek	Low	silt	Needs Monitored: Inconclusive Data
Rapid Creek	Low	silt, flow	Delisted: Reclassified-Class 4
Goose Creek			WWTP Permit Renewal: ammonia, fecal, chlorine

Big Goose Creek was listed as a high priority, Little Goose as a medium priority, and Soldier Creek and Rapid Creek as low priorities. Both Big Goose and Little Goose Creek were retained on the 1998 list on "Table A: 303(d) Waterbodies with Credible Impairment Data." These listings were for fecal coliform bacteria related to recreational use based on data collected by the USGS. The classification of Rapid Creek changed from a class 2 in 1996 to a class 4 in 1998 and thus it was included on “Table D: Waterbodies Delisted from 1996 303(d) list.” Soldier Creek was among several waterbodies that were determined to have insufficient data and included in the 1998 303(d) list on “Table E: 1996 303(d) Waters Requiring Further Monitoring.”

In 2000, WDEQ added Beaver Creek, Goose Creek, Jackson Creek, Kruse Creek, Park Creek, Rapid Creek (reclassified as Class 2), Sackett Creek, and Soldier Creek on “Table A: 303(d) Waterbodies with Water Quality Impairments” for fecal coliform bacteria related to recreational use. Credible data collected by WDEQ and/or USGS during 1998 and 1999 were the basis for these listings. McCormick Creek was first listed in 2004 for fecal coliform bacteria related to contact recreation. In 2006, Goose Creek and Little Goose Creek within the City of Sheridan were listed for sediment impairments related to coldwater fish and aquatic life uses. As of 2009, there are 13 impairment listings on 11 waterbodies in the Goose Creek Watershed (Table 3-4).

Table 3-4. Summary of the 2008 303(d) Goose Creek Watershed impairments

Waterbody	Location	Listing Date	Uses Not Supported	Pollutant
Park Creek	entire-2.6 mil	2000	Recreation	*E. coli*
Rapid Creek	entire-3.2 mil	2000	Recreation	*E. coli*
Big Goose Creek	to above Beckton-18.7 mil	1996	Recreation	*E. coli*
Beaver Creek	entire-5.7 mil	2000	Recreation	*E. coli*
Sackett Creek	entire-3.0 mil	2000	Recreation	*E. coli*
Jackson Creek	entire-6.1 mil	2000	Recreation	*E. coli*
Little Goose Creek	to above Big Horn-15.3 mil	1996	Recreation	*E. coli*
Little Goose Creek	to above Big Horn-15.3 mil	2006	Aquatic Life, Cold Water Fish	Habitat, Sediment
McCormick Creek	entire-2.1 mil	2004	Recreation	*E. coli*
Kruse Creek	entire-2.5 mil	2000	Recreation	*E. coli*
Goose Creek	entire-12.6 mil	2000	Recreation	*E. coli*
Goose Creek	entire-12.6 mil	2006	Aquatic Life, Cold Water Fish	Habitat, Sediment
Soldier Creek	entire-2.8 mil	2000	Recreation	*E. coli*

4. HISTORICAL AND CURRENT DATA

Historical data for the purposes of this project are defined as data greater than five years old from the start of the 2001-2002 Assessment. These historical data were 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 were provided in tabular form in the Appendices to the 2001-2002 Final Report. These data are not repeated in this document.

A summary of current water quality data collected by the USGS, and not provided in the 2001-2002 Final Report or 2005 interim 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 2009 are shown. USGS did collect water quality samples for additional parameters, but they are not included in this report.

5. MONITORING DESIGN

5.1 MONITORING PARAMETERS

Water quality monitoring during 2009 included the following parameters: water temperature, pH, conductivity, dissolved oxygen, discharge, turbidity, 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 2009. BURP monitoring, to include macroinvertebrate sampling and habitat assessments, was also performed at six stations.

5.2 SITE DESCRIPTIONS

In 2005, SCCD selected 18 of the 46 original stations for the interim water quality monitoring. The 18 monitoring stations utilized during 2009 monitoring season were located at the same locations as the previous 2005 interim water quality monitoring and the 2001-2002 Assessment (Table 5-1). 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 2001-2002 Assessment Final Report (SCCD, 2003) and in the 2009 Sampling and Analysis Plan (SCCD, 2009).

Table 5-1. 2009 Monitoring Site Descriptions

Site	Type(s) of Monitoring Performed	Water Quality Sample Site Description	Benthic Macroinvertebrate Sample Site Description
GC1	Temperature Water Quality BURP	Goose Creek ~75 yards downstream HWY 339 bridge at USGS Station No. 06305700	Riffle ~ 300 yards upstream from HWY 339
GC2	Water Quality BURP	Goose Creek ~200 yards downstream Sheridan WWTP	Riffle ~ 200 yards downstream WWTP
GC4	Water Quality	Soldier Creek ~10 yards downstream Dana Ave	
BG2	Temperature Water Quality BURP	Big Goose Creek ~100 yards downstream of footbridge at Works and Elk St intersection	First riffle upstream of footbridge
BG6	Temperature Water Quality	Big Goose Creek at west end of Paulson Youth Camp	
BG9	Water Quality	Beaver Creek ~25 yards upstream of confluence	
BG10	Water Quality BURP	Big Goose Creek ~40 yards upstream from County Road 87 bridge	Riffle near first bend upstream bridge
BG16	Water Quality	Rapid Creek ~150 yards upstream from confluence	
BG18	Temperature Water Quality	Big Goose Creek near the mouth of canyon at USGS Station No. 06302000	
LG2	Temperature Water Quality BURP	Little Goose Creek ~30 yards upstream concrete flood channel in downtown Sheridan	LG2A - Riffle ~100 yards downstream Coffeen Avenue bridge
LG5	Water Quality	Little Goose Creek ~100 yards upstream Brundage Lane bridge	
LG8	Temperature Water Quality	Little Goose Creek ~ ¼ mile downstream from McCormick Creek near Cox Valley Road.	
LG9	Water Quality	McCormick Creek ~20 yards upstream from confluence	
LG10	BURP		First riffle below Kruse Creek confluence
LG11	Water Quality	Kruse Creek ~100 yards upstream from confluence	
LG13	Water Quality	Little Goose Creek ~10 yards upstream from County Road 60 bridge at Knode Ranch subdivision	
LG17	Water Quality	Jackson Creek ~20 yards upstream from confluence	
LG19	Water Quality	Sackett Creek ~10 yards upstream from confluence	
LG22	Temperature Water Quality	Little Goose Creek above County Road 77 bridge at USGS Station No. 06303700	

Each sampling site was equipped with a staff gauge for flow measurements. Staff gauges were calibrated to develop stage-discharge relationships. During the initial site reconnaissance and site set-up SCCD identified land uses and other site characteristics (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	UTM Coordinates Zone 13	Elevation (feet)	Land Use(s)
GC1	44°52.992' / 106°59.263'	04971898N, 343019E	3,660	Grazing and irrigated haylands upstream to Sheridan. A few residences along Goose Creek. Railroad and HWY 338 parallel east side.
GC2	44°49.340' / 106°57.932'	04965093N, 344608E	3,701	A concrete plant on south of creek with settling ponds to the north. Sheridan WWTP is upstream.
GC4	44°49.198' / 106°57.719'	04964824N, 344882E	3,705	Downer Addition (residences) on lower Soldier Creek. Grazing and irrigated lands upstream.
BG2	44°47.751' / 106°58.164'	04962159N, 344231E	3,745	Predominantly urban / residential.
BG6	44°46.384' / 107°02.755'	04959778N, 338115E	3,890	Recreational (youth camp), cattle grazing, and haylands.
BG9	44°45.579' / 44°45.579'	04958287N, 335884E	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.
BG10	44°45.778' / 107°04.501	04958714N, 335784E	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.
BG16	44°43.752' / 107°08.667'	04955106N, 330190E	4,160	Cattle grazing, irrigated haylands, and wildlife habitat.
BG18	44°42.137' / 107°10.894'	04952194N, 327171E	4,505	Primarily wildlife habitat. Cattle grazing was infrequent during assessment. The BNF boundary is about 1 mile upstream from the site. The Alliance Ditch intake is about 50 yards downstream.
LG2	44°48.086' / 106°57.148'	04962747N, 345585E	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'	04959605N, 345666E	3,775	Located just upstream from Sheridan, uses are mainly wildlife habitat, irrigated haylands, and rural residential.
LG8	44°43.185' / 106°57.068'	04953671N, 345473E	3,895	Small acreage properties with livestock grazing, wildlife habitat, and irrigated haylands.
LG9	44°43.110' / 106°57.229	04953537N, 345257E	3,905	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.
LG10	44°42.749' / 106°57.229	04952869N, 345241E	3,915	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.
LG11	44°42.615' / 106°57.444'	04952627N, 344951E	3,915	Small acreage properties with cattle grazing and irrigated haylands.
LG13	44°42.149' / 106°58.104'	04951786N, 344059E	3,940	Large subdivisions with small acreage lots, wildlife habitat, and haylands.
LG17	44°41.357' / 106°59.121	04950352N, 342680E	4,020	Small acreage properties with cattle grazing and irrigated haylands.
LG19	44°43.110' / 106°57.228'	04953537N, 345258E	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'	04942831N, 338304E	4,533	Ranch buildings, cattle grazing, and wildlife habitat. The BNF boundary is approximately 3 miles upstream.

5.3 MONITORING SCHEDULE

The purpose of the 2009 interim monitoring was to evaluate long-term trends in water quality in relation to water quality improvement efforts. The Goose Creek Watershed Management Plan includes implementation of BMP's and education activities targeted to watershed residents (SCCD, 2004).

As with the 2001-2002 Assessment and the 2005 interim monitoring, sampling was based on a random, (unbiased) systematic sampling design and focused on parameters that exceeded water quality standards during the initial assessment.

The 2009 monitoring schedule is similar to the 2005 monitoring and includes the geometric mean of five *E. coli* bacteria samples in May and August, which corresponds to seasonal high and low flows during the recreation season. These months were also directly comparable to sampling periods used during the 2001-2002 Assessment, which were April, May, August, and October. In previous monitoring, May and August had the highest rate of exceeding the pathogen indicator standard. During collection of bacteria samples, SCCD also collected turbidity samples and measured instantaneous temperature, pH, conductivity, dissolved oxygen, and discharge. Continuous temperature data loggers were used to measure instream temperatures at seven stations from May 5, 2009 through September 30, 2009. BURP monitoring was performed at six stations during September 2009. The 2009 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 (SCCD, 2009) according to accepted analytical methods (Table 5-3). 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. Discharge measurements at all sites was calculated with the use of calibrated staff gauges. Staff gauge calibrations were performed by measuring instantaneous discharge with a Marsh-McBirney 2000 current meter. Turbidity and *E. coli* samples were hand delivered to Inter-Mountain Laboratories (IML) in Sheridan, Wyoming for analysis. Macroinvertebrate samples were sorted by Aquatic Assessments, Inc. (AA) in Sheridan, Wyoming and analyzed by Aquatic Biology Associates, Inc. (ABA) in Corvallis, Oregon.

Table 5-3. Standard Field and Laboratory Methods

Parameter	Units	Method / Reference[1]	Location of Analyses	Preservative	Holding Time
Temperature	°C	grab/USEPA 1983 170.1	On-site	n/a	n/a
Temperature	°C	continuous recorder	On-site	n/a	n/a
pH	SU	grab/USEPA 1983 150.1	On-site	n/a	n/a
Conductivity	µmhos/cm	grab/USEPA 1983 120.1	On-site	n/a	n/a
Dissolved Oxygen	mg/l	grab/USEPA 1983 360.1	On-site	n/a	n/a
Turbidity	NTU	grab/USEPA 1983 180.1	IML[2]	Ice; at or below 4°C	48 hours
E. coli	col/100 ml	grab/SM 9222G[3]	IML[2]	Ice; at or below 4°C	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	AA[4] ABA[5]	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]SM refers to Eaton et. al., 1995. Standard Methods for the examination of water and wastewater. Washington, D.C.
[4]AA refers to Aquatic Assessments, Inc. in Sheridan, Wyoming.
[5]ABA refers to Aquatic Biology Associates, Inc. in Corvallis, Oregon.

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; USEPA, 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 (USEPA,1980; USEPA, 1990). 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. Project QA/QC is fully described in the SCCD QAPP (SCCD, 2007) and in the Project SAP (SCCD, 2009).

6.2 TRAINING

SCCD personnel had adequate training/experience for the proper implementation of the project. This was obtained through a combination of college studies, previous employment experiences, and on the job training. The District Manager had an M.S. from the University of Wyoming in Rangeland Ecology and Watershed Management (Water Resources Option). The Conservation Technician had an M.A. from Chadron State College in Rangeland Management. The District Manager and Conservation Technician participated in the WACD water quality training program and had environmental and water quality skills obtained through prior employment experiences. 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.

Other SCCD and USDA-NRCS personnel provided field and other assistance as needed. These personnel were trained to follow the necessary field protocols and were under the direct supervision of the District Manager and/or the Conservation Technician supervising the sample collection.

6.3 SAMPLE COLLECTION, PRESERVATION, ANALYSIS, AND CUSTODY

6.3.1 Collection, Preservation, and Analysis

Accepted referenced methods for the collection, preservation and analysis of samples were adhered to as described in the SAP. In addition to field data sheets, samplers carried a field log book to document conditions, weather, and other information for each site. Calibration logs were completed for each instrument every time a calibration was performed.

6.3.2 Sample Custody

Project field measurements were recorded on field data sheets. Water samples requiring laboratory analysis were immediately preserved (if required), placed on ice and hand delivered to the laboratory. A Chain of Custody (COC) form was prepared and signed 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. After samples changed custody, laboratory internal COC procedures were implemented according to their Quality Assurance Plan.

Benthic macroinvertebrate samples were preserved in the field, 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 hand delivered to AA for sorting. COC forms were signed by SCCD and AA personnel receiving the samples. Sorted samples, COC forms, and lab bench sheets were then shipped to ABA. Upon receipt, ABA 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 after completion of analyses.

6.4 CALIBRATION AND OPERATION OF FIELD EQUIPMENT

The sampler was responsible for the proper and consistent calibration and maintenance of instrumentation. The SAP outlined the calibration and maintenance requirements for field equipment (SCCD, 2009). On every sampling event before leaving the office, the pH meter, conductivity meter, and DO meter were calibrated according to the manufacturer's instructions as described in the SAP. A calibration and maintenance log was completed by the sampler for all equipment used.

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 550A 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 (Appendix E-6).

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 use.

6.5 SUMMARY OF QA/QC RESULTS

This section provides a summary of the QA/QC procedures and results as described in the SAP (SCCD, 2009). 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 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.

6.5.2 Trip Blanks

Trip blanks were prepared to determine whether samples might be contaminated by the sample container, preservative, or during transport and storage conditions. *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) on sampling days. No trip blanks used during the project contained detectable levels of *E. coli* bacteria (Appendix E-5). Turbidity results for May 26, 2009 (two of them), May 28, 2009, and August 4, 2009 and August 24, 2005 were reported as 0.3, 0.2, 0.1, and 0.2 NTU, respectively. These turbidity data were considered acceptable because they were at, or approached, the minimum detection limit value of 0.1 NTU. On August 18, 2009, the trip blank yielded 10.5 NTU turbidity. However, the sample results from the samples collected that day did not appear to be affected. Most of the sample results were lower than that recorded for the trip blank and none seemed unusually high for the site. Turbidity results from that day were used in the summary statistics.

6.5.3 Sample Holding Times

All IML prepared laboratory data sheets were reviewed to ensure all samples were analyzed before their holding times had expired. This review determined that all *E. coli* samples were analyzed within the required 6 hour holding time with the exception of

- three *E. coli* samples from GC1 on 5/20/2009, 8/4/2009, and 8/11/2009;
- two *E. coli* samples from GC2 on 5/20/2009 and 8/11/2009;
- two *E. coli* samples from GC4 on 5/20/2009 and 8/11/2009; and
- one *E. coli* sample from BG2 on 8/11/2009.

The holding time exceedences were within 49 minutes and samples were preserved on ice in a cooler. As a result, data from these samples were used in the summary statistics and in the calculation of geometric means. All turbidity samples were analyzed within the required 48 hour holding time. All water quality field samples were analyzed on-site immediately following sample collection. There is no holding time for benthic macroinvertebrate samples.

6.5.4 Duplicates

Duplicate chemical, physical, biological, and habitat samples were obtained for all field and laboratory analyzed parameters (Table 6-1). Duplicate water quality samples were obtained by collecting consecutive water quality samples from a representative riffle. Duplicate macroinvertebrate samples were collected by two field samplers, each equipped with a surber net, collecting samples simultaneously and adjacent to one another. Duplicate habitat assessments were collected by two field samplers performing independent assessments without communication at the same site and same time. In 2009, 11% of the water quality samples were duplicated, which was above the target DQO of 10%. The percent duplicated for macroinvertebrate samples and habitat assessments, at 16.7%, also exceeded the DQO of 10%.

Table 6-1. Summary of 2009 Duplicates

Parameter	Samples Collected	Duplicates Collected	Percent Duplicated	DQO (%)
Water Quality Samples	180	20	11	10
Macroinvertebrate Samples	6	1	16.7	10
Habitat Assessments	6	1	16.7	10

6.5.5 Precision

Precision is the degree of agreement of a measured value as the result of repeated application under the same condition. The Relative Percent Difference (RPD) statistic was used, because the determination of precision is affected by changes in relative concentration for certain chemical parameters. Precision was determined for chemical, physical, biological, and habitat measurements by conducting duplicate samples at 10 percent of sampling sites (Appendix E-3, E-4). All parameters, with the exception of turbidity met precision DQO's for the project (Table 6-2 through 6-4). Precision results for turbidity were above the DQO of 10% for both Duplicate 1 (25.4%) and Duplicate 2 (15%). Because turbidity values can be relatively low, small variations can result in higher RPDs.

Table 6-2. Precision results for the 2009 Goose Creek Watershed monitoring data

Parameter	Dup 1 (GD1) Precision (%-RPD)	Dup 2 (GD2) Precision (%-RPD)	Average Precision (%-RPD)	DQO (%)
Water Temperature	0.6	0.9	0.8	10
pH	0.7	0.7	0.7	5
Conductivity	2.7	3	2.9	10
Dissolved Oxygen	0.3	0.4	0.4	20
Turbidity	25.4	15	20.2	10
E. coli	14.3	36	25.2	50

Table 6-3. Precision results for the 2009 Goose Creek Watershed macroinvertebrate monitoring data

Parameter	Dup 1 (BG2)	Dup 2 (BG2)	Precision (%-RPD)	DQO (%)
Total Abundance	1455	1280	12.8	50
Total Taxa	32	34	6.1	15

Table 6-4. Precision results for the 2009 Goose Creek Watershed habitat monitoring data

Parameter	Dup 1 (BG2)	Dup 2 (BG2)	Dup 3 (BG2)	Average Precision (%-RPD)	DQO (%)
Intra-Crew Habitat Assessments	130.5	125.0	115.0	8.4	15

6.5.6 Accuracy

Accuracy is the degree of agreement between a measured value and the true or actual value. Accuracy for water quality parameters measured in the field was assured by calibration of equipment to known standards. Conductivity and pH meters were calibrated on the morning of every sampling event. The DO meter was calibrated in the field. There are no current laboratory methods to determine the accuracy of biological samples. Therefore, the accuracy of *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. Precision served as the primary QA check for *E. coli* bacteria, benthic macroinvertebrates, and habitat assessments.

6.5.7 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 is 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. All parameters except DO met the completeness DQOs for this project (Table 6-5). On May 6, 2009, the DO meter yielded extremely high results at all sample sites, which were discarded. After cleaning the probes and recalibrating, the meter functioned properly. Some of the discharge measurements were not collected because the staff gauges were submerged or the values were outside of the calibrated range. However, the completeness value for discharge was still within the DQO for the project.

Table 6-5. Completeness of 2009 Goose Creek Watershed Monitoring Data

Parameter	% Completeness	DQO (%)
Water Temperature	100.0	95
pH	100.0	95
Conductivity	100.0	95
Dissolved Oxygen	90.0	95
Discharge	96.7	95
Turbidity	100.0	95
E. coli	100.0	95
Macroinvertebrates	100.0	95
Habitat Assessments	100.0	95

6.5.8 Stage Discharge Relationships

The relationship between stage height and discharge for a given location yields an equation that allows the calculation of discharge at various stage heights recorded on a staff gauge. A correlation coefficient (R^2 value) of at least 0.95 (95%) is desirable for proper calibration of the gauge. Stage-discharge relationships were established for all staff gauges installed by SCCD (Table 6-6). These relationships were developed by recording the stage height and measuring discharge using the mid-section method (WDEQ, 2004) on at least three occasions with varying flow conditions. The 2009 discharge measurements were calculated under the following scenarios:

- eight gauges were reinstalled in 2009 and had new equations developed (new);
- two existing gauges and relationships were considered stable and the previous years' calculations were used (prior);
- three gauges were considered stable but previous years' equations were not satisfactory; additional measurements were taken and combined with previous years (combined); and
- five gauges were reinstalled, but were able to be tied back to a known benchmark; relationships were made between measurements from previous years' and from 2009 (adjusted).

Correlation coefficient values for GC4, BG16, and LG19 were slightly below the DQO of 0.95 at 0.92. Values for BG10, LG8, and LG9 were below 0.90 at 0.88, 0.83, and 0.84, respectively. Because these presented the best, and in some cases the only, flow information available, the values were used in the calculation of summary statistics and will be used in the development of load estimates, where appropriate.

Table 6-6. Summary of R^2 values for 2009 Goose Creek Watershed Stage-Discharge relationships

Site	Gauge /Curve Status for 2009	R^2 value	DQO Minimum R_2 Value
GC1	Adjusted	0.97	0.95
GC2	Adjusted	0.95	0.95
GC4	New	0.92	0.95
BG2	New	0.98	0.95
BG6	Prior	0.98	0.95
BG9	Combined	1.00	0.95
BG10	New	0.88	0.95
BG16	New	0.92	0.95
BG18	Prior	0.97	0.95
LG2	Adjusted	1.00	0.95
LG5	Adjusted	1.00	0.95
LG8	Adjusted	0.83	0.95
LG9	New	0.84	0.95
LG11	New	0.99	0.95
LG13	Combined	0.95	0.95
LG17	Combined	1.00	0.95
LG19	New	0.92	0.95
LG22	New	0.98	0.95

6.5.9 CONTINUOUS TEMPERATURE DATA LOGGERS

SCCD used Onset Tidbit Model #TBI32-05+37 temperature loggers at stations GC1, BG2, BG6, BG18, LG2, LG8, and LG22 during the 2009 monitoring project. 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). To test a data logger's accuracy, Onset recommends performing a crushed ice test. To perform the test, a seven pound bag of crushed ice was emptied into a 2.5 gallon bucket. Distilled water was added to just below the level of the ice. The mixture was stirred and the data loggers were submerged in the ice bath. The bucket was 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 $\pm$0.23°C.

On May 4, 2009, SCCD performed the crushed ice test on the data loggers (Appendix E-6). The results show the data logger's environmental response as they were transferred from room temperature conditions to the crushed ice bath mixture. Each data logger started the test near 24°C in room temperature conditions and cooled to near or below 0°C before stopping the test. Variations in response times shown in the data are due to variations in the times that loggers were submerged and removed from the ice bath. All of the loggers recorded minimum temperatures within the recommended range of 0°C $\pm$0.23°C.

6.6 DATA VALIDATION

Data generated by the contract laboratories was subject to the internal contract laboratory QA/QC process before it was released. Except in cases where holding times were exceeded, data were assumed valid because the laboratory adhered to its internal QA/QC plan. Where holding times were exceeded, SCCD evaluated the length of time exceeded and storage conditions to make a determination on whether the data were usable. 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.

Two discharge calculations were discarded because the stage readings were outside of the calibrated range and unreasonably high for the site and conditions. These occurred on BG9 (Beaver Creek) on May 26 and May 28, 2009. Based on field notes, it was believed that high flows from Big Goose Creek were backing up water into Beaver Creek. There were four instances where no gauge height could be established because the gauge was submerged, including two measurements each at GC2 and BG18 on May 26 and May 28, 2009. Dissolved oxygen measurements collected on May 6, 2009 from all 18 sites were discarded because of problems associated with the meter.

There was one *E. coli* sample reported as below the detection limit of one colony per 100 milliliters; the sample was reported as ½ the detection limit (0.5) for the purpose of summary statistics, as specified in the SAP (Gilbert 1987).

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.

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 CONSTRUCTION AND DATA REDUCTION

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.

After data validation and database construction, data were statistically summarized to determine the:

- Number of samples;
- Maximum;
- Minimum;
- Median;
- Mean;
- Geometric mean; and
- Coefficient of variation.

These statistics and analyses provided insight for temporal and spatial water quality changes within the watershed (Appendix B.). Microsoft Excel® and Arc Map 9.2® were used to generate the statistical tables and graphics for this report. A single lab result was below the detection limit and was reported as ½ the detection limit for the purpose of summary statistics (Gilbert, 1987). Discharge measurements outside the calibrated range of the staff gauge or instances where the staff gauge was submerged were not used in the calculation of summary statistics.

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 and other interested parties as necessary. Copies of this report will be available through the SCCD office.

7. DISCUSSION OF RESULTS

7.1 2009 FIELD WATER CHEMISTRY AND PHYSICAL PARAMETERS

Water quality data were collected from April through October, 2009 at all 18 sites (Appendix B). Summary statistics were calculated for instantaneous monitoring parameters at all sites on accepted data (Appendix B). Most specific conductivity, pH, and dissolved oxygen results were within Wyoming Water Quality Standards during the project.

7.1.1 Instantaneous Water Temperature

Instantaneous temperature measurements were recorded above the maximum 20°C instream temperature standard at LG2 (21.0 on 8/4/09) and LG5 (20.0 on 8/4/09). However, these exceedences were infrequent and occurred only once at each site. Both of these measurements occurred on 8/4/2009, which corresponded to a 5-day period where the mean daily air temperature was at or above 70° F (Appendix Figure B-9). Instantaneous temperature measurements collected during 2009 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.

7.1.2 pH

Ranging from 8.1-9.1 SU, observed pH values showed little variability and are higher than values in 2005 (maximum 8.69) and 2001-2002. There were four samples that exceeded the Wyoming Water Quality Standard of 9.0 SU, including one on Little Goose Creek (LG13) on August 4 at 9.07 and three on Little Goose Creek (LG22) on May 20, May 26, and August 4 at 9.07, 9.1, and 9.03 respectively.

7.1.3 Specific Conductivity

Specific Conductivity generally increased from upstream to downstream. With the exception of Jackson and Sackett Creeks, Specific Conductivity values were, for the most part, lower in 2009 than in 2005. Tributary sites had higher Specific Conductivity values than adjacent mainstem sites. Maximum Specific Conductivity on tributaries was 1426 on McCormick Creek, followed by 830 on Soldier creek. On the mainstem sites, the maximum Specific Conductivity was 662 (GC1); the minimum was 38 (BG18).

7.1.4 Dissolved Oxygen

Dissolved Oxygen values were fairly consistent among sites throughout the watershed, ranging from 6.95 to 11.8 mg/L. All sites met the minimum instantaneous DO concentration standard of 5.0 mg/L for early life stages and in most cases, the 8.0 mg/L water column concentration recommended to achieve the 5.0 mg/L intergravel concentrations (WDEQ, 2007). Seven sites had values below 8.0 mg/L on at least one occasion (Table 7.1); with all of the seven yielding DO measurements below 8.0 mg/L on 8/4/2009. Half of the values on Goose Creek just above the confluence with Tongue River (GC1) were below 8.0 mg/L. All but two of the remaining 11 measurements below 8.0 mg/L were on tributaries.

Table 7-1. Observed Dissolved Oxygen values below the 8.0 mg/L water column concentration recommended to achieve the 5.0 mg/L intergravel concentrations

Site	Date	DO (mg/L)
Goose Creek at confluence with Tongue River (GC1)	5/20/09	7.99
	8/4/09	7.55
	8/11/09	7.66
	8/25/09	7.97
	9/1/09	6.98
Sackett Creek above confluence (LG19)	5/28/09	7.67
	8/4/09	6.95
	8/11/09	7.89
	9/1/09	7.99
Soldier Creek above confluence(GC4)	8/4/09	7.99
	8/11/09	7.86
	9/1/09	7.98
Little Goose Creek above Brundage Lane (LG5)	8/4/09	7.87
Big Goose Creek above confluence (BG2)	8/4/09	7.95
Kruse Creek above confluence (LG11)	8/4/09	6.96
McCormick Creek above confluence (LG9)	8/4/09	7.18

7.1.5 Turbidity

Turbidity values ranged widely throughout the watershed though observed highest and lowest generally increased from upstream to downstream (Appendix B). The highest Turbidity value was 88.1 NTU observed on Soldier Creek (GC4); the lowest value was 0.8 NTU observed on Big Goose Creek in the canyon (BG18). Turbidity samples on sampled tributaries were typically higher than the values on the mainstem sites. On Goose Creek sites, Soldier Creek, McCormick Creek, Kruse Creek, and Lower Little Goose Creek sites, the geometric mean of August turbidity samples was higher than the geometric mean of the May samples. All sites on Big Goose Creek and its tributaries had higher geometric means in May. Maximum values for 2009 were typically lower than in 2005, with the exception of McCormick Creek (LG9). Higher 2005 turbidity maximums occurred in May 2005 and are likely 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). This precipitation event resulted in local streamflows at or above the bankfull stage for an extended period (SCCD, 2006).

7.1.6 Discharge

SCCD installed and used calibrated staff gauges to determine discharge at sampling events (Appendix B). Sites on Goose Creek and Big Goose Creek had the highest discharge from May 20-28, with the peak on May 26. Discharge is highest on Soldier Creek, Beaver Creek, and Rapid Creek within this same period, with the peak on Rapid Creek occurring on May 20 instead of May 26. Discharge on Little Goose Creek sites was also highest between May 20 and May 28; however, the peak discharge occurred on May 20 instead of May 26. On tributaries to Little Goose Creek, the date of peak discharge varied, occurring on May 20 on McCormick Creek (LG9) and May 18 on Jackson (LG17) and Sackett (LG19) Creeks. There was not a corresponding increase of precipitation during May; 2009 precipitation is lower than normal throughout 2009 and there was little to no precipitation in May (Appendix Figure B-10). However, mean daily air temperatures from May 16 through May 31, were consistently higher than normal (Appendix Figure B-9). Of all of the sample stations, Kruse Creek (LG11) is the only waterbody that had the highest discharge in August, with a peak discharge on August 25.

7.1.7 Current USGS Water Quality Data

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) were summarized for parameters that correspond to those collected by SCCD in 2005 and 2009.

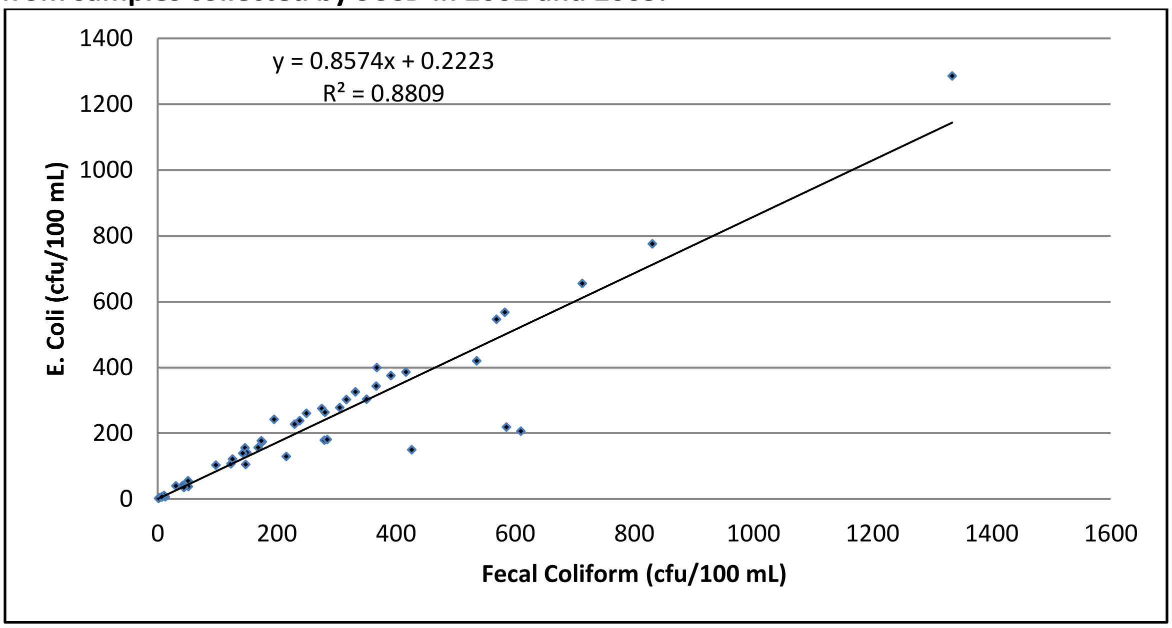
All three USGS stations reported instantaneous water temperatures that approached or exceeded 20°C in 2005-2008. There were no data collected at Station 06305700 (Goose Creek near Acme) in 2009. Temperatures recorded in 2009 at stations 06305500 (Goose Creek below Sheridan) and 06304500 (Little Goose Creek at Sheridan) were less than 20°C.

Dissolved Oxygen measurements from all three USGS stations were above the minimum instantaneous DO concentration standard of 5.0 mg/L for early life stages and in most cases, the 8.0 mg/L water column concentration recommended to achieve the 5.0 mg/L intergravel concentrations. With the exception of two measurements of 5.3 and 5.7, at 06304500 (Little Goose at Sheridan) and 06305500 (Goose Creek below Sheridan), respectively, the measurements below 8.0 mg/L were between 7.1 and 7.8 mg/L.

7.2 *E. COLI* BACTERIA

As in 2005, *E. coli* samples were obtained from each of the 18 monitoring stations during the months of May and August, 2009 (Appendix B). In 2001, 2002, and 2005, fecal coliform bacteria were the indicator for pathogens under Wyoming Water Quality Standards. However, during the revision of Chapter 1, in 2007, *E. coli* became the indicator. In anticipation of this change, SCCD collected both *E. coli* and fecal coliform at a select number of sites in 2002 and at all stations in 2005, so that *E. coli* samples could be compared to fecal coliform data from previous years. While there is no standard conversion from fecal coliform to *E. coli*, it is possible to find a relatively consistent relationship within an individual watershed (Rasmussen, 2003). Within the Goose Creek watershed, the R^2 value of this comparison was 0.88, which SCCD determined was sufficient for looking at long-term trends (Figure 7.1). SCCD converted fecal coliform results from 2001 and 2002 to *E. coli* so comparisons among years could be made (Appendix Table B-21). These converted data were not used in any listing determination or other regulatory action. Ten sites that did not exceed the fecal coliform bacteria standard in 2001 and/or 2002 did exceed the *E. coli* standard when *E. coli* figures were calculated.

Figure 7-1. Goose Creek Watershed Fecal Coliform and E. Coli bacteria comparison from samples collected by SCCD in 2002 and 2005.



The number of comparable mainstem sites exceeding the *E. coli* standard increased from 2001 to 2009 for both May and August (Table 7.2). The number of tributary sites exceeding the standard for *E. coli* in May was highest in 2005, but higher in August of each year. The highest total number of sites exceeding the *E. coli* standard occurred in August 2009.

Bacteria concentrations on the mainstem sites were typically lower than on the tributary sites. The August 2005 and 2009 levels were higher than those found during 2001 and 2002 when streamflows were much lower; the 2005 and 2009 concentrations are more 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 stream reaches were found to be impaired in 2009 as those found during previous monitoring efforts.

Table 7-2. Number of sites exceeding *E. coli* bacteria standard

Sample Period	Mainstem sites	Tributary sites	Total sites
May 2001	0	4	4
May 2002	2	1	3
May 2005	3	6	9
May 2009	4	3	7
August 2001	4	6	10
August 2002	5	7	12
August 2005	8	7	15
August 2009	9	7	16

Most stations on Goose Creek, Big Goose Creek, and Little Goose Creek showed increases in bacteria concentrations from 2005 to 2009, with an average increase of 38%. Decreases of 7-27% were observed on GC2, BG2, LG2, LG5, and LG8, all of which were for samples collected in August. The only station where a decrease was observed in May was on LG2 with a 51% decrease from 2005 to 2009. Bacteria concentrations at over half of the mainstem sites increased by 20% or more from May 2005 to May 2009. Bacteria concentrations decreased an average of 15% on tributary stations. Increases of 1-88% were observed on Beaver Creek (BG9), Rapid Creek (BG 16), and Jackson Creek (LG17) from May 2006-May2009. Beaver Creek increased 105% in August.

The general trend in bacteria concentrations on Goose Creek appears to be increasing upward since 2001. Drought conditions in 2001-2002 may have contributed to the lower concentrations. On station GC2 bacteria concentrations were highest in August 2001 and May 2009; on GC1 bacteria concentrations were highest in May 2005. On Big Goose and Little Goose Creek Stations, August sample results are typically higher than in May of the same year with a couple of exceptions. The general trend also appears to be moving upward. Station LG2, within the City of Sheridan is the main exception and showed a consistent increase in bacteria numbers from May 2002 through August 2005. For the most part, tributary stations had similar results as the mainstems. Soldier Creek behaved nearly identical to GC2, just downstream in 2001 and 2002, but more similar to GC 1 in 2005 and 2009. With the exception of Rapid Creek, tribuataries to Big Goose and Little Goose Creek followed a similar pattern as the adjacent mainstem locations, with higher bacteria levels in August.

Some of the higher bacteria concentrations during May 2005 are likely attributable to the above average spring run-off condition, resulting from the May 8-13, 2005 precipitation event. During this period, local streamflows were at or above the bankfull stage for an extended length of time (SCCD, 2006).

Conditions in 2005 and 2009 may 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. Heavy precipitation events, including run-off from snowmelt, contribute 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).

Figure 7-2. Mainstem *E. coli* Bacteria Trends in the Goose Creek Watershed

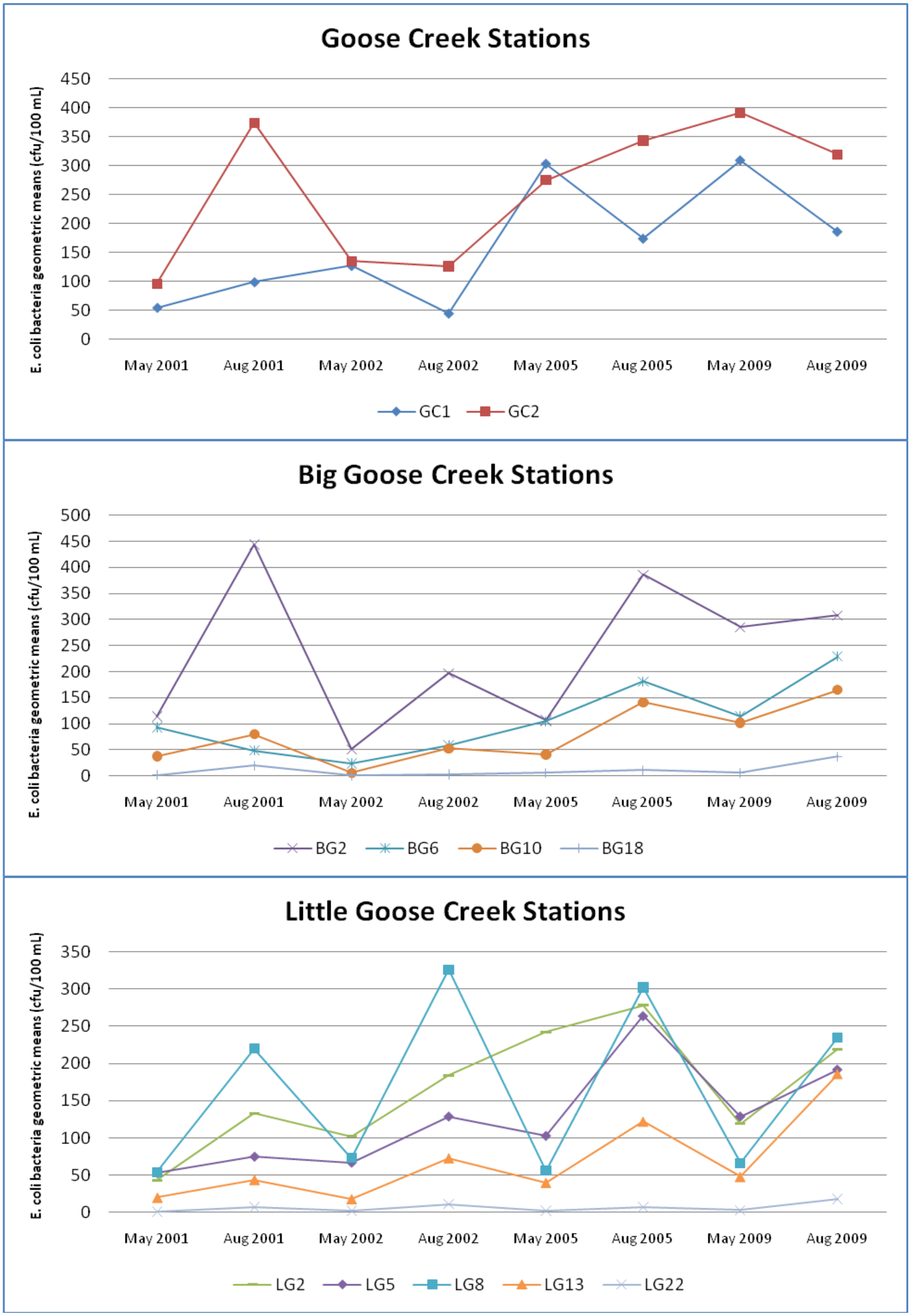
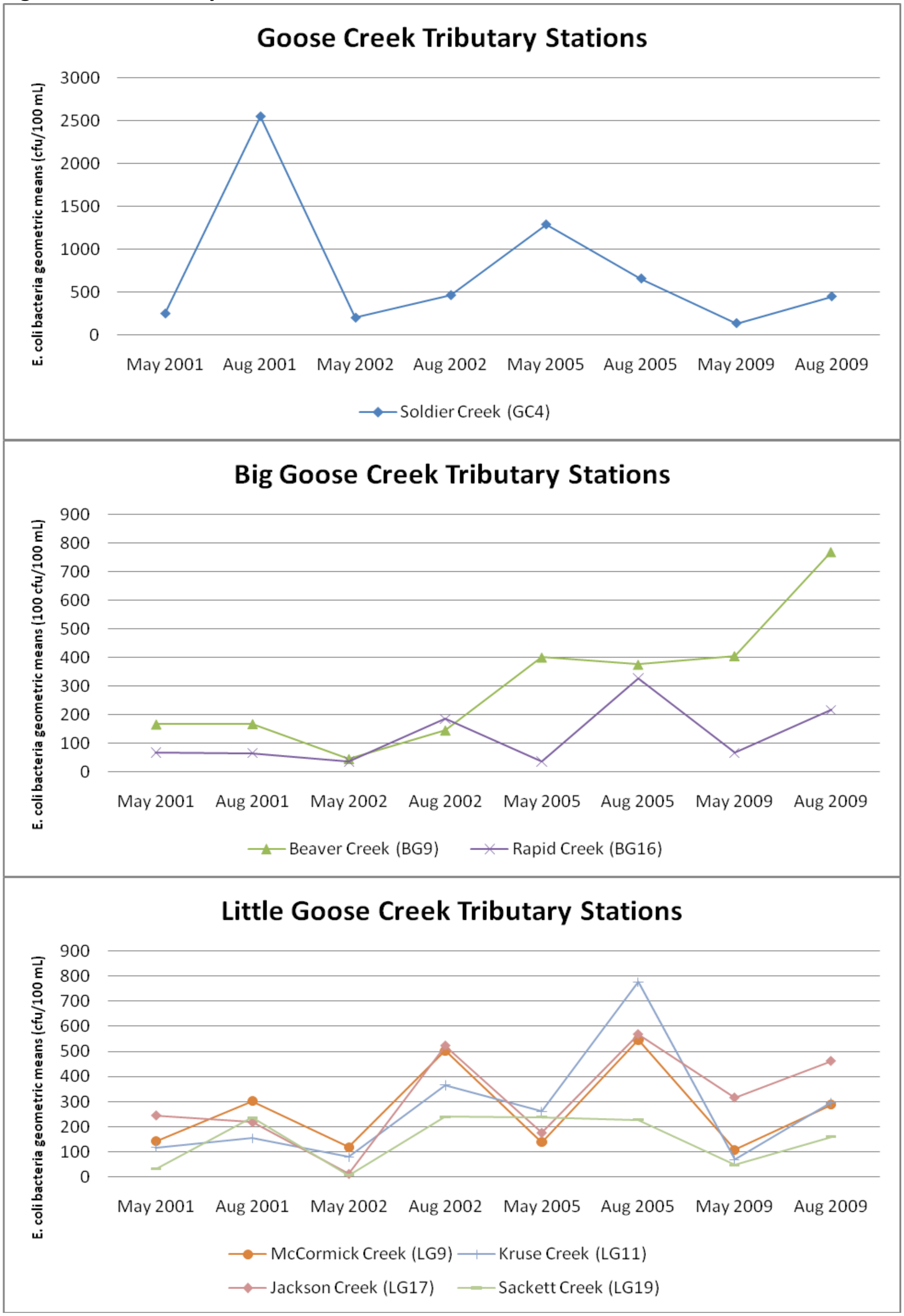


Figure 7-3. Tributary E. coli bacteria trends in the Goose Creek Watershed



The USGS collected bacteria data at two stations, Goose Creek Below Sheridan (Station 06305500) and Little Goose Creek at Sheridan (Station 06304500). Bacteria data collected by USGS included single sample E. coli and fecal coliform in 2005, 2006, and 2007; there were no geometric means calculated. At Goose Creek Below Sheridan (Station 06305500) 10 of 20 samples were above 126 col/100 mL, ranging from 180 col/100 mL in May 2005 to 2700 col/100 mL in May 2008. Samples that exceeded 126 col/100 mL occurred in May and July 2005, May and August 2006, August 2007, May and August 2008, and May and August 2009. Results were similar for Little Goose Creek At Sheridan (Station 06304500) with 9 of 20 samples above 126 col/100 mL. Samples above 126 col/100 mL ranged from 130 col/100 mL in December 2008 to 3200 col/100 mL in May 2008.

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 May 2009 through September 2009 (Appendix Figures B1-7). Continuous temperature was also monitored at these same sites during 2001, 2002 and 2005. Data loggers were positioned in relatively deep river waters and programmed to measure water temperature at 15 minute intervals. Daily and seasonal temperature variations are shown within these figures.

In general, water temperatures were cooler in 2009 and 2005 than during 2001 and 2002 at all stations. Mean daily water temperatures for 2001, 2002, 2005, and 2009 were calculated on GC1 for comparison; cooler water temperatures were typically observed during 2009 (Appendix Figure B-8). The number of days in which the maximum instream water temperatures exceeded 20°C was fewer at all sites during 2009 (Table 7-3). The maximum daily water temperatures recorded for each season were also generally lower in 2009.

Table 7-3. Continuous Water Temperature Data for 2001, 2002, 2005 and 2009

Site	Number of days when water temperatures exceeded 20°C				Maximum daily temperature recorded (°C)			
	2001	2002	2005	2009	2001	2002	2005	2009
GC1	103	93	59	59	30.17	30.36	27.96	25.42
BG2	92	76	47	34	29.88	29.14	26.86	24.01
BG6	100	90	46*	31	30.52	31.67	28.73	24.42
BG18	0	0	0	0	19.74	18.93	19.11	16.37
LG2	110	88	55*	55	29.93	29.21	29.88	26.16
LG8	90	63	25*	20	27.29	27.65	25.44	22.81
LG22	2	0	0	0	20.62	18.51	18.88	16.75

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

7.4 HYDROLOGICAL AND METEOROLOGICAL DATA

Precipitation for the May 1, 2009 through October 31, 2009 monitoring period was 7.95 inches, which was lower than the normal average collected by the National Weather Service at the Sheridan County Airport (Appendix Figure B-9). Normal precipitation for this same period averages 9.06 inches.

Average monthly air temperatures during 2009 were generally cooler than the 30 year average as compared with years 2001 and 2002 (Table 7-4). May, June, and July, had cooler air temperatures in 2009 than either 2001 or 2002. Mean Daily air temperatures were higher than normal in May 2009 and lower in June and October (Appendix Figure B-10).

Table 7-4. Summary of Mean Monthly Air Temperatures (°F) for the Sheridan County Airport (data from the National Weather Service)

Month	2001	2002	2005	2009	Normal
April	45.6	40.7	42.2	41.5	43.9
May	55.3	50.3	49.2	53.4	52.5
June	62.9	64.3	61.8	58.3	61.6
July	74.0	75.1	71.7	67.1	68.8
August	73.1	65.3	66.6	66.4	68.2
September	61.2	58.4	58.0	62.3	57.1
October	45.1	38.3	46.0	37.8	45.1
Season Average	59.6	56.0	56.5	55.3	56.7

USGS did not collect discharge information within the watershed after 2008; comparisons of 2009 Mean daily flow and Normal Mean daily flow could not be compared. Instantaneous discharge measurements collected by SCCD in 2009 at site GC1 were typically higher than the Normal Mean Daily Discharge at USGS Station 06305700 (Goose Creek Near Acme) for the period between 1984 and 2007 (Appendix B-11).

7.5 BENTHIC MACROINVERTEBRATES

7.5.1 Previous Benthic Macroinvertebrate Sampling

The historic 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). Subsequent benthic macroinvertebrate data collected by WDEQ in 2004 and SCCD in 2005 in the Goose Creek watershed were presented and discussed in the *2005 Goose Creek Watershed Monitoring Project Final Report* (SCCD, 2006). No benthic macroinvertebrate samples were collected in the Goose Creek watershed during 2003, 2006, 2007 and 2008.

During 2001 and 2002, a total of twenty-one samples were collected each year by SCCD from nineteen stations (SCCD, 2003). A total of seven benthic macroinvertebrate samples were collected by SCCD in 2005 from six stations (SCCD, 2006). WDEQ collected ten benthic macroinvertebrate samples at nine stations in the Goose Creek watershed during 2004. The 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). With the exception of four of the 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 was presented in Table 7-4 in SCCD (2006).

7.5.2 Benthic Macroinvertebrate Sampling In 2009

A total of seven benthic macroinvertebrate samples were collected by SCCD in 2009 from six stations. Two benthic macroinvertebrate samples were collected from two Goose Creek stations (station GC1 and station GC2), three 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 Big Goose Creek station BG2. The duplicate sample was used only 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.

The sampling stations and the number of samples collected by SCCD were the same in both 2005 and 2009. However, the reduced number of sample stations and samples collected during 2005 and 2009 when compared to the sampling regime in 2001 and 2002 precluded a complete evaluation of the benthic macroinvertebrate communities between years and the comparison of biological condition at each station in the Goose Creek watershed.

Field benthic macroinvertebrate sample collection methods and laboratory analytical methods employed by SCCD in in 2001, 2002 and 2005 were the same as those used for sampling in 2009. In addition, WDEQ benthic macroinvertebrate sampling methods for samples collected in 2004 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.

7.5.3 Benthic Invertebrate Taxa

Taxa lists for Goose Creek watershed benthic macroinvertebrate samples collected in 2009 are presented in Appendix C, Tables C-1 through C-7. The cumulative list of macroinvertebrate taxa collected in the Goose Creek watershed from 2001 through 2009 is presented in Appendix C, Table C-8. The list of benthic macroinvertebtrate metrics for samples collected in 2001, 2002, 2004, 2005 and 2009 for those stations sampled during 2009 is presented in Appendix C, Tables C-9 through C-11.

A total of 210 benthic macroinvertebrate taxa have been identified since 2001 from a total of 66 samples collected during the project (Appendix C, Table C-8). All taxa have been previously identified from north-central Wyoming streams and rivers with the exception of the mayfly genera *Tricorythodes explicates* and *Stenonema femoratum* and, and the cranefly genus *Pseudolimnophila*. The common mayfly genus *Tricorythodes minutus* was synonymized with *Tricorythodes explicates* by Baumgardner (2009). Accordingly, previous taxa lists containing *Tricorythodes minutus* will be replaced with *Tricorythodes explicates.* The presence of *Stenonema femoratum* is likely due to enhanced taxonomic resolution since the genus *Stenonema* has been previously identified at Goose Creek station GC3 and Big Goose Creek stations BG8 and BG10. *Stenonema femoratum* was identified from six sampling stations during 2009 suggesting that it may be common within the lower portion of the watershed.

The cranefly genus *Pseudolimnophila* is widespread throughout the United States (Merritt and Cummins, 2008) 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.

No threatened or endangered benthic macroinvertebrate taxa or fish species (incidentally captured during macroinvertebrate sampling) were identified. The widespread occurrence of the freshwater shrimp genera *Gammarus* and *Hyalella*, and the freshwater shrimp species group *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.

As noted in SCCD (2006), the midge fly genus *Zavrelimyia* was reported from four (N = 4) samples collected by WDEQ in 2004 in the Goose Creek watershed. The presence of this taxon in the Goose Creek watershed was surprising since from over 950 samples collected from north-central Wyoming streams, *Zavrelimyia* has been reported only once from Little Sourdough Creek, a cold-water mountain stream in the BNF 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 was unlikely since the streams represent warm-water habitat. It is probable 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 through 2009 (Appendix C, Table C-8), but was not identified in the 2004 WDEQ samples. This observation suggests that *Pentaneura* was misidentified as *Zavrelimyia*. 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 97% of the total samples collected (Appendix C, Table C-8). The mayfly genus *Tricorythodes* occurred in 93% of samples and oligochaete worms occurred in 89% of samples. The riffle beetle genus *Microcylloepus* (89%), the mayfly genera *Tricorythodes* (94%), the mayfly species *Fallceon quilleri* (88%), the midge fly genera *Cricotopus* (88%) and *Rheotanytarsus* (82%), Acari (water mites) (86%) 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.

Chironomidae, Coleoptera, Diptera, and Ephemeroptera were present in 100 percent of samples collected in the Goose Creeks watershed since 2001. Oligochaeta were present in 89 percent of samples. The Diptera family Chironomidae (midges) had the greatest number of taxa in the project area (N = 50 taxa), followed by the order Ephemeroptera (N = 33 mayfly taxa), the order Trichoptera (N = 30 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-8).

7.6 BIOLOGICAL CONDITION

Biological condition scores were determined using the Wyoming Stream Integrity Index (WSII) initially developed by Jessup and Stribling (2002) and revised by Hargett and ZumBerge (2006). The WSII is based on the analysis of benthic macroinvertebrate monitoring data collected by WDEQ from 1993 through 2001 from multiple reference and non-reference quality streams statewide. The WSII identified seven bioregions for Wyoming. Each bioregion used different scoring criteria because the biological communities naturally differ between bioregions.

Biological condition scoring criteria developed for the Bighorn and Wind River Foothills bioregion were used to evaluate biological condition for streams in the lower Goose Creeks watershed. Table 7-5 lists the WSII metrics and metric formulae used to determine biological condition for benthic macroinvertebrate communities in the Bighorn and Wind River Foothills bioregion.

Table 7-5. Wyoming Stream Integrity Index (WSII) metrics and scoring criteria for benthic macroinvertebrate communities in the Bighorn and Wind River Foothills bioregion (from Hargett and ZumBerg, 2006)

Macroinvertebrate Metric	Metric Scoring Formulae	5^{th} or 95^{th} %ile (as per formula)
No. Ephemeroptera Taxa	100*X / 95^{th}%ile	9
No. Trichoptera Taxa	100*X / 95^{th}%ile	11
No. Plecoptera Taxa	100*X / 95^{th}%ile	7
% Non-insect	100*(74-X) / (74-5^{th}%ile)	0.3
% Plecoptera	100*X / 95^{th}%ile	19
% Trichoptera (w/o Hydropsychidae) (% within the Trichoptera)	100*X / 95^{th}%ile	100
% Collector-gatherer	100*(91.4-X) / (91.4-5^{th}%ile)	16.5
% Scraper	100*X / 95^{th}%ile	50.3
HBI	100*(8-X) / (8-5^{th}%ile)	1.8
No. Semivoltine Taxa (less semivoltine Coleoptera)	100*X / 95^{th}%ile	5

The calculated biological condition value was then used to rate the biological community as Full-support, Indeterminate, or Partial/Non-support (Table 7-6). A biological condition rating of Full-support indicates full support for narrative aquatic life use. The Indeterminate biological classification is not an attainment category in itself, but is a designation indicating the need for additional information or data to determine the proper narrative aquatic life use designation such as Full-support or Partial/Non-support (Hargett and ZumBerge, 2006). The Partial/Non-support classification indicates the aquatic community is stressed and water quality or habitat improvements are required to restore the stream to full support for narrative aquatic life use.

Table 7-6. Assessment rating criteria for benthic macroinvertebrate communities based on the Wyoming Stream Integrity Index (WSII; from Hargett and ZumBerg, 2006) in the Bighorn and Wind River Foothills bioregion of Wyoming.

Rating of Biological Condition (Aquatic Life Use Support)	Bighorn and Wind River Foothills bioregion
Full Support	>62.1
Indeterminate Support	41.4 – 62.1
Partial/ (Non - Support)	0-41.3

Table 7-7 lists other select macroinvertebrate metrics that may be evaluated when assessing biological condition since their expected response to water quality and habitat change is relatively well known. Biological condition for each station sampled during 2009 is presented in Table 7-8 and illustrated in Figure 7-4.

Table 7-7. Definition of select macroinvertebrate metrics and expected response to perturbation including water quality and habitat change (from King, 1993 and Barbour et al., 1999).

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

Table 7-8. Biological condition score and rating for comparable historic and current Goose Creek Watershed benthic macroinvertebrate sample stations sampled in 2009; based on the Wyoming Stream Integrity Index for the Bighorn and Wind River Foothills bioregion (from Hargett and ZumBerge, 2006).

Sampling Station and Year	Sampling Group	Score	Rating
Goose Creek GC1 (2009)	SCCD	32.8	Partial/Non Support
Goose Creek GC1 (2005)	SCCD	38.4	Partial/Non Support
Goose Creek GC1 (2002)	SCCD	34.9	Partial/Non Support
Goose Creek GC1 - Dup (2002)	SCCD	37.9	Partial/Non Support
Goose Creek GC1 (2001)	SCCD	33.8	Partial/Non Support
Goose Creek GC1 (1998)	WDEQ	40.2	Partial/Non Support
Goose Creek GC2 (2009)	SCCD	30.1	Partial/Non Support
Goose Creek GC2 (2005)	SCCD	29.4	Partial/Non Support
Goose Creek GC2 (2002)	SCCD	25.0	Partial/Non Support
Goose Creek GC2 - Dup (2002)	SCCD	26.7	Partial/Non Support
Goose Creek GC2 (2001)	SCCD	21.1	Partial/Non Support
Big Goose Creek BG2 (2009)	SCCD	37.6	Partial/Non Support
Big Goose Creek BG2 - Dup (2009)	SCCD	37.6	Partial/Non Support
Big Goose Creek BG2 (2005)	SCCD	31.8	Partial/Non Support
Big Goose Creek BG2 (2004)	WDEQ	35.4	Partial/Non Support
Big Goose Creek BG2 (2002)	SCCD	35.2	Partial/Non Support
Big Goose Creek BG2 (2001)	SCCD	40.9	Partial/Non Support
Big Goose Creek BG2 (1998)	WDEQ	47.4	Indeterminate Support
Big Goose Creek BG2 (1994)	WDEQ	34.1	Partial/Non Support
Big Goose Creek BG10 (2009)	SCCD	46.6	Indeterminate Support
Big Goose Creek BG10 (2005)	SCCD	37.6	Partial/Non Support
Big Goose Creek BG10 (2002)	SCCD	45.8	Indeterminate Support
Big Goose Creek BG10 (2001)	SCCD	55.1	Indeterminate Support
Little Goose Creek LG2A (2009)	SCCD	32.1	Partial/Non Support
Little Goose Creek LG2A (2005)	SCCD	33.9	Partial/Non Support
Little Goose Creek LG2A (2004)	WDEQ	27.6	Partial/Non Support
Little Goose Creek LG2A (2002)	SCCD	32.1	Partial/Non Support
Little Goose Creek LG2A (2001)	SCCD	24.4	Partial/Non Support
Little Goose Creek LG2A (1998)	WDEQ	35.9	Partial/Non Support
Little Goose Creek LG2A (1997)	WEST	30.2	Partial/Non Support
Little Goose Creek LG2A (1994)	WDEQ	22.0	Partial/Non Support
Little Goose Creek LG10 (2009)	SCCD	38.7	Partial/Non Support
Little Goose Creek LG10 (2005)	SCCD	33.7	Partial/Non Support
Little Goose Creek LG10 (2002)	SCCD	37.9	Partial/Non Support
Little Goose Creek LG10 (2001)	SCCD	44.6	Indeterminate Support
Little Goose Creek LG10 - Dup (2001)	SCCD	42.5	Indeterminate Support

7.6.1 Goose Creek Biological Condition

Biological condition was partial/non supporting at Goose Creek stations GC1 and GC2 during sampling each year (Table 7-8). A general improvement in biological condition was observed since 2001 at Goose Creek station GC2 while a slight decline in biological condition was present since 1998 at Goose Creek station GC1. The greatest improvement in biological condition since 2001 occurred at station GC2 located downstream of the Sheridan WWTF (Figure 7-4).

Continued sampling should be conducted at station GC1 and station GC2 and at all original Goose Creek stations to determine if the changes observed in biological condition through 2009 continue. However, it should be noted that even though biological condition may appear to improve at certain Goose Creek stations, the generally low biological condition scores continue to indicate partial/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.

7.6.2 Big Goose Creek Biological Condition

Biological condition was partial/non supporting at Big Goose Creek station BG2 during the most recent sampling event in 2009 (Table 7-8). Biological condition has varied at this station since 1994 (Figure 7-4). Biological condition increased from 1994 to 1998, then gradually declined from 1998 to 2005. A slight increase in biological condition was observed from 2005 to 2009. A similar pattern was observed at station BG10 where biological condition decreased from 2001 to 2005 with a subsequent increase in biological condition from 2005 to 2009.

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 have been consistently sampled. Whether biological condition has improved or declined at the other Big Goose Creek stations since 2002 is unknown since they were not sampled.

Continued macroinvertebrtate sampling should be conducted at all Big Goose Creek stations to track changes in biological condition.

7.6.3 Little Goose Creek Biological Condition

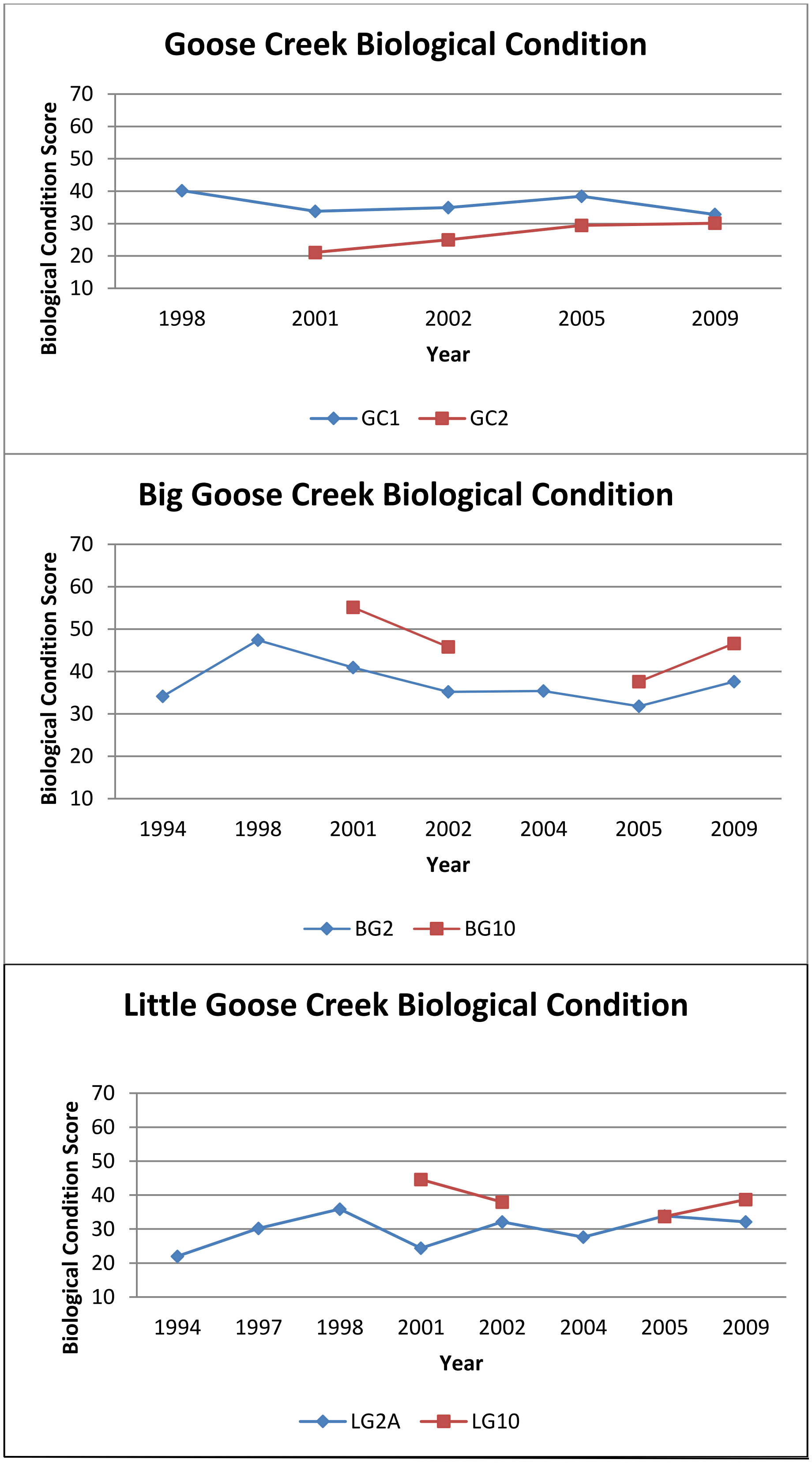
Biological condition at station LG2A has been partial/non supporting since sampling by WDEQ began in 1994 (Table 7-8; Figure 7-4). Biological condition scores were more variable at station LG2A when compared to any other station in the Goose Creek watershed. This observation may be due to the fact that this station is located downstream of a large storm drain outfall that likely discharges highly variable quantity and quality of storm drain effluent. In contrast, biological condition at station LG10 decreased from 2001 to 2005 with a subsequent increase in biological condition from

2005 to 2009. This observation was similar in pattern to that described for Big Goose Creek station BG10 (Figure 7-4).

Change in the benthic macroinvertebrate communities through the entire length of Little Goose Creek within the project area could not be determined because only two stations (LG2A and LG10 were sampled out of the total seven benthic macroinvertebrate stations established in 2001. Whether biological condition has improved or declined at the other Little Goose Creek stations since 2002 is unknown since they were not sampled.

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.

Figure 7-4. Biological condition at select stations in the Goose Creek Watershed.



7.7 HABITAT ASSESSMENTS

7.7.1 Previous Habitat Assessments

The historic 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). Subsequent habitat assessment data collected by WDEQ in 2004 in the Goose Creek watershed were presented and discussed in the *2005 Goose Creek Watershed Monitoring Project* (SCCD, 2006). No habitat assessments were conducted in the Goose Creek watershed during 2003, 2006, 2007 and 2008.

During 2001 and 2002, a total of nineteen habitat assessments were conducted each year by SCCD from nineteen stations (SCCD, 2003). 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 reduced number of stations assessed during 2005 (as well as during 2009) prevented a direct 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.

7.7.2 Habitat Assessments In 2009

Habitat assessments in 2009 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 in 2009 from six stations. Two habitat assessments were conducted from two Goose Creek stations (station GC1 and station GC2), two habitat assessments were conducted from two Big Goose Creek stations (station BG2 and station BG10) and two samples habitat assessments were conducted from two Little Goose Creek stations (station LG2A and station LG10).

The habitat assessment stations and the number of habitat assessments performed by SCCD were the same in both 2005 and 2009. However, the reduced number of stations and assessments conducted during 2005 and 2009 when compared to the sampling regime in 2001 and 2002 precluded a complete evaluation of the habitat between years and the comparison of habitat condition at each station in the Goose Creek watershed.

Field habitat assessment methods employed by SCCD in in 2001, 2002 and 2005 were the same as those used in 2009.

The habitat assessments were conducted in September or October. Habitat assessments at a station were generally conducted on sampling dates within ± two (2) weeks of one another each year. Results from the habitat assessments are presented in Appendix D. 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.

7.7.3 Goose Creek Habitat Assessments

There was no large change in habitat at Goose Creek stations GC1 or GC2 since 2001. 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 126 in 2009 (Appendix D, Table D-1). Stream substrate composition at station GC1 and station GC2 generally improved since 2001 with an increase in percent cobble and percent 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) was variable at station GC1 and station GC2 since 2001.

7.7.4 Big Goose Creek Habitat Assessments

Habitat quality at Big Goose Creek station BG2 has improved slightly from 2001 to 2009 (Appendix D, Table D-2). The habitat quality at station BG10 declined from 2001 to 2005, then improved to 2009. 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). The percent sand subsequently dropped approximately 19 in 2009 to 3 percent. This reduction in sand was encouraging since 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 from 2002 to 2005 indicated an unknown disruption within the watershed upstream of this station that contributed sand to the stream bed. Stream substrate composition has been stable at station BG10 from 2001-2002 to 2009. Cobble dominated the substrate and comprised from 75 percent of the substrate in 2001, 91 percent in 2002, 80 percent in 2005 and 81 percent of substrate in 2009 (Appendix D, Table D-2)

7.7.5 Little Goose Creek Habitat Assessments

Habitat quality has remained low at Little Goose Creek station LG2A since 2001-2002 (Appendix D, Table D-3). The lower habitat score (102.5) at station LG2A during 2009 was due primarily to channelization of Little Goose Creek for flood control in Sheridan that reduced undercut banks, the number of pools, instream cover for fish, and the riparian zone. The channelization for flood control 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 2nd lowest among all stations assessed in the Goose Creeks watershed during 2001-2002 (SCCD, 2003). Cobble dominated the stream substrate followed by coarse gravel and then sand. Sand has averaged about 18 percent of the stream substrate since 2001 which was considered relatively high.

There were no large changes in habitat at Little Goose Creek station LG10 from 2001 to 2009 (Appendix D, Table D-3). The average total habitat assessment score was 138 during this period compared to an average total habitat assessment score of 103 at station LG2A. Cobble dominated the stream substrate followed by coarse gravel and then sand. Sand has averaged about 18 percent of the stream substrate since 2001 which was considered relatively high.

7.7.6 Relation Of Habitat To Biological Condition

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 Indeterminate Support or Partial/ (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.

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 and 2009. 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, Tongue River, and Prairie Dog Creek watersheds, SCCD has observed the greatest variations in bacteria concentrations during and shortly after heavy precipitation and/or snow melt run-off events.

The general trend in bacteria concentrations on Goose Creek appears to be increasing upward since 2001. Drought conditions in 2001-2002 may have contributed to the lower concentrations in those years. Wetter conditions in 2005 and 2009 may have resulted in increased bacteria concentrations through additional run-off and overland flow and resuspension of instream sediments. The extremes in short and long-term weather conditions during the years of monitoring on the watershed have produced bacteria data that are not directly comparable between years. 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.

Biological condition at Goose Creek, Big Goose Creek and Little Goose Creek stations sampled in 2009 were partial/non supporting based on the evaluation of the stream benthic macroinvertebrate communities. The partial/non-support classification indicates the aquatic communities are stressed and water quality or habitat improvements are required to restore the stream to full support for the narrative WDEQ standard for aquatic life use. Planning and implementation of remedial measures to restore full aquatic life use support in the streams in the Goose Creek watershed should continue. Continued benthic macroinvertebrate sampling should be conducted at stations in the watershed to track changes in biological condition.

The positive effects on water quality improvements through the local watershed planning and implementation efforts are not readily measurable at this time. The watershed planning process has improved widespread local awareness about several important resource issues and has led to more public interest in the watershed. The SCCD anticipates that voluntary, incentive based watershed planning and implementation efforts will be successful; however, it may require several years to actually measure these achievements. Continued monitoring can provide information on water quality changes over the long-term. SCCD will use information from the Goose Creek Watershed TMDL to determine whether changes in monitoring sites, frequency, and/or parameters should be considered.

9. REFERENCES

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APPENDICES

APPENDIX A
GOOSE CREEK WATERSHED MAPS

APPENDIX B
2009 WATER QUALITY DATA ON THE GOOSE CREEK WATERSHED

APPENDIX C
BENTHIC MACROINVERTEBRATE DATA

APPENDIX D
HABITAT DATA

APPENDIX E
QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION