GEI Consultants

Geotechnical
Environmental
Water Resources
Ecological

Summary of Aquatic Monitoring Data for Streams in the Vicinity of Wharf and Golden Reward Mines, Lawrence County, SD

Submitted to:
Wharf Resources (USA), Inc.
10928 Wharf Rd
Lead, SD 57754

Submitted by:
GEI Consultants, Inc.
Ecological Division
4601 DTC Boulevard, Suite 900
Denver, CO 80237

December 2010
Project 100500

Table of Contents

1.0 Introduction 1

1.1 Monitoring History 3

1.1.1 Wharf 3

1.1.2 Golden Reward 5

2.0 Study Area 6

2.1 Wharf 6

2.1.1 Annie Creek 6

2.1.2 Ross Valley 7

2.1.3 Lost Camp Gulch 7

2.1.4 Deadwood Creek 7

2.1.5 False Bottom Creek 8

2.1.6 McKinley Gulch 8

2.1.7 Cleopatra Creek 8

2.1.8 Reference Sites 9

2.2 Golden Reward 9

2.2.1 Fantail Creek 9

2.2.2 Nevada Gulch 10

2.2.3 Stewart Gulch 10

2.2.4 Whitetail Creek 10

3.0 Methods 11

3.1 Habitat 11

3.1.1 Standard Habitat Method 11

3.1.2 South Dakota Habitat Method 12

3.2 Fish Populations 13

3.3 Benthic Macroinvertebrate Populations 14

3.4 Periphyton Populations 16

3.5 Data Analysis 17

4.0 Results and Discussion 20

4.1 Habitat 20

4.1.1 Wharf 20

4.1.2 Golden Reward 26

4.2 Fish Populations 30

4.2.1 Wharf 30

4.2.2 Golden Reward 37

4.3 Benthic Macroinvertebrate Populations 40

4.3.1 Wharf 40

4.3.2 Golden Reward 58

4.4 Periphyton Populations 69

4.4.1 Wharf 69

4.4.2 Golden Reward 75

5.0 Conclusions 80

5.1 Habitat 80
5.2 Fish 81
5.3 Benthic Macroinvertebrates 82
5.4 Periphyton 84

6.0 References 86

List of Figures

Figure 1: Aquatic biological sampling sites on streams in the vicinity of the Wharf and Golden Reward mines and expansion areas near Lead, South Dakota.

Figure 2: Mean daily flow of Annie Creek using USGS data from January 1990 to October 2010, near Lead, South Dakota.

Figure 3: Density and biomass of mountain suckers collected during sampling at Site AC-2-BIO in Annie Creek, 1990 - 2010. NS = Not Sampled, NM = Not Measured, and NF = Sampled But No Fish collected.

Figure 4: Density and biomass of brook trout, brown trout, and mountain suckers collected at Site AC-3-BIO in Annie Creek, 1990 - 2010. NS = Not Sampled.

Figure 5: Density and biomass of brook trout collected at Site DC-2-BIO in Deadwood Creek, 2001 - 2010. NS = Not Sampled.

Figure 6: Density and biomass of brook trout collected during sampling at Site FB-1-BIO in False Bottom Creek, 1995 - 2010. NS = Not Sampled.

Figure 7: Density and biomass of brook trout collected during sampling at the Stewart Gulch Site, 1986 - 2010. NR = Not Reported. NS = Not Sampled.

Figure 8: Density and biomass of brook trout collected during sampling at the Whitetail Creek Site, 1986 - 2010. NR = Not Reported. NS = Not Sampled.

Figure 9: Benthic invertebrate density (1992 – 2005) and abundance (2006 – 2010) data for Site AC-1-BIO on Annie Creek. S = Sampled but results not presented as methods not comparable. * = Ephemeroptera were present at densities < 40 organisms/m^2.

Figure 10: Total number of invertebrate taxa and EPT taxa for Site AC-1-BIO on Annie Creek, 1992 – 2010. SDDENR sampling protocols were followed in 2006 – 2010, while other sampling protocols were used prior to 2006. S = Sampled but results not presented as methods not comparable.

Figure 11: Benthic invertebrate density (1992 – 2004) and abundance (2005 – 2010) data for Site AC-2-BIO on Annie Creek. S = Sampled but results not presented as methods not comparable.

Figure 12: Number of taxa and number of EPT taxa for Site AC-2-BIO on Annie Creek, 1992 - 2010. SDDENR sampling protocols were followed in 2006 – 2010, while other sampling protocols were used prior to 2006. S = Sampled but results not presented as methods not comparable.

Figure 13: Benthic invertebrate density (1992 – 2005) and abundance (2006 – 2010) data for Site AC-3-BIO on Annie Creek. S = Sampled but results not presented as methods not comparable. NS = Not Sampled.

Figure 14: Number of taxa and number of EPT taxa for Site AC-3-BIO on Annie Creek, 1992 - 2010. SDDENR sampling protocols were followed in 2006 – 2010, while other sampling

protocols were used prior to 2006. S = Sampled but results not presented as methods not comparable. NS = Not Sampled.

Figure 15: Benthic invertebrate abundance (2006 – 2010) data for Site RV-2-BIO on Ross Valley. NS = Not Sampled.

Figure 16: Number of taxa and number of EPT taxa for Site RV-2-BIO on Ross Valley, 2006 - 2010. SDDENR sampling protocols were followed in all years. NS = Not Sampled.

Figure 17: Benthic invertebrate density (1992 – 1999) and abundance (2009 - 2010) data for Site DC-1-BIO on Deadwood Creek.

Figure18: Number of taxa and number of EPT taxa for Site DC-1-BIO on Deadwood Creek, 1995 - 2010. SDDENR protocols were followed for sample collection in 2009 and 2010, while other sampling protocols were used from 1995 – 1999.

Figure 19: Benthic invertebrate density (2000 – 2005) and abundance (2010) data for Site DC-2-BIO on Deadwood Creek, 2000 - 2010. NS = Not Sampled.

Figure 20: Number of taxa and number of EPT taxa for Site DC-2-BIO on Deadwood Creek, 2000 – 2010. SDDENR protocols were followed for sample collection in 2010, while other sampling protocols were used from 2000 - 2005. NS = Not Sampled.

Figure 21: Density (1995 – 2005) and abundance (2006 – 2010) parameters for Site FB-1-BIO on False Bottom Creek. * = Ephemeroptera were present at abundances ≤ 5 organisms/sample.

Figure 22: Number of taxa and number of EPT taxa for Site FB-1-BIO on False Bottom Creek, 1995 - 2010. SDDENR protocols were followed for sample collection in 2006 – 2010, while other sampling protocols were used prior to 2006.

Figure 23: Benthic invertebrate abundance (2006 – 2010) data for Site CC-1A-BIO on Cleopatra Creek. NS = Not Sampled. * = Ephemeroptera present at abundances ≤ 15 organisms/sample.

Figure 24: Number of taxa and number of EPT taxa for Site CC-1A-BIO on Cleopatra Creek, 2006 - 2010. SDDENR sampling protocols were followed in all years. NS = Not Sampled.

Figure 25: Density (1995 – 2004) and abundance (2005 – 2010) data for the Fantail Creek site. * = ephemeropteran abundance ≤ 18 organisms.

Figure 26: Number of taxa and number of EPT taxa parameters for Fantail Creek, 1995 - 2010. SDDENR protocols were followed for sample collection in 2005 through 2010, while other sampling protocols were used prior to 2005.

Figure 27: Density (1995 – 2004) and abundance (2005 and 2010) data for Upper Nevada Gulch. NS = Not Sampled.

Figure 28: Number of taxa and number of EPT taxa parameters for Upper Nevada Gulch, 1995 - 2010. SDDENR protocols were followed for sample collection in 2005 and 2010, while other sampling protocols were used prior to 2005.

Figure 29: Density (1995 – 2004) and abundance (2005 – 2010) data for the Lower Nevada Gulch site.

Figure 30: Number of taxa and number of EPT taxa for the Lower Nevada Gulch site, 1995 - 2010.

Figure 31: Density (1995 – 2004) and abundance (2005 – 2010) data for the Stewart Gulch site.

Figure 32: Number of taxa and number of EPT taxa for the Comparison of richness parameters for the Stewart Gulch site, 1995 - 2010. SDDENR protocols were followed for sample collection in 2005 through 2010, while other sampling protocols were used prior to 2005.

Figure 33: Density (1995 – 2004) and abundance (2005 – 2010) data for the Whitetail Creek site.

Figure 34: Number of taxa and number of EPT taxa for the Whitetail Creek site, 1995 – 2010. SDDENR protocols were followed for sample collection in 2005 through 2010, while other sampling protocols were used prior to 2005.

Figure 35: Number of periphyton taxa for sites on Annie Creek, Lost Camp Gulch, and Ross Valley near the Wharf Mine, 2000 - 2010. NS = Not Sampled

Figure 36: Number of periphyton taxa for sites on False Bottom Creek, Cleopatra Creek, and Deadwood Creek near the Wharf Mine, 2000 - 2010. NS = Not Sampled
Figure 37: Number of periphyton taxa for sites in streams in the vicinity of the Golden Reward Mine, 2000 - 2010.

List of Tables

Table 1: GPS coordinates for Wharf and Golden Reward sites included in the baseline analysis.

List of Appendices

Appendix A: Aquatic Biological Monitoring Activities for Wharf and Golden Reward
Appendix B: Flow Data
Appendix C: Historical Fish Data
Appendix D: Historical Benthic Macroinvertebrate Data - Wharf Sites
Appendix E: Historical Benthic Macroinvertebrate Data - Golden Reward Sites
Appendix F: Historical Periphyton Data - Wharf Sites
Appendix G: Historical Periphyton Data - Golden Reward Sites

1.0 Introduction

Wharf Resources (USA), Inc. (Wharf) is submitting a large-scale mine permit in anticipation of expanding their existing heap-leach gold operations. The permit area would include expansions near the Wharf and Golden Reward mines, both of which are located west of Lead, South Dakota, in Lawrence County (Figure 1). The proposed Wharf and Golden Reward Expansion permit areas consists of approximately 73 and 140 acres, respectively, of private land. The Wharf expansion areas are located along the southern edge of the existing Wharf Mine permit boundary, and the Golden Reward expansion areas are located along the eastern base of Terry Peak. Prior to this expansion, baseline environmental studies in these expansion areas are to be completed per the requirements of the South Dakota Department of Environment and Natural Resources (SDDENR). As part of these studies, this report describes the existing aquatic ecology in the proposed mining area that may be potentially affected by mining operations.

GEI Consultants, Inc. (GEI) has conducted aquatic species and habitat surveys for multiple years on streams that flow through or have drainages within the expansion areas for Wharf and Golden Reward Mining Company (GRMC). These surveys have provided recent and historical data on fish populations, benthic macroinvertebrate populations, periphyton populations, and habitat for the following streams in the vicinity of Lead: Annie Creek, Ross Valley, Deadwood Creek, False Bottom Creek, McKinley Gulch, Cleopatra Creek, Nevada Gulch, Fantail Creek, Stewart Gulch, and Whitetail Creek.

The most recent data for these streams were collected in August 2010 as part of the current sampling plan. In addition, the normal scheduled annual sampling for Wharf and GRMC was supplemented by sampling a new site on Lost Camp Gulch, sampling previously discontinued sites on Deadwood Creek and Nevada Gulch, and adding fish and habitat sampling at sites that were not scheduled to be sampled for these parameters until 2011. These supplementary sampling sites and parameters were included to better characterize the aquatic ecology of the expansion area for the baseline analysis.

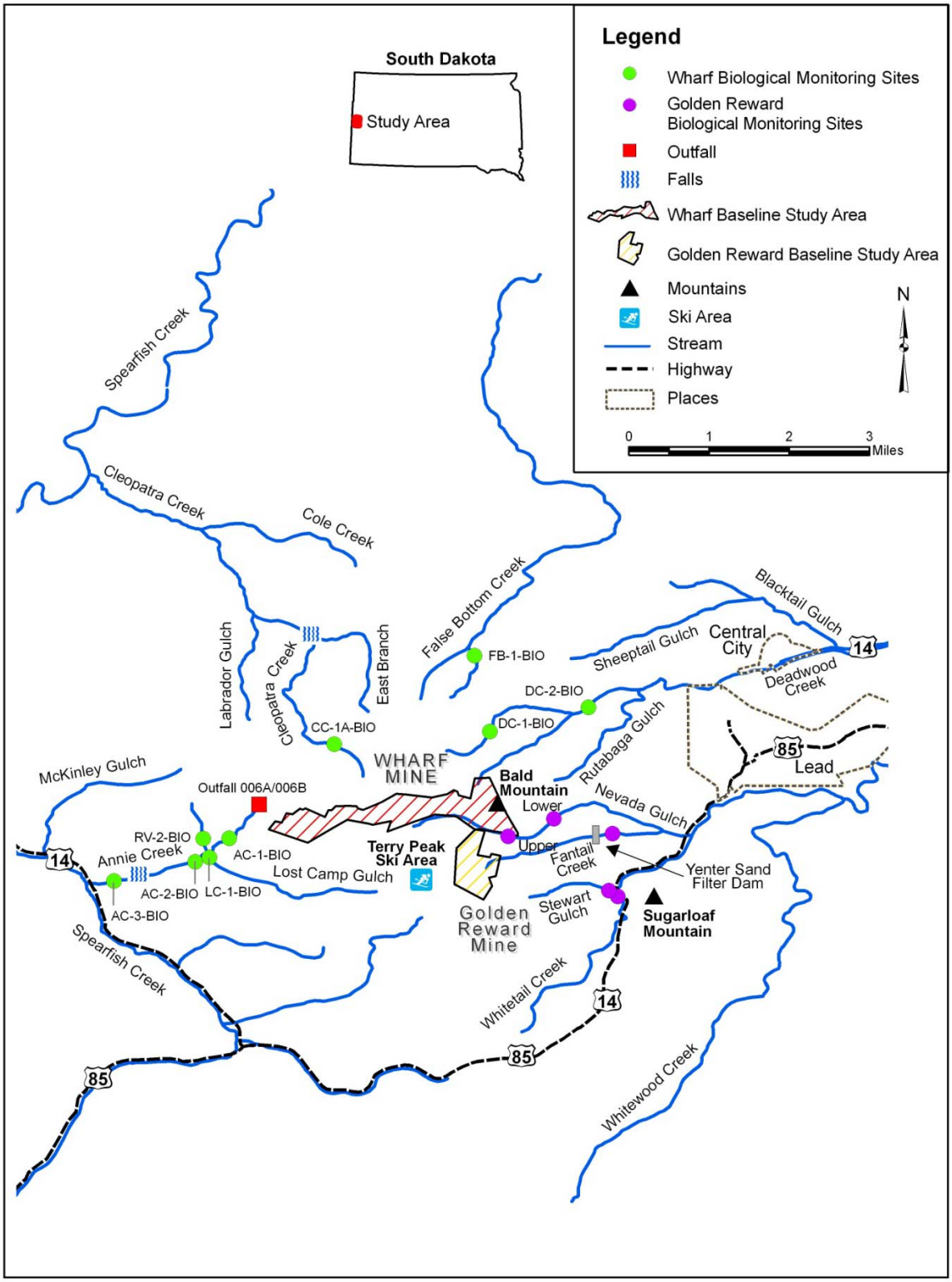

Figure 1: Aquatic biological sampling sites on streams in the vicinity of the Wharf and Golden Reward mines and expansion areas near Lead, South Dakota.

1.1 Monitoring History

1.1.1 Wharf

Limited sampling began on Annie Creek in 1990, and habitat, fish, and benthic macroinvertebrates were more extensively sampled for the Annie Creek/Reliance Tailings Project in 1992 (Chadwick & Associates, Inc. [C&A] 1993, Mariah Associates, Inc. 1990, 1992a, 1992b). This sampling provided data on the existing fish populations at six sites in Annie Creek, and indicated that brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) were limited to the lower portion of Annie Creek, upstream of the confluence with Spearfish Creek. Near the middle of Annie Creek, mountain suckers (*Catostomus platyrhynchus*) were abundant, but no trout were present. The absence of trout is due to the presence of Annie Creek falls, which acts as a barrier to upstream fish movement. Immediately upstream of the confluence of Annie Creek and Ross Valley, a small number of suckers were collected in 1992, but no fish have been collected at the monitoring site 0.5 kilometers (km) upstream of that confluence since then.

Sampling was again conducted in 1995, with dead fish and invertebrates observed during the sampling event in Annie Creek at the site established upstream of the falls (Chadwick Ecological Consultants, Inc. [CEC] 1996a, b). Subsequent investigation revealed that ammonia and cyanide were accidentally released via Ross Valley into Annie Creek, resulting in reductions in fish and invertebrate populations. Subsequent annual monitoring conducted from 1996 through 2000 indicated that the benthic macroinvertebrate community had recovered from the 1995 release (CEC 1996b, 1997a, 1998a, 1999a, 2000a, 2001a). From 2002 through 2010, fish populations were sampled annually as well (CEC 2002a, 2003a, 2004a, 2005a, 2006a; GEI [previously CEC] 2007a, 2008a, 2009a, 2010a; *in progress*[a]).

Sampling has generally been conducted in late summer, but an additional spring sampling event was conducted in April 2002 to evaluate any biological effects that occurred in response to elevated ammonia levels recorded in February 2002 (CEC 2003a). Elevated ammonia levels also occurred in April 2004. In 2007, high biological oxygen demand (BOD) water that exceeded standards was released into upper Annie Creek by Wharf Resources, Inc., and ammonia and cyanide standards were also exceeded downstream of mining activities in Annie Creek in that year. Biomass accumulations on the stream bottom were detected by SDDENR personnel in November 2007, and were observed by GEI personnel in August 2007 as well (GEI 2008a). Wharf was ordered to clean up the biomass accumulations by August 2008 in an amended order for the violations of the surface water discharge and mining permit. The clean-up effort was supervised by GEI personnel, and included the use of a vacuum truck to collect the biomass and affected sediments from the surface of the riparian areas and the streambed of Annie Creek in July 2008. Sampling of aquatic biological populations in 2008 was therefore conducted in both June, prior to clean-up activities, as well as in August, after clean-up activities (GEI 2008a, b).

Other streams included in Wharf's monitoring plan include Deadwood Creek, False Bottom Creek, Ross Valley, Cleopatra Creek, and McKinley Gulch. Surveys of the aquatic populations in Upper Deadwood Creek and False Bottom Creek were initiated in 1995 in anticipation of a previous mine expansion (CEC 1996c). The mine expansion was approved in 1998, with construction beginning in 1999. Data collected in 1995 indicated that aquatic habitat in upper Deadwood Creek was very limited due to low, interrupted flows and did not support a fish community. However, invertebrate and periphyton communities were sampled from 1996 through 1999 at this site and at two sites on False Bottom Creek (CEC 1997b, 1998b, 1999b, 2000a). Sampling was reduced to one site on False Bottom Creek in 2000 because of the similarity of the two sites, but sampling has continued annually at the upstream site (CEC.2001a, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). From 2000 to 2008, the upper Deadwood Creek site was dry, but limited water was present in 2009 and 2010, allowing for sample collection in these years (CEC.2001a, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a, 2010a; *in progress*(a)). A second Deadwood Creek site further downstream was established in 2000 to provide a site on this stream with perennial flow and fish populations. This downstream site continued to be sampled annually through 2005, and was then discontinued from the sampling plan (CEC 1997b, 1998b, 1999b, 2000a, 2001a, 2002a, 2003a, 2004a, 2005a, and 2006a). However, it was again sampled in 2010 as part of the supplemental sampling for the baseline analysis.

Monitoring of Cleopatra Creek began in 1985. In 1991, LAC Minerals and Wharf Resources shared an aquatic sampling location designated as Site CC-1. This site continued to be sampled through 2005. Previous designations for this site have been SQ-1 (Knudson 2003) and SQ-1-BIO (CEC 2000b). In 2006, the monitoring site on Cleopatra Creek was moved upstream of its former location to the headwaters of Cleopatra Creek between Monitoring Well-41 and Compliance Point 004 and designated as Site CC-1A-BIO (GEI 2007a). Results of the 2006, 2007, 2008, 2009, and 2010 sampling at Site CC-1A-BIO were used to monitor the status of the aquatic biological populations in Cleopatra Creek in relation to ongoing mine operations (GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]).

The macroinvertebrate and periphyton populations at two sites on Ross Valley were sampled in April 2004 in response to the release of ammonia (CEC 2005a). However, these sites were located upstream and downstream of the current Ross Valley monitoring site. The current site was established in 2006 and has been sampled annually since then. This site represents a site downstream of mining activities, as it flows from the Ross Valley Ore Depository and water treatment pond at the head of the valley into Annie Creek upstream of the falls. McKinley Gulch has historically been dry, but is visited each year to verify the lack of water. A new site on Lost Camp Gulch was established in 2010 as part of the supplemental sampling necessary for the baseline analysis.

1.1.2 Golden Reward

The aquatic biological monitoring program was initiated in 1986 for two of the Golden Reward streams, Fantail Creek and Stewart Gulch. In the initial sampling effort, these two streams were monitored to collect baseline data on their aquatic resources prior to establishment of the gold mine (GRMC 1987). Nevada Gulch and Whitetail Creek were added to the scope of the monitoring program in 1987. The 1986 and 1987 surveys provided baseline data on habitat, benthic macroinvertebrates, fish, and periphyton for these streams prior to operation of the gold mine. Mining commenced in 1989 and continued until 1996. GRMC received approval for temporary cessation of mining in 1996 and remained in temporary cessation until the end of 2001. GRMC entered into final reclamation in 2002 and reclaimed approximately 189 acres from April through November. All disturbed land (approximately 403 acres) is currently reclaimed, with the exception of 5.23 acres. These acres are in the process area and are currently being used for permanent record storage or leased to Black Hills Chairlift Company for snowmaking purposes (Carol Koerner, Wharf Resources [USA], Inc., personal communication). In January 2009, the South Dakota Board of Minerals and Environment approved the reclamation and placed the site into Post Mine Closure and Monitoring status.

Subsequent to the baseline investigations, stream habitat was surveyed in 1989, 1991, 1994, 1997, 1998, 2001, 2004, 2005, 2008; 2009, and 2010; fish populations in 1991, 1994, 1997, 1998, 2001, 2004, 2005, 2008, and 2010; and invertebrate and periphyton populations in 1989 and annually from 1991 through 2010 (GRMC 1990, 1992, 1993; C&A 1994a, 1995a; CEC 1996d, 1997c, 1998c, 1999c, 2000c, 2001b, 2002b, 2003b, 2004b, 2005b, 2006b; GEI 2007b, 2008c, 2009b, 2010b; *in progress*[b]). The annual sampling schedule follows guidelines established for large-scale mines by the South Dakota Department of Game, Fish, and Parks, Division of Wildlife (SDGFP 1991). This schedule was revised in 1998 to synchronize sampling with the schedule for the Wharf Mine. Sampling from 2006 to 2010 followed the activities and methods outlined in the most recent monitoring plan (CEC 2006c), but fish populations and habitat surveys originally scheduled for 2011 at these sites were instead conducted in 2010 to provide additional data for the baseline analysis.

2.0 Study Area

All study sites included in the baseline analysis area are located near Lead, South Dakota, and several years of monitoring data are available for most sites (Appendix A). Streams sampled for the Wharf study plan include Annie Creek, Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek (CEC 2006d). Fantail Creek, Nevada Gulch, Stewart Gulch, and Whitetail Creek have been monitored as part of the Golden Reward study plan (CEC 2006c), and will provide baseline data for the Golden Reward expansion areas. All sampled streams are located in the Middle Rockies ecoregion (Omernick 1987, Omernick and Gallant 1987). GPS coordinates (Table 1) and brief descriptions of the sampling sites are provided. More detailed descriptions of the sampling sites and monitoring history of each stream are available in the most recent annual monitoring reports for Wharf and Golden Reward (GEI 2010a, 2010b).

Table 1: GPS coordinates for Wharf and Golden Reward sites included in the baseline analysis.

Stream/Site	GPS Coordinates
Wharf Sites	
Annie Creek, Site AC-1-BIO	N44º 20' 15" W103º 52' 05"
Annie Creek, Site AC-2-BIO	N44º 19' 56" W103º 52' 29"
Annie Creek, Site AC-3-BIO	N44º 19' 38" W103º 53' 38"
Ross Valley, Site RV-2-BIO	N44º 20' 5.0" W103º 52' 23"
Lost Camp Gulch, Site LC-1-BIO	N44º 18' 38" W103º 45' 57"
Deadwood Creek, Site DC-1-BIO	N44º 21' 18" W103º 49' 18”
Deadwood Creek, Site DC-2-BIO	N44º 21' 35" W103º 48' 15”
False Bottom Creek, Site FB-1-BIO	N44º 22' 12" W103º 49' 33"
Cleopatra Creek, Site CC-1A-BIO	N44º 21' 10.0" W103º 51' 02"
Golden Reward Sites	
Stewart Gulch	N44º 19' 33.5" W103º 47' 59.8"
Upper Nevada Gulch	N44º 20' 09.1" W103º 49' 09.1"
Lower Nevada Gulch	N44º 20' 25.9" W103º 48' 33.8"
Fantail Creek	N44º 20' 12.0" W103º 47' 29.8
Whitetail Creek	N44º 19' 31.7" W103º 47' 56.6"

2.1 Wharf

2.1.1 Annie Creek

Annie Creek is a tributary to Spearfish Creek in the Black Hills National Forest, approximately 5.5 km west of Lead, South Dakota. Three sites on Annie Creek have been sampled as part of Wharf’s current study plan (CEC 2006d). All sites are downstream of Outfall 006A/006B (Figure 1). Limited sampling began at these sites in 1990 (Mariah

Associates, Inc. 1990) and has continued annually in most years since then (Appendix B, Table B-1). Site AC-1-BIO is located near the headwaters of Annie Creek, approximately 0.5 km and 0.7 km upstream of Compliance Points 001 and 005, respectively. This site is also upstream of Ross Valley and Lost Camp Gulch. Site AC-2-BIO is located approximately 0.4 km downstream of Ross Valley, and is downstream of Lost Camp Gulch and Compliance Point 001 as well. This site is upstream of Compliance Point 005. Site AC-3-BIO is located approximately 0.2 km upstream of the confluence with Spearfish Creek, and is upstream of the USGS gaging station also. This site is downstream of the falls and Compliance Point 005. It provides information on the lowest portion of Annie Creek.

2.1.2 Ross Valley

The headwaters of Ross Valley are located approximately 7.7 km west of Lead, South Dakota (Figure 1), at an elevation of 1,805 meters (m) above sea level. The stream flows from the Ross Valley Ore Depository and water treatment pond at the head of the valley and enters Annie Creek from the west between sites AC-1-BIO and AC-2-BIO. While other locations were sampled previously on Ross Valley (CEC 2005a), the current sampling site was established in 2006 and designated as Site RV-2-BIO. This site represents a site downstream of mining activities and is located about 200 m upstream of the confluence with Annie Creek.

2.1.3 Lost Camp Gulch

The headwaters of Lost Camp Gulch are located approximately 7 km west of Lead, South Dakota (Figure 1), at an elevation of approximately 1,747 m above sea level. The stream enters Annie Creek from the east between sites AC-1-BIO and AC-2-BIO near the Ross Valley confluence. Site LC-1-BIO on Lost Camp Gulch is located approximately 70 m upstream of the confluence with Annie Creek. This site was established in 2010.

2.1.4 Deadwood Creek

The headwaters of Deadwood Creek are located approximately 4.8 km west of Lead at an elevation of 1,740 m above sea level. The stream flows to the northeast and enters Whitewood Creek near the town of Deadwood (Figure 1). Near its headwaters, Deadwood Creek is choked with woody debris and overgrown with riparian vegetation. Proceeding downstream, the stream channel and vegetative canopy widen slightly, making the stream more accessible. Two sites have been sampled on Deadwood Creek. The upstream site, Site DC-1-BIO, is located on the northern branch of Deadwood Creek, approximately 1.7 km upstream of the confluence of the northern and southern branches of Deadwood Creek. This section of stream is characterized by a narrow, meandering channel, very little or no flow, and a dense mix of deciduous and coniferous riparian vegetation. Stream flow in this section periodically subsides below the surface of the streambed. This portion of Deadwood Creek does not contain fish and often exhibits intermittent flows or a dry streambed. Site DC-1-BIO was dry at the time of sampling from 2000 to 2008, but had water present in 2009 and 2010.

Site DC-2-BIO was established in 2000 in a reach of Deadwood Creek with perennial flow that is downstream of Site DC-1-BIO. This site supports a fish population. It is located approximately 300 m downstream of the confluence of the northern and southern branches of Deadwood Creek (Figure 1).

2.1.5 False Bottom Creek

The headwaters of False Bottom Creek are located approximately 1.2 km north of the Deadwood Creek study site (Figure 1), at an elevation of 1,740 m. False Bottom Creek flows north and eventually joins the Belle Fourche River between the towns of Spearfish and Whitewood, South Dakota. Near its headwaters, False Bottom Creek is characterized by a semi-open vegetative canopy. Several historic mine sites are located upstream of the monitoring site in a recently permitted expansion area, including the historic Bald Mountain Mill and tailings. The mill was dismantled and tailings reclaimed in 1993. Subsequent to the approval of the Wharf Resources Expansion Permit in 1998, the area was fully reclaimed as the Trojan Rock Facility in 2003 (Kim Schultz, Wharf Resources, Inc., personal communication). While a second site has been monitored in the past, currently only Site FB-1-BIO on False Bottom Creek is sampled annually. This site is located just upstream of an unnamed tributary, which flows into False Bottom Creek approximately 1 km downstream from its headwaters.

2.1.6 McKinley Gulch

McKinley Gulch is a small intermittent tributary to Spearfish Creek, approximately 6.0 km west of Lead, South Dakota that flows into Spearfish Creek approximately 0.8 km downstream of the inflow from Annie Creek (Figure 1). Permitted Compliance Point 003 is located within McKinley Gulch and its headwaters are located in close proximity to mining operations by Wharf Resources. To ensure protection of aquatic populations, the lower portion of McKinley Gulch just above Spearfish Creek (upstream of the highway) is visited during the stream surveys to determine if flow is present. McKinley Gulch has historically been dry, as it was during the most recent survey in 2010.

2.1.7 Cleopatra Creek

Cleopatra Creek is a tributary to Spearfish Creek, approximately 8.0 km northwest of Lead, South Dakota. Cleopatra Creek joins Spearfish Creek (Figure 1) at the community of Maurice. The headwaters of Cleopatra Creek are located near mining operations by Wharf, but this stream also flows near the LAC Minerals Richmond Hill Mine. The original monitoring site on Cleopatra Creek was relocated upstream in 2006, and this location has been sampled since then. The relocated site was designated as Site CC-1A-BIO. This site is located between Monitoring Well-41 and Compliance Point 004, and is in the headwaters of Cleopatra Creek, just downstream of the toe of mining activities. The previous location of Site CC-1-BIO was downstream of Compliance Point 004 between the East Branch and Labrador Gulch.

2.1.8 Reference Sites

All of the monitoring sites for the Wharf project are downstream of mining activities and therefore cannot be used as reference sites. As agreed upon by Wharf, the SDGFP, and the SDDENR, reference sites included in the monitoring plan for Golden Reward are used as reference sites for the Wharf study area as well.

From 1987 to 2005, the Upper Nevada Gulch site was used as the reference site for aquatic biological populations at sites AC-1-BIO, RV-2-BIO, DC-1-BIO, McKinley Gulch, and CC-1A-BIO. Due to its small stream size, Site LC-1-BIO on Lost Camp Gulch will also use the Upper Nevada Gulch site for a reference site. Based on a recommendation from the SDGFP, the downstream study site on Nevada Gulch (Lower Nevada Gulch) was chosen to replace Upper Nevada Gulch as the reference site beginning in 2006 (CEC 2006d). The Whitetail Creek site has been used as the reference site for populations at sites AC-2-BIO, AC-3-BIO, and FB-1-BIO. The Whitetail Creek site is in a larger section of stream than the Nevada Gulch reference site, with relatively undisturbed habitat and a population of brook trout. These sites are further described in the following section.

2.2 Golden Reward

2.2.1 Fantail Creek

Fantail Creek flows northeast from the base of Terry Peak toward Lead for approximately 3 km before it joins Nevada Gulch directly upstream of the confluence of Nevada Gulch and Whitetail Creek (Figure 1). This stream skirts the northern boundary of the Golden Reward mine operation. Fantail Creek flows through a narrow valley for most of its length. The upper portion of the Fantail Creek drainage basin contains portions of the Terry Peak Ski Area and the GRMC operations, while the lower portion of the basin contains several private residences. Flow in Fantail Creek is ephemeral in its headwaters from Terry Peak to the former location of the GRMC guard house (Kim Schultz, personal communication). Due to sedimentation concerns from the newly reclaimed mine site, GRMC installed a sand filter dam in Fantail Creek. Work was initiated on the Yenter Sand Filter Dam in 2002. Rock was added to the face of the dam in August 2003 to increase the area of sediment filtration (Kim Schultz, personal communication).

The historic study site on Fantail Creek was downstream near the confluence with Nevada Gulch, approximately 1.0 km downstream of the Yenter Sand Filter Dam and downstream of past mining operations. In 2005, at the request of SDGFP, the Fantail study site was moved upstream so that the top of the study reach was at the Yenter Sand Filter Dam outfall. This new location has been sampled since 2005.

2.2.2 Nevada Gulch

Nevada Gulch flows east from its headwaters on the northeast slopes of Terry Peak to its confluence with Whitetail Creek (Figure 1). The drainage is a narrow valley that contains a paved state road and several private residences. An upstream site on Nevada Gulch (Upper Nevada Gulch) was selected in 1987 to serve as a reference site upstream of the potential mine impact area. However, as described previously, the SDGFP recommended that this site be removed as a sampling site in 2005, as the habitat characteristics in this small section of the stream made it unsuitable as a reference site. Instead the downstream study site on Nevada Gulch (Lower Nevada Gulch) was chosen to replace Upper Nevada Gulch as the reference site beginning in 2006 (CEC 2006c). This lower site was originally established in 1987 at GRMC water sampling station SS-5. During sampling in 2009, the Lower Nevada Gulch site was dry; therefore, the site was moved approximately 200 feet upstream, where there was flowing water. For the purposes of the potential mine expansion, both the upper and lower sites on Nevada Gulch were sampled in 2010. While the sites on Nevada Gulch are not impacted by mining activities and thus are utilized as reference streams, Nevada Gulch is impacted by other factors in the basin, such as road maintenance, residential housing, and the activities at the Terry Peak Ski Area.

2.2.3 Stewart Gulch

Stewart Gulch is located south of the mine and flows due east for approximately 1.5 km before joining Whitetail Creek (Figure 1). The majority of the flow in Stewart Gulch comes from an adit located in abandoned mine workings approximately 0.4 km upstream of the confluence with Whitetail Creek. The Stewart Gulch study site is downstream of this adit and directly upstream of the confluence with Whitetail Creek near monitoring well PWO2.

2.2.4 Whitetail Creek

Whitetail Creek flows north and east from its headwaters at the outflow of the Astoria Pond, near the divide between the Whitewood Creek and Spearfish Creek drainages, and is a reference site upstream of activities at the Golden Reward Mine. U.S. Highway 85 parallels Whitetail Creek and confines its east bank (Figure 1). The highway and a rock and earth dike impede flow in Whitetail Creek several hundred yards downstream of the Astoria Pond. Whitetail Creek re-emerges directly downstream of the dike and continues flowing toward Lead, receiving flow from Stewart Gulch and Nevada Gulch. The Whitetail Creek study site is located approximately 45 m upstream of the confluence with Stewart Gulch, at a point where the habitat in Whitetail Creek is relatively undisturbed. As this site is upstream of the influence of the mine (CEC 2006c), it is used as a reference site. However, it is impacted by other factors in the basin, such as road maintenance, residential housing, and the activities at the Terry Peak Ski Area.

3.0 Methods

The monitoring plans for Wharf and Golden Reward were updated and implemented in 2006 and 2005, respectively (CEC 2006c, 2006d). Benthic macroinvertebrate and periphyton collection and assessment methods were modified from past data collection procedures. The biomonitoring schedules and sampling methods were also modified to satisfy the SDDENR surface water discharge permit conditions (SDDENR 2002, 2005).

3.1 Habitat

Habitat data are generally collected every year at the Wharf stream sites, and every three years at the Golden Reward stream sites, as stated in the updated monitoring plans (CEC 2006c, 200d). However, while the habitat at the Golden Reward sites was surveyed in 2008 and thus was not scheduled for habit data collection again until 2011, data from all stream sites for both projects were collected in 2010 to provide additional recent data for the expansion project.

Habitat evaluation at the biological monitoring sites is conducted using two different methods. Standard habitat methods, previously used by CEC and GEI, were utilized at all but one each of the Golden Reward sites and Wharf sites each year, and included parameters from the U.S. Forest Service (Platts et al. 1983; Overton et al. 1997). The second habitat method is more comprehensive and was developed by SDDENR and based on work done in South Dakota and in part on the U.S. Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP) procedures (SDDENR 2002, 2005). This method required more time and effort than the standard habitat assessment procedure, and is performed at one Wharf and one Golden Reward site per year on a rotating basis. The data collected by the standard method represent a subset of the data collected by the SDDENR method; thus, there is continuity in the data for most parameters even though two methods were utilized.

3.1.1 Standard Habitat Method

Individual habitat units (e.g., riffle, run, pool, etc.) were identified, working from the bottom to the top of each monitoring site. Measurements for the following parameters were made within each habitat unit over the entire length of the monitoring site:

1. **Channel Width** – measurement of water width plus width of left and right banks, measured at each transect.
2. **Water Width** – measurement of the surface water width, measured at each transect.
3. **Water Depth** – measurement of water depth, measured at 25%, 50%, and 75% of the water width along each transect.

4. **Maximum Water Depth** – measurement measured at the deepest point in each habitat unit.
5. **Water Velocity** – measurements measured at 25%, 50%, and 75% of the water width along each transect.
6. **Percent Surface Fines** – substrate measurement based on a grid sampling device, as described in Overton et al. (1997). Measurements are collected at three or more individual locations in each habitat unit.
7. **Eroding Stream bank** – length of eroding stream bank along each bank for entire length of habitat unit.
8. **Stream bank Vegetation** – visual estimate of percentage of stream bank covered by different vegetation types along entire length of a habitat unit.
9. **Stream bank Cover** – describes the dominant stream bank vegetation at each transect.
10. **Stream bank Angle** – rating of whether stream bank is sloping, vertical, or undercut at each transect.
11. **Stream bank Undercut** – depth of undercut bank for each bank at each transect.
12. **Vegetation Overhang** – measurement of vegetation overhanging water column providing fish cover at each transect.
13. **Substrate Composition** – estimate of the percent of the stream bottom covered by boulder, rubble, gravel, and coarse or fine sediment along each transect.

3.1.2 South Dakota Habitat Method

The data collected using the SDDENR method were summarized to match the data collected with the standard habitat method whenever possible. The SDDENR habitat method (2005) included data collected for 11 different sections (Sections A through L, Section K omitted). The 11 sections and the parameters that comprise each section are described briefly below.

General site description information was collected for Section A including site name, stream name, legal description, date and time of sampling, GPS coordinates (in UTMs) of the top and bottom of the site, and the investigators present.

A preliminary mean stream width (PMSW) was calculated, consistent with Section B, to determine transect spacing by measuring water width (or streambed width if low flows confine widths to a small portion of the streambed) at ten locations. The average width of these measurements was the PMSW. Eleven transects were established, three PMSWs apart, or at least 10 m apart, for a total distance of at least 100 m. Transects were used for most other habitat measurements and for macroinvertebrate and periphyton sampling.

Section C pertains to instream water quality; however, these data were not collected as part of habitat monitoring. Wharf and Golden Reward Mining Company performed standard

water quality analyses as part of their National Pollution Discharge Elimination System (NPDES) monitoring activities.

Habitat types were identified using SDDENR (2005) methods and counted in Section D. Each riffle was measured for length and matched to its nearest transect. All potential pool-forming elements were noted. In addition, to provide data comparable to the standard habitat method used at the remaining sites, all other habitat units were measured and recorded on Section D, although this is not required by the SDDENR method.

A hand-drawn map (Section E) characterized the location of habitat units, transects, photographic points, and any other notable items.

Streambed substrate composition was evaluated, consistent with Section F, using a modified Wolman pebble count method. Each transect was divided into eight divisions, with one particle randomly chosen from each division. All 88 particles from the 11 transects were then classified to the size categories outlined in the protocol (SDDENR 2005).

Each piece of large woody debris was identified, measured, and counted in Section G as described in the protocol (SDDENR 2005). In addition to large woody debris enumeration, position of this debris within the stream channel was noted.

Canopy cover was measured using a modified model C concave spherical densiometer for Section H. Six measurements were collected at each transect (four measurements in four directions at mid-channel and one at each bank) at a height of 0.3 m above the water surface.

Seventeen stream bank and riparian features were measured or characterized for each bank at each of the 11 transects according to Section I. For Section J, bankfull depth, water depth, and velocity were measured at multiple locations along the horizontal transect, at each of the 11 transects.

Stream discharge measurements were performed according to Section L at the most appropriate transect, with all rocks and other obstructions removed. This transect was divided into at least 15 units, with depth and velocity measured at each unit. Water velocity was measured at 60% of the depth for each unit. The depth, velocity, and width of each unit were used to calculate unit discharges. Unit discharges were then summed for a total site discharge.

3.2 Fish Populations

Over the course of the studies, fish populations were quantitatively sampled at the monitoring sites by electrofishing to determine species composition, density, biomass, and size structure of the fish assemblage. The section of stream sampled at each site was chosen to be representative of the habitat present in that stream reach in terms of pool to riffle ratio, shading, bank stability, etc. Sampling has consisted of making three passes through the

representative section of stream (approximately 100 m reaches) using backpack electrofishing gear. If no fish were collected in the first pass, only one pass was conducted. Upper and lower boundaries at each site were closed off with block nets to reduce fish immigration or emigration during sampling.

Fish captured from each pass were retained separately to allow for estimates of population density. Estimates were obtained by using a maximum likelihood estimator and the MicroFish program developed for the U.S. Forest Service (Van Deventer and Platts 1983, 1986). All fish were identified, counted, measured for total length, weighed, and released. These sampling procedures provided species lists and estimates of density (number of fish/ha) and biomass (kg/ha). In addition, length-frequency data were used to analyze the size structure of the fish populations to determine whether recruitment occurred from natural reproduction or by immigration from other sources (Everhart and Youngs 1981; Anderson and Neumann 1996).

3.3 Benthic Macroinvertebrate Populations

Sampling procedures for the benthic macroinvertebrates have varied substantially over the course of the monitoring studies at both the Wharf and Golden Reward sites. During the initial sampling conducted at the Wharf sites in 1990 and 1991, invertebrates were collected with a Surber sampler, with 3 replicate samples collected in 1990 from random locations within the stream channel, and a single sample collected in 1991 (Mariah Associates 1990, 1992a, and 1992b). In 1992 and 1995 through 2005, sampling procedures for these sites instead consisted of three replicate, quantitative Hess or Surber samples in riffles, supplemented with a qualitative sweep sample in other habitat types in 1992 through 1999. At the Golden Reward sites, benthic macroinvertebrates were originally collected with a qualitative timed kick sample in riffle habitat in 1986 and 1987, while, similar to the Wharf sites, sampling methods consisted of three replicate, quantitative Hess or Surber samples in riffles supplemented with a qualitative sweep sample in other habitat types from 1995 through 2004 (CEC 2005b).

Beginning in 2006 at the Wharf sites and in 2005 at the Golden Reward sites and continuing through 2010, invertebrate data were collected using the SDDENR procedure (SDDENR 2005; CEC 2006c, 2006d). This procedure is based on Environmental Monitoring and Assessment Program (EMAP) methods (Peck et al., unpublished draft), and samples an area of 1 m^2 using a kick net with 500 μm mesh size at each of 11 transects. Transects are established based on the methods described for the habitat surveys. One sample was collected at each transect at 25%, 50%, or 75% of the wetted width from the left bank, determined by random assignment of the first transect, and rotated at subsequent transects. In erosional habitat, loose rocks and large substrates were scrubbed by hand and finer substrates were kicked vigorously for 30 seconds to dislodge organisms into the net. In depositional habitats, the same techniques were used, except that the net was dragged through the standing water within the 1m^2 area to capture suspended organisms. Habitat type (pool, riffle, or cascade) and dominant substrate size class (fine/sand, gravel, coarse, or other) in which the individual sample was collected

were recorded at each transect. The collected organisms were then combined into a single, "reach-wide" composite sample for each site.

Samples collected by all methods were preserved in the field using 95% ethanol and delivered to the GEI laboratory for analysis. In the laboratory, organisms were sorted from the debris. If the number of organisms was excessive (i.e., > 300 organisms/sample), the sample was subsampled such that a minimum of 300 organisms in a minimum of 1/10 of the sample was sorted (Vinson and Hawkins 1996; Carter and Resh 2001). For quality assurance, sorting of all samples were checked by a taxonomist or an experienced technician and quality assurance procedures were performed for 10% of the samples, chosen at random. Sorting procedures were continued until quality assurance checks indicated greater than or equal to 95% thoroughness for sorting.

The sorted invertebrates were then identified to the lowest practical taxonomic level (Carter and Resh 2001) using available taxonomic keys and counted by taxon. Quality assurance for identifications and counts (Whittaker 1975; Stribling et al 2003) was randomly conducted on 10% of the samples and indicated 95% or higher agreement for accuracy.

Chironomids and oligochaetes were mounted on glass microscope slides and cleared prior to identification and counting. If the number of chironomids or oligochaetes was excessive (i.e., > 30 organisms/sample), they were subsampled prior to mounting such that 10% of the total number (minimum of 30 individuals each) were mounted. Chironomid identification was conducted by Dr. Leonard Ferrington, Jr. of the University of Minnesota. Oligochaete identification was conducted by the GEI laboratory.

This laboratory analysis provided data on species composition, estimates of abundance (number of organisms/sample), and number of taxa present at each site. Further analyses have been conducted each year to calculate additional population metrics including measures of species richness, community composition, tolerance, and trophic habit metrics. Complete descriptions of these metrics are given in the most recent monitoring reports for Wharf and Golden Reward (GEI 2010a, 2010b). However, for the purposes of summarizing the invertebrate data collected at the Wharf and Golden Reward sites over the years of the study, not all of these metrics are discussed. The long-term data analysis has instead focused on abundance estimates, number of total taxa, number of EPT taxa, and the Shannon-Weaver diversity index.

The number of taxa metric represents the taxonomic richness, or number of species, at a site. High numbers of taxa suggest that a wide variety of environmental conditions exist and are adequate to support a diverse assemblage of different taxa (Barbour et al. 1999). Number of taxa is expected to decrease with increased perturbation in streams.

In mountain streams such as those in the northern Black Hills, the presence of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa (collectively referred to as the EPT taxa) can be used as an indicator of water quality (Lydy et al. 2000).

These insect groups are considered to be sensitive to a wide range of pollutants (Hynes 1970; Wiederholm 1984; Klemm et al. 1990; Barbour et al. 1999; Merritt et al. 2008). Stress to aquatic systems can be detected by comparing the number of EPT taxa between unimpacted reference sites and potentially impacted sites. Number of EPT taxa would be expected to be higher in unimpacted sites compared to impacted sites. Mayflies are considered to be particularly sensitive to metals, (Kiffney and Clements 1993; Clements and Kiffney 1994). Because of the sensitivity of mayflies to metals, the abundance and relative contribution of mayflies (percent Ephemeroptera abundance, expressed as a percent of the total density or abundance) within the community was also calculated.

The Shannon-Weaver Diversity Index (H') is a diversity index recommended for use by the U.S. Environmental Protection Agency (EPA) as a measure of the effects of stress on benthic macroinvertebrate communities (Klemm et al. 1990). This index has values generally ranging from 0-4, with values greater than 2.50 indicative of a healthy macroinvertebrate community. Diversity values less than 1.00 indicate a stream community under severe stress (Wilhm1970; Klemm et al. 1990; Bukantis 1998).

3.4 Periphyton Populations

Similar to the macroinvertebrate samples, collection methods for periphyton samples have varied over the monitoring period. Beginning in 1993 for the Wharf sites and 1994 for the Golden Reward sites, periphyton populations were sampled quantitatively at monitoring sites by scraping a known area of a submerged rock with a metal knife blade. Up through 2001, three rocks were scraped, equaling a total area of 28.8 cm^2, while four rocks were scraped in the following years for a total area of 38.4 cm^2. Periphyton populations sampled prior to these years were qualitative in nature, as the area sampled was not recorded or standardized.

As with the invertebrate sampling, SDDENR protocols began to be used for periphyton collection methods beginning in 2005 for Golden Reward sites and 2006 for Wharf sites. As recommended by the SDDENR (2005), periphyton samples were collected at each site following the EMAP procedures (Peck et al., unpublished draft). Using this protocol, an area of 12 cm^2 was sampled at each of the 11 transects delineated as described in Section 3.1. One sample was collected from each transect at either 25%, 50%, or 75% of the wetted width from the bank, determined by random assignment at the first transect, and rotated for subsequent transects. In erosional habitats, a piece of substrate was collected and an area of 12 cm^2 was scrubbed with a stiff-bristled toothbrush for 30 seconds and washed into a 500 milliliter (mL) plastic collection bottle. In depositional habitats, the top 1 cm of sediment from a 12 cm^2 area was collected with a 60 mL syringe and added to the 500 mL plastic collection bottle.

All of the samples from the 11 transects were composited into a single “reach-wide” composite sample. After thorough mixing, a 50 mL aliquot was removed and preserved with Lugol’s solution. This preserved sample was later used for taxonomic identification and

enumeration. A second aliquot of 25 mL was filtered onto a Whatman GF/F glass fiber filter for chlorophyll *a* determination and stored on dry ice in a centrifuge tube in darkness. A third aliquot of 25 mL was also filtered onto a separate Whatman GF/F filter for ash-free dry mass (AFDM) biomass determination.

All samples were labeled with the appropriate site name, sample type, and date, and returned to the GEI laboratory with a Chain of Custody form. Samples for identification and enumeration were sent to three different companies over the course of the monitoring period, including C&A (prior to 2000), PhycoTech (2000 to 2001), and Aquatic Analysts (2002 to 2010). The methods used by individual phycologists differ slightly from one another as techniques change and improve over the years. The filters for chlorophyll *a* and biomass determination were processed by the GEI laboratory.

As with the macroinvertebrate data, several metrics were calculated from the periphyton data each year, including richness, composition, tolerance, and trophic habit metrics as selected from Barbour et al. (1999). All of these metrics are described in detail in the most recent Wharf and Golden Reward monitoring reports (GEI 2010a, 2010b). However, for the purposes of the data summary, discussion and analysis of the periphyton data focused on the abundance, number of taxa, and composition of the periphyton community present at each site. The total number of taxa represents the biological diversity at a given site. This measure includes taxa from all algal Divisions present. Several taxa within some algal Divisions are often too small to be seen or identified in a routine examination (e.g., several Cyanophyta). Number of taxa is expected to decrease with increased perturbations.

3.5 Data Analysis

Aquatic biological monitoring data were summarized and analyzed in relation to mine and mine reclamation activities and natural occurrences, such as unusual flow and weather events. When appropriate, fish, invertebrate, and periphyton community data were qualitatively correlated with flow data to explain temporal and spatial variation in the aquatic community.

As the lack of replicate sampling for fish precluded statistical analysis, fish population abundance and biomass estimates were compared qualitatively between years and sites. Species composition and size structure were used within sites to determine if fish are naturally reproducing at the site or are being recruited from other sources.

As discussed previously, sampling procedures for macroinvertebrates have varied substantially over the course of the monitoring period at both the Wharf and Golden Reward sites. During the initial sampling conducted at the Wharf sites in 1990 and 1991, one to three Surber samples were collected from random locations within the stream channel (Mariah Associates 1990, 1992a, and 1992b), while the initial samples for the Golden Reward sites in 1986 and 1987 were collected as timed kick samples in riffle habitat. In 1992 and 1995 through 2005, sampling procedures for the Wharf sites instead consisted of three replicate, quantitative Hess

or Surber samples in riffles, supplemented with a qualitative sweep sample in other habitat types in 1992 through 1999. This protocol was also followed at the Golden Reward sites from 1995 through 2004. Beginning in 2006 at the Wharf sites and in 2005 at the Golden Reward sites and continuing through 2010, benthic macroinvertebrate data were collected using the SDDENR methods (CEC 2006c, 2006d).

The SDDENR procedure differs from most earlier methods used at both the Wharf and Golden Reward sites in part in that the data collected using these procedures resulted in a single value for population parameters and metrics for each site. This lack of within-site variance and their usual non-normal distributions fail to meet assumptions for statistical analyses. Therefore, within year site-to-site comparisons could be could not be analyzed statistically and were instead compared qualitatively.

Differences in sampling procedures also complicate the evaluation of the long-term trends in the data. Over time, the SDDENR data collection procedure will provide sufficient data to allow for the evaluation of trends. However, with only five years of data for the Wharf sites (2006 through 2010) and six years of data for the Golden Reward sites (2005 to 2010), comparisons to past data collected with the earlier methods were necessary to evaluate trends. Metrics such as density and abundance of invertebrates per sample are sensitive to the different levels of effort. Thus, while such metrics were discussed, they were not analyzed statistically over time for the trend analysis, but were instead evaluated qualitatively. As the total number of taxa and number of EPT taxa are important for characterizing populations and are probably less sensitive to the changes in methods over the years, these two metrics were instead chosen for statistical comparisons over time. Data used in these comparisons included data collected in 1992 for the Wharf sites and in 1995 through 2010 for both the Wharf and Golden Reward sites. These time periods include the qualitative data collected more recently through the SDDENR procedures, as well as the composite data collected via the three quantitative Surber or Hess samples plus the qualitative sweep samples in most years. These data collection methods were considered to be the best match, as both sampled multiple habitat types at each site and were deemed more comparable than the original methods used in 1990 and 1991 at the Wharf sites and in 1986 and 1987 at the Golden Reward sites.

Long-term trend analyses of the number of taxa and number of EPT taxa at the Wharf and Golden Reward sites was performed using linear regression to determine if values for these parameters significantly increased, decreased, or stayed the same over time. In addition, long-term differences in the mean number of taxa and number of EPT taxa among study sites and reference sites were compared. For the Wharf sites, data from each site have historically been compared to data from either the Lower Nevada Gulch site or the Whitetail Creek site, with the appropriate reference site chosen based on similarities in stream size and habitat to the sites downstream of the Wharf mining activities. Data from the two Golden Reward sites downstream of mining activities have historically been compared to both reference sites. Therefore, comparisons to reference sites are conducted by performing t-tests for the Wharf

data and by using Analysis of Variance (ANOVA) for the Golden Reward sites. Tukey's pairwise multiple comparisons test was performed on means that ANOVA determined were different to determine which values (i.e., which sites) differed (Hintze 2000).

Similar to the macroinvertebrate data, periphyton samples also consisted of one composite sample, so within year site-to-site comparisons could not be statistically tested. As discussed previously, analysis of periphyton samples has been conducted by three different companies over the course of the studies, and the methods used by individual phycologists have differed slightly from one another. In addition, as with the invertebrate sampling methods, SDDENR protocols began to be used for periphyton collection methods beginning in 2005 for Golden Reward sites and 2006 for Wharf sites. These changes in collection and identification methods over time further complicate the evaluation of long-term trends in periphyton communities.

Periphyton population evaluations focused on changes over time in long-term relative abundance, community composition, and number of taxa. Similar to invertebrate data, the different sampling procedures would be expected to have more of an effect on periphyton abundance parameters than on the number of taxa metric. Therefore, abundance data are compared qualitatively over time, with no statistical analysis conducted. Changes over time in the community composition of the periphyton community were also assessed qualitatively. However, long-term trends in the number of taxa were statistically evaluated for both the Wharf and Golden Reward data using linear regression. Data used in these analyses were limited to data collected in 2002 or later; thus reducing the effect that the different identification methods might have on number of taxa, as Aquatic Analysts were used for sample analysis during these years. The regression analysis was used to determine statistically whether the number of taxa increased, decreased, or stayed the same over time. Long-term differences in the mean number of taxa among study sites were also compared using t-tests or Analysis of Variance (ANOVA). Tukey's pairwise multiple comparisons test was performed on means that ANOVA determined were different to determine which means (i.e., which sites) differed (Hintze 2000).

4.0 Results and Discussion

4.1 Habitat

4.1.1 Wharf

The most recent sampling plan for the Wharf sites states that habitat surveys be conducted each year (CEC 2006d). Habitat data for some or all of these sites were collected in 1993, 1995, 1998, and annually from 2000 to 2010. In addition, some earlier data exist for Annie Creek from other sources (Mariah Associates, Inc. 1990, 1992a, 1992b). Use of the current standard methods began in 2000, with SDDENR methods used to evaluate one site per year beginning in 2006. Prior to 2000, the methods and parameters evaluated differed from those used from 2001 through 2010, and not all parameters are directly comparable to previous data. However, general trends are still evaluated and discussed.

4.1.1.1 Annie Creek

Habitat evaluations conducted since the recent methods were employed in 2000 indicate that all three reaches of Annie Creek surveyed are dominated by fast water habitat types, primarily riffles (CEC 2001a, 2002a, 2003a, 2004a, 2005a, and 2006a; GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). From 2000 through 2006, only riffle and run habitat was observed at Site AC-1-BIO, but several pools have been observed in each year since then. Pool and run habitat have been present at the two downstream Annie Creek sites in every year in addition to riffle habitat. While some differences in the types of habitat present have occurred from year to year at the three Annie Creek sites, generally the available habitat at these sites has been diverse, with multiple habitat types and units observed each year.

Habitat characteristics at the three Annie Creek sites were stable from 2000 through 2006 (CEC 2001a, 2002a, 2003a, 2004a, 2005a, and 2006a; GEI 2007a). Low variability in all of the habitat parameters was the result of a stable channel configuration and the lack of high flows, which could reconfigure the stream channel. In June 2007, flow in Annie Creek was recorded at almost 3 cubic meters per second (m^3/s), which was about four times greater than the maximum flows that occurred from 1999 through 2006 (Figure 2; USGS 2010). This high flow event in 2007 was approximately half of the high flow event that occurred in 1995 (Figure 2; USGS 2010), which caused noticeable increases to the stream width of Annie Creek (CEC 1996b). The 2007 flow event appears to have resulted in only minor changes to the habitat structure of Annie Creek. In particular, there was some evidence of debris movement, scouring, and an increase in the percent of exposed bank in 2007 and 2008, especially at Site AC-3-BIO (GEI 2008a, 2009a). However, no exposed banks were observed at any of the sites in 2009 and 2010 (GEI 2010a, *in progress*[a]), indicating riparian vegetation has been recovering at this site. The peak flows from 2008 to 2010 were more

similar to the peak flows that occurred from 1999 through 2006 than those that occurred in 2007, and do not appear to have resulted in any substantial changes to the stream channel.

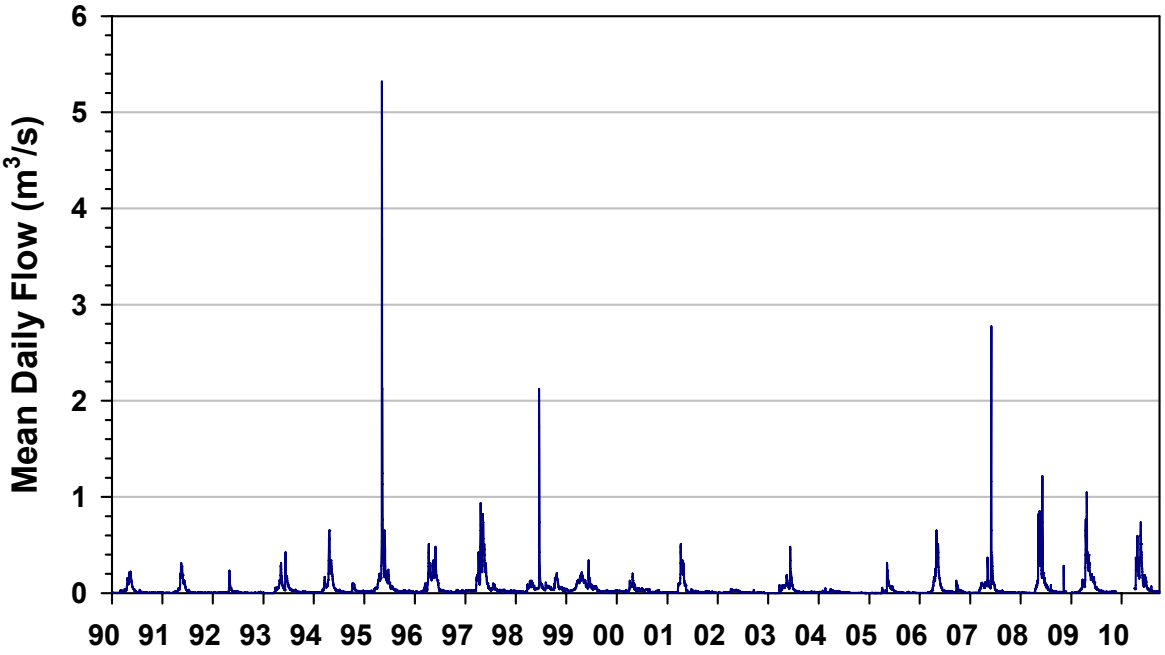

Figure 2: Mean daily flow of Annie Creek using USGS data from January 1990 to October 2010, near Lead, South Dakota.

Values for many habitat parameters such as mean widths, depths, and maximum depths have been lower at Site AC-1-BIO and higher at Site AC-3-BIO than at the other sites on Annie Creek, which is indicative of the increase in stream size downstream. Generally, stream widths in riffle habitat have been approximately 1 m at the upstream Annie Creek site and have increased to 2 m or more at the downstream Annie Creek site. Flows measured at the time of sampling show a similar pattern from Site AC-1-BIO to Site AC-2-BIO, but increase little if at all between the two downstream sites. These flows at the three Annie Creek sites have ranged from 0.00017 m^3/s to 0.02850 m^3/s from 2002 through 2010 (Appendix B, Table B 1).

Substrate composition in these reaches of Annie Creek has varied from fine sediment to boulders in most years. Rubble or fine sediment has typically been the most abundant substrate size. Since 2006, fine substrates have been markedly higher at the two upstream Annie Creek sites in comparison to Site AC-3-BIO, where larger substrates such as rubble and boulders have been common (GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). Percent surface fines have historically been high at sites AC-1-BIO and AC-2-BIO, particularly in pool habitat. Percent surface fines were moderately high at Site AC-3-BIO through 2003, lower in 2004 through 2006, but then increased again in 2007 after the high flows (Figure 2). Since 2007, percent surface fines have been measured at 26% or less at this site.

The banks at all three Annie Creek sites have typically been characterized as sloping and stable over the course of the study, with little to no erosion present at sites AC-1-BIO and AC-2-BIO. While limited to small areas, eroded banks have been present at Site AC-3-BIO each year since 2000. Undercut banks have been limited or absent at these three sites, providing little fish cover. No exposed banks were observed at any of the Annie Creek sites from 2000 to 2006, but they were observed at the two downstream sites in 2007 and 2008. However, banks were again fully vegetated in 2009 and 2010. Bank vegetation has been dominated by grasses, sedges, and trees. Small amounts of overhanging vegetation have been observed at the three sites each year.

4.1.1.2 Ross Valley

Habitat surveys have been conducted at Site RV-2-BIO annually since 2006 (GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). While pools were observed at this site in 2006 and 2007, only high and low gradient riffle habitat has been present in 2008 through 2010, limiting habitat diversity throughout this reach of Ross Valley. Ross Valley is a small and shallow stream, with low flows. Stream widths have approximated 1 m within this reach in most years, but were slightly higher in 2008 and 2009 than in the other years surveyed. Average depths have been 7 cm or less in all habitat types since 2006. Flows since 2006 ranged from 0.00005 m^3/s to 0.00555 m^3/s (Appendix B, Table B-1).

Substrate at this site has typically been a relatively even mixture of substrate sizes, with gravel being slightly more abundant than the other substrates in some years (GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). The percentage of surface fines was low in 2008 and 2010, but was substantially higher in 2009. Streambanks have demonstrated no evidence of erosion and have been vegetated with no exposed banks present in all five years during which the habitat was surveyed. Little to no undercut banks were observed at this site since 2006.

4.1.1.3 Lost Camp Gulch

Site LC-1-BIO on Lost Camp Gulch was added to the study in 2010 to provide further data for the baseline analysis. Habitat at this site was comprised mainly of low gradient riffle and run habitat, with pools and a step run present as well (GEI *in progress*[a]). Average water widths and depths were similar to those observed at Site AC-1-BIO and DC-2-BIO, although deeper pools were present at this site. Flow at the time of sampling in 2010 was 0.00237 m^3/s (Appendix B, Table B-1). The substrate was diverse and comprised of a mixture of sizes, with rubble being the most abundant substrate type. Percent fines were low in the riffle habitat, but substantially higher in the pool habitat. No eroding or undercut banks were observed, and all banks were stable and sloping. Bank vegetation consisted of sedges, willows, and trees.

4.1.1.4 Deadwood Creek

While some habitat data were collected in 1995, 1996, and 1998 at the upstream site on Deadwood Creek, this site was dry from 2000 to 2008 (CEC 1996c, 1997b, 1998b, 1999b, 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a). In addition, habitat at Site DC-1-BIO was evaluated using the SDDENR method in 2009, which provides comparable data for many of the parameters measured using the other method, but does not evaluate a few parameters (GEI 2010a). Using this limited data, stream width and depths appears to have remained relatively stable over the course of sampling despite the intermittent flows, with most habitat data from 1995, 1996, and 1998 being similar to data collected in 2009 and 2010 (CEC 1999b, GEI 2009a; *in progress*[a]). Pool widths and depths were slightly higher in 2010 than had been observed previously (GEI *in progress*[a]).

Riffle habitat comprised almost all of Site DC-1-BIO in 2009 and 2010, with small pools present as well. Previous habitat data from 1995 through 1998 did not estimate the percentage of riffles in comparison to other habitat types. Flows were low in 2009 and 2010, ranging from 0.00009 m^3/s to 0.00053 m^3/s (Appendix B, Table B-1).

Some changes in habitat appear to have occurred between 1998 and the last two years of sampling. Fine sediment has dominated the substrate in the last two years of sampling, particularly in 2010. While fine substrates comprised a substantial proportion of the substrate in 1995, 1996, and 1999 as well, larger substrates were more common than in the past two years (CEC 1999b). The low or nonexistent flows that have occurred at this site since 2000 have likely contributed to the accumulation of fine sediment, as such flows would not have been sufficient to flush fine sediments downstream. The bank vegetation appears to have changed some since 1998 as well, with bank vegetation dominated by grasses and sedges in 1995, 1996, and 1998 (CEC 1999b), while trees covered most of the banks in 2009 and 2010 (GEI 2010a, *in progress*[a]). Eroding banks were minimal in 2009 and 2010, and all banks were stable and sloping, with no exposed areas.

Habitat at Site DC-2-BIO was surveyed from 2000 to 2005, but then was not surveyed again until 2010 (CEC 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; *in progress*[a]). Unlike at the upstream Deadwood Creek site, flowing water was present each year, with flows at the time of sampling ranging from 0.00057 m^3/s to 0.00540 m^3/s during the years in which the habitat was sampled (Appendix B, Table B-1). Typically, this site has been dominated by fast water habitat types such as riffles and runs over the course of the study, with smaller amounts of pool habitat formed by boulders or woody debris present.

Most habitat parameters showed little variability from 2000 to 2005, and widths were generally similar in 2010 to previous data (CEC 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; *in progress*[a]). However, maximum and average depths were higher in 2010 than in previous years. Substrate at Site DC-2-BIO has been heterogeneous over the course of the study, but gravel and rubble have often been abundant. Percent surface fines were 34% or

lower from 2000 through 2005, but were slightly less in 2010 than in most of the previous years of the study. Streambank habitat characteristics at this site in the past suggested some erosion potential, as both banks have had small to moderate areas of erosion noted each year from 2000 through 2005 (CEC 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; *in progress*[a]). However, only a small area of the right bank showed any erosion in 2010 (GEI *in progress*[a]). Likewise, the banks in 2010 were stable and fully vegetated, but some areas of exposed banks were observed in earlier years of the study (CEC 2001a, 2002a, 2003a, 2004a, 2005a, 2006a). No undercut banks have been observed at this site over the course of the study in any of the habitat surveys.

4.1.1.5 False Bottom Creek

Habitat surveys using the current methods were conducted at Site FB-1-BIO annually from 2000 through 2010 (CEC 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). Earlier habitat data collected using slightly different methods are also available for this site and a site further downstream in 1995, 1996, and 1998 (CEC 1999b). Since 2000, riffle habitat has comprised most of the reach included in Site FB-1-BIO. Little variation in the types of available habitat were observed at this site from 2000 through 2006, with run and pool habitat observed in addition to the riffle habitat. In most years since 2007, glide habitat has also been present.

Most habitat characteristics have been similar since 1995 at Site FB-1-BIO, but wetted widths increased from 2006 through 2008 (CEC 1999b, 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). These changes were likely related to bank scouring from spring high flow events (Figure 2; USGS 2010). However, the mean wetted widths in 2009 and 2010 were lower than in the previous two years and were similar to those observed in 2006. Flows at the time of sampling from 2002 through 2010 ranged from 0.00018 m^3/s to 0.00446 m^3/s (Appendix B, Table B-1).

Substrate at Site FB-1-BIO was a mixture of all size categories in most years, with gravel often being the most abundant type of substrate. Bedrock was observed in the earlier surveys in 1995, 1996, and 1998 (CEC 1999b), but has not been observed since then (CEC 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). Percent surface fines were low in the riffle habitat in most years since 2000, but were higher in 2007 and 2008. Percent surface fines have been higher in pool habitat than in riffle habitat each year, but also increased in 2007 through 2008.

While some bank erosion has been present at Site FB-1-BIO each year since 2000, the percentage of erosion increased from 2006 through 2008 (CEC 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a). These changes were likely related to bank scouring from spring high flow events (Figure 2, USGS 2010). The percent eroded banks decreased from 2008 to 2009, but then increased again in 2010 (GEI 2010a, *in progress*[a]). However, this site was surveyed using the SDDENR method in 2010, which calculates bank

erosion at each transect point rather than over the entire length of the habitat unit, and does not provide directly comparable numbers to the standard methods used in other years. Based on this, some bank erosion is clearly present at Site FB-1-BIO, but it may not represent an increase to what was observed in 2009.

While stream banks in the last two years of surveys have been fully vegetated and sloping, exposed and vertical banks were observed in most of the previous years, and the percent of exposed banks increased in 2007 and 2008 (CEC 1999b, 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). The absence of exposed or vertical banks in 2009 and 2010 indicates that some recovery has occurred at this site since the high flows in 2007. Small areas of undercut banks have also been present in most years. Grasses or sedges have comprised most of the bank vegetation over the course of the study.

4.1.1.6 Cleopatra Creek

While earlier habitat data exists for a site further downstream, habitat surveys have only been conducted at Site CC-1A-BIO since 2006 (GEI 2007a, 2008a, 2009a; 2010a, *in progress*[a]). The five years of habitat data available for this site indicate that most habitat characteristics varied little at Site CC-1A-BIO from 2006 through 2010. Cleopatra Creek at Site CC-1A-BIO is a small stream, with stream widths in the low gradient riffle habitat being approximately 1 m in most years, with wider stream widths observed in the pools. Flows have been low at the time of sampling since 2006, varying from 0.00012 m^3/s to 0.00085 m^3/s (Appendix B, Table B-1).

While boulders and rubble are the most abundant substrate types present at Site CC-1A-BIO, smaller substrates have also been observed over the course of the study (GEI 2007a, 2008a, 2009a; 2010a, *in progress*[a]). Percent fines were low in the riffle habitat in 2009 and 2010, but were higher in the earlier years, especially in 2006, when percent fines were estimated at 68% in the riffle habitat and even higher in most of the pools (GEI 2007a). This suggests that percent fines have decreased over time. The high flow event in June 2007 likely flushed some of the fine sediment downstream.

Streambanks at this site have demonstrated no evidence of bank erosion since 2006 (GEI 2007a, 2008a, 2009a; 2010a, *in progress*[a]). Banks have been characterized as stable, sloping, and fully vegetated in most years over the course of the study. Small amounts of exposed banks were present in 2006, but have not been observed since then. Bank vegetation has largely consisted of grasses, sedges, and trees.

4.1.1.7 Summary

Habitat data are available for some of the Wharf sites dating back to 1995, while other sites were added to the monitoring program as recently as 2006. All of the Annie Creek sites are dominated by fast water habitat types such as riffles and runs, with smaller pools present at most sites and years as well. Values for many habitat parameters such as mean widths,

depths, and maximum depths have been lower at Site AC-1-BIO and higher at Site AC-3-BIO than at the other sites on Annie Creek, which is indicative of the increase in stream size downstream. Habitat characteristics at the three Annie Creek sites were stable from 2000 through 2006, likely as the result of a stable channel configuration and the lack of high flows, which could reconfigure the stream channel. A high flow event in June 2007 appears to have caused some minor changes in habitat characteristics, with some evidence of debris movement, scouring, and an increase in the percent of exposed bank in 2007 and 2008, especially at Site AC-3-BIO. However, no exposed banks were observed at any of the sites in 2009 and 2010, indicating riparian vegetation has been recovering at this site. Some sediment deposition has been present at the two upstream sites on Annie Creek, particularly in the pool habitat.

Sites on Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, and Cleopatra Creek have also typically been dominated by riffle habitat, with pool habitat generally present at all of these sites as well except for Site RV-2-BIO on Ross Valley. A diverse mixture of substrate sizes has been present at each site, with gravel or rubble being abundant at some sites. Fine sediment was high at the upstream Deadwood Creek site, which has had water present for the past two years after being dry from 2000 through 2008. Banks have generally been stable at most of these sites, but eroded banks were more common at sites DC-2-BIO and FB-1-BIO. Increases in eroded and exposed banks were observed at Site FB-1-BIO in some recent years, which are thought to be a result of scouring from high spring flow events. However, no exposed banks were present at this site in the past two years.

4.1.2 Golden Reward

The most recent sampling plan for the Golden Reward sites does not require that habitat surveys be conducted each year (CEC 2006c). Using the current standard methods, habitat data at the five Golden Reward sites were collected in 2001, 2004, 2005, 2008, and 2010, with SDDENR methods used to evaluate one site per year beginning in 2005. While the methods used and parameters evaluated differed from those used from 2001 through 2010, historical habitat data also exists prior to 2001, with this data collected in 1986, 1989, 1991, 1994, 1997, and 1998 (CEC 1999c). Due to changes in the methodology, not all parameters are directly comparable to previous data; however, general trends are still observed and discussed.

4.1.2.1 Fantail Creek

The reach of Fantail Creek surveyed was dominated by low gradient riffle habitat in all years in which habitat surveys were conducted from 2001 through 2010 (CEC 2002b, 2005b, 2006b; GEI 2009b, 2010b; *in progress*[b]). In most years, run and pool habitat were also present. Fantail Creek is a smaller stream than Whitetail Creek and Stewart Gulch, with stream widths of approximately a meter and low velocities. Water width in Fantail Creek was greatest in 2008, probably a result of higher flows in late summer at the time of sampling than in other years (Appendix B, Table B-2). Water widths have also generally been higher

since 1998, with historical data collected from 1986 through 1997 indicating that average stream widths were 0.8 m or less (CEC 1999c). A high precipitation period occurred in this region in the summer of 1998 (Tim Thomure, GRMC, pers. comm.), which may have contributed to the greater stream widths. Flows at the time of sampling in this reach of Fantail Creek since 2002 have ranged from 0.00044 m^3/s in 2006 to 0.00264 m^3/s in 2008 (Appendix B, Table B-2). Flows were not measured in 2009.

Substrate composition monitoring has demonstrated an increase in the proportion of fine substrate in Fantail Creek in recent years. Fine sediment comprised 39% to 49% of the substrate in 1989, 1991, and 1994, but no fine sediments were observed in 1998 (CEC 1999c). The proportion of fine substrates remained low in 2001, but increased proportions were observed in 2004, 2005, and 2008, particularly in pool habitat. The percent surface fines was not measured at this site during the 2010 sampling event, but the proportion of fine sediment in relation to other substrate types was similar to 2008 values (GEI 2009b, *in progress*[b]). While fine sediments have increased over time since 2001, gravel and rubble have typically been the most abundant substrate sizes present since 1997.

The stream banks within this reach of Fantail Creek have generally been stable over the monitoring period, but some erosion was observed in 2005, 2008, and 2010. Little to no undercut banks have been observed at this site since 1986. Limited areas of exposed banks were observed in 1998, 2005, and 2008 (CEC 1999, 2006b; GEI 2009b), but banks were fully covered with vegetation during the 2010 survey (GEI *in progress*[b]). In the earlier years of the study, sedges and grasses dominated the bank vegetation, but trees have become more common in recent years.

4.1.2.2 Nevada Gulch

Habitat surveys were conducted in 2001, 2004, 2005, 2008, and 2010 at the Lower Nevada Gulch site, but the Upper Nevada Gulch site was not surveyed in 2008 (CEC 2002b, 2005b, 2006b; GEI 2009b, 2010b; *in progress*[b]). In addition, historical data exist for both sites for 1986, 1989, 1994, 1997, and 1998 (CEC 1999c). Riffle habitat has comprised most of the reach surveyed at the Upper Nevada Gulch site, but pool habitat formed by boulders or woody debris has also generally been present (CEC 1999c, 2002b, 2005b, 2006b; GEI 2009b; *in progress*[b]). In addition, runs were observed in 2001 and again in 2010. Stream widths at this site have generally been a meter or less, but were slightly greater in 1998 (CEC 1999c). Depths are shallow, measuring near 4 cm in the riffle habitat in most years since 2001. Flow data were collected at the time of sampling from 2002 through 2005, and again in 2010. Flows over this period have been low, measuring 0.00087 m^3/s or less in each of these years (Appendix B, Table B-2).

Heterogeneous substrate has been present at the Upper Nevada Gulch during the habitat surveys, with rubble frequently being the most abundant size class since 2001. Gravel was more prevalent during the 2010 survey, as well as in surveys prior to 2001. As the SDDENR

habitat methods were used in 2010, the percentage of surface fines was not measured during the most recent habitat survey. However, percent surface fines were higher in 2005 than in 2004 and 2001, but has remained at 25% or lower in all habitat types since 2001 (CEC 2002b, 2005b, 2006b; GEI 2009b).

Bank stability has been high since 1986. Small amounts of bank erosion were observed in 2001, 2004, and 2005, but none was observed in 2010. Undercut banks have been minimal to absent each year, but small amounts of overhanging vegetation have been observed. While areas of exposed banks were noted at this site in 1986, 1997, 1998, 2004, and 2005, the banks were fully vegetated in 2010 (CEC 1999c, 2002b, 2005b, 2006b; GEI 2009b; *in progress*[b]). Grasses and sedges have generally been the dominant vegetation each year, with some willows and trees present as well.

Similar to the Upper Nevada Gulch site, low gradient riffles have predominated at the Lower Nevada Gulch reference site as well, with runs also observed in most years (CEC 2002b, 2005b, 2006b; GEI 2009b; *in progress*[b]). Pool habitat was present in most years as well, but was absent in 2004 and 2005. A series of step pools or runs were present in 2008 and 2010, respectively. Data collected at the time of sampling from 2002 through 2010 showed flows ranging from less than 0.00001 m^3/s to 0.00030 m^3/s (Appendix B, Table B-2).

Historical data for the Lower Nevada Gulch site showed variability in some stream habitat parameters over the monitoring period. Water widths at the Lower Nevada Gulch site have often been slightly less than a meter. Water widths were greater in 1998 and 2008, probably because of the higher August flows in these years (CEC 1999c, GEI 2009b). Depths have typically been 6 cm or less in the riffle and run habitat, with greater depths in the pool habitat in those years in which it was observed. The substrate composition was dominated by boulders in 1986 and 1989, and then by gravel and rubble from 1997 through 2005 (CEC 1999c, 2002b, 2005b, 2006b). Fine and coarse sediments were more abundant in 2008 than in 2005, but rubble was again the dominant substrate in 2010 (GEI 2009b, *in progress*[b]). Percent surface fines were higher in 2008 and 2010 compared to earlier years, particularly in the pool habitat.

Stream banks in Lower Nevada Gulch have typically been stable since 2001, with grasses and sedges often being the most abundant vegetation types. Willows were more common in 2010 than in previous years. No bank erosion was observed in most of the habitat surveys, but small amounts were present in 2001 and 2010. Little or no undercut banks have been observed at the Nevada Gulch site since sampling began.

4.1.2.3 Stewart Gulch

High habitat diversity has been present at the Stewart Gulch site since 2001, with a greater number of habitat types observed at this site than at the other Golden Reward sites in most

years in which the surveys were conducted (CEC 2002b, 2005b, 2006b; GEI 2009b; *in progress*[b]). Similar to the other sites, riffle habitat has comprised much of the site, with smaller amounts of pool, glide, and run habitat present. A series of step runs was present in 2010.

Habitat in Stewart Gulch has demonstrated some variability over the monitoring period, similar to the other Golden Reward sites. Water width since 1991 has generally measured between 1.9 and 2.8 m depending on the habitat unit; however, greater widths were observed in the pool and glide habitat in 2010. Average depths have remained more consistent over time, with depths in 2008 and 2010 falling within the range observed in the earlier years of the study. Flows are substantially greater in Stewart Gulch than at the Fantail Creek and Nevada Gulch sites, ranging from 0.01755 m^3/s to 0.03364 m^3/s (Appendix B, Table B-2).

Larger substrates (i.e., rubble and boulder) comprised higher proportions of the stream substrate in 1998, 2001, 2004, and 2005, as well as in some of the previous years (CEC 1999c, 2002b, 2005b, 2006b). However, gravel was more abundant in 2008 and 2010 (GEI 2009b, *in progress*[b]). Percent surface fines have been minimal in most habitat types, but were greater than 20% in most of the pool habitat observed in 2001 and 2005.

Areas of exposed banks were observed in almost every year in which the habitat was surveyed at Stewart Gulch, but these areas appear to have decreased based on 2008 and 2010 data in comparison to 2005 data. While banks have been predominately sloping, undercut banks, vertical banks, or both have been present in all years. Sedges and grasses have generally comprised most of the bank vegetation each year.

4.1.2.4 Whitetail Creek

While the Whitetail Creek reference site has demonstrated variability in some habitat characteristics over the monitoring period, similar to the other Golden Reward sites, the habitat types present each year since 2001 have remained stable. Low gradient riffle habitat has comprised most of this reach of Whitetail Creek, but several pools formed by boulders in the stream channel have also been observed each year (CEC 2001b, 2005b, 2006b; GEI 2009b; *in progress*(b)). In addition, run habitat was present during most habitat surveys, but was not observed during the most recent one in 2010.

Water width has varied between 1.4 and 2.5 m since 1997 depending upon the habitat units measured and annual variations in flow. Widths were less in surveys conducted from 1987 through 1994 (CEC 1999c). Average depths ranged from 4 cm to 16 cm, and were generally greatest in 2008. Flows at the time of sampling have ranged from 0.00068 m^3/s to 0.02207 m^3/s, and are slightly less than the flows in Stewart Creek (Appendix B, Table B-2).

Rubble and gravel have typically been the most abundant substrate in this reach of Whitetail Creek, although boulders were common in 2004 and in some of the earlier years of the study. No consistent increasing or decreasing trends in percent fines were evident, but the highest

percentages at this site were recorded in the run habitat present in 2004. However, data from 2008 and 2010 had values near or lower than 2001 values (CEC 2002b, 2005b, 2006b; GEI 2009b; *in progress*[b]).

Stream banks in Whitetail Creek have been relatively stable over the monitoring period with slightly higher erosion observed in 2001, 2004, and 2005 than in other years. No evidence of bank erosion was observed in 2008 and 2010. While some areas of exposed banks or banks comprised of bedrock were observed in 1998 and 2001, these have not been observed in the years since then. Bank vegetation has consisted mainly of grasses, sedges, and willows. No undercut banks were observed in most years since 1987.

4.1.2.5 Summary

Sites at all four of the Golden Reward streams have been dominated by riffle habitat over the course of the study. Pools comprised a much smaller proportion of the total length, but were present at each site. Stream habitat features such as widths, depths, and flows varied between sites and years. Stewart Gulch and Whitetail Creek are the largest of the four study streams, while Fantail Creek and Nevada Gulch are smaller. Substrate at each site was heterogeneous, but rubble or gravel have often been the most abundant substrate size category. Banks at these sites have generally been stable since 1998, but eroded banks have been observed in many to most years in which habitat surveys were conducted at Fantail Creek and Stewart Gulch sites.

Habitat conditions at all study sites have varied considerably since monitoring began in 1986. In many cases, these variations appear to be the result of natural changes in flow conditions over the years. Water widths at some sites were greatest in 1998 and 2008, likely as a result of higher flows in late summer at the time of measurement than in most other years. In general, although habitat characteristics have been variable, few trends have been observed other than an increase in the percentage of fine substrate at the Fantail Creek site.

4.2 Fish Populations

4.2.1 Wharf

4.2.1.1 Annie Creek

No fish have been collected at Site AC-1-BIO over the course of the study (CEC 1996a, 1996b, 1998a, 2002a, 2003a, 2004a, 2005a, and 2006a; GEI 2007a, 2008a, b, 2009a, 2010a; *in progress*[a]). The absence of fish at this site reflects its headwater location upstream of perennial fish habitat (C&A 1993). In addition, small waterfalls that act as barriers to upstream migration of fish are common in this section of the stream.

Mountain suckers have been present in low densities during several years of the study at Site AC-2-BIO (Figure 3; Appendix C, Table C-1). Mountain sucker density and biomass was high during initial sampling events at Site AC-2-BIO on Annie Creek in 1990 and 1992.

Following the 1995 accidental release of ammonia and cyanide into Annie Creek via Ross Valley (CEC 1996a), this species has apparently maintained very low populations. Three fish were collected at this site immediately after the spill in 1995, no fish were found in 1998, and only one fish was found in qualitative sampling in 1999. Fish populations were scheduled to be sampled at all study sites in 2000 (CEC 2000a, 2000b), but forest fire hazards and associated forest restrictions enacted by the U.S. Forest Service pre-empted sampling operations. However, two mountain suckers were incidentally observed at Site AC-2-BIO during invertebrate and periphyton sampling in 2000. The presence of 18 mountain suckers in 2001, suggested that populations were beginning to recover from the accidental ammonia and cyanide release in 1995 (CEC 2002a).

Elevated ammonia levels were again recorded in Annie Creek in February 2002 and April 2004. The presence of fish after these events indicated that the population remained, although at very low density and biomass levels (Figure 3). Successful reproduction in the past had been inferred by the continued persistence of more than one age class (CEC 2003a). In 2004, 2005, 2006, and 2008, older mountain suckers were collected at Site AC-2-BIO, but no young-of-the-year (YOY) were observed (CEC 2005a, 2006a; GEI 2007a, 2009a). No suckers were present in 2007 and 2009 (GEI 2008a, 2010a), and only a single adult sucker was collected at this site in 2010.

The absence of mountain suckers during sampling in August 2007 may have been related to the high flow event that occurred in June 2007 (Figure 2), which could have temporally displaced an already depleted mountain sucker population from upper Annie Creek. Alternatively, their absence may have been related to low dissolved oxygen in Annie Creek upstream of the falls. High biological oxygen demand (BOD) water was released into Annie Creek upstream of Site AC-1-BIO in 2007 by Wharf, creating low dissolved oxygen levels in Annie Creek. In addition, ammonia and cyanide standards were exceeded downstream of mining activities in Annie Creek in 2007 (GEI 2008a, b). Mountain suckers may have temporally moved downstream out of the study reach to more oxygenated waters. The presence of a few suckers at Site AC-2-BIO in 2008 indicated that some of these fish had moved back into the study reach, but their absence in 2009 and the single sucker collected in 2010 indicate that the mountain sucker population at this site may not have recovered from the release of the high BOD water in 2007.

In addition, the absence of YOY suckers and the low numbers of adult suckers collected since 2004 indicates that successful reproduction of these fish in this reach of Annie Creek has been limited. There does not appear to be any upstream sources of these fish, and movement of fish from the most downstream reach of Annie Creek is barred by Annie Creek falls. These restrictions, as well as the low dissolved oxygen levels and exceedances of ammonia and cyanide standards that occurred in 2007 and in previous years, appear to have created conditions that are continuing to limit the mountain sucker population at this site.

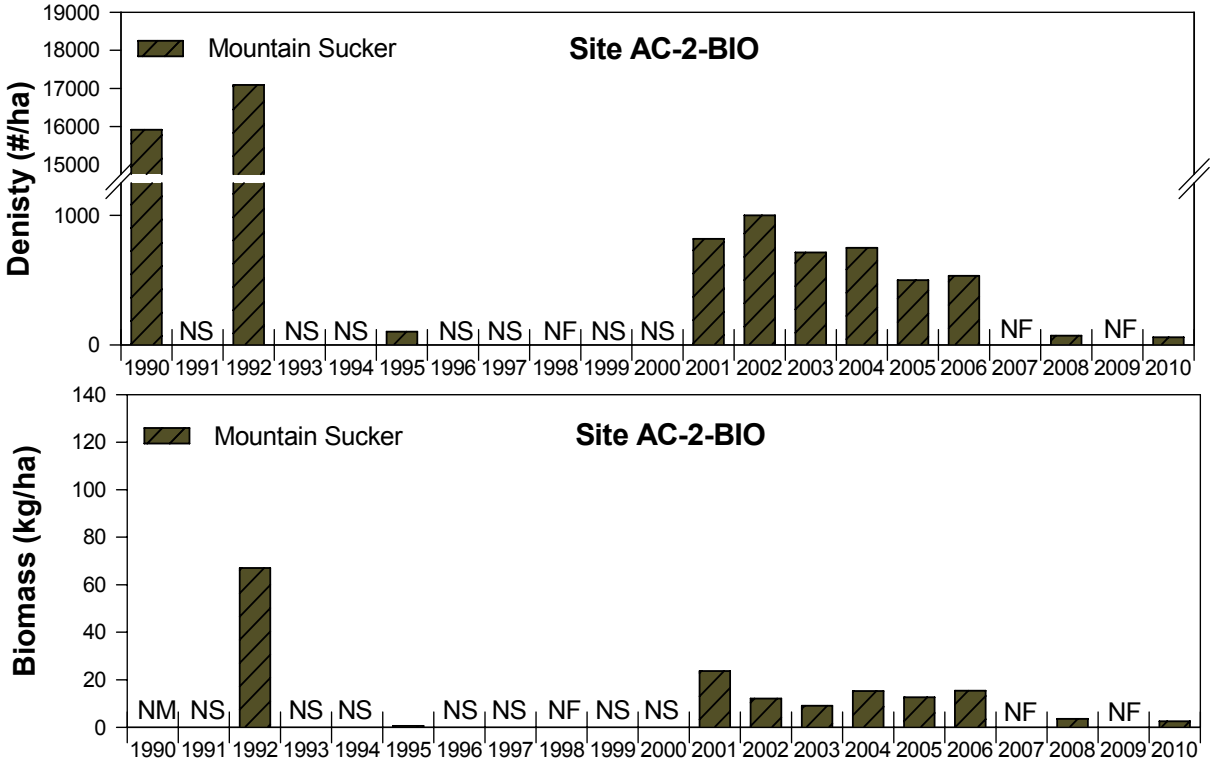

Figure 3: Density and biomass of mountain suckers collected during sampling at Site AC-2-BIO in Annie Creek, 1990 - 2010. NS = Not Sampled, NM = Not Measured, and NF = Sampled But No Fish collected.

In general, brook trout density has increased at Site AC-3-BIO since 2001 while brown trout density has decreased (Figure 4; Appendix C, Table C-2). Brook trout density was slightly lower in 2007 through 2009 than in 2006, but then peaked in 2010. Biomass increased steadily for brook trout from 2004 through 2007, and has remained high since 2007 (Figure 4). In August 2010, brook trout biomass was slightly higher than the range of values observed over the course of the study. Length-frequency data for brook trout from 2010 and previous years of the study suggest that resident populations of brook trout exist in this lower section of Annie Creek, with YOY, juvenile, and adult trout collected most years.

Brown trout biomass also increased from 2004 through 2007 at Site AC-3-BIO, but then decreased substantially in 2008, when fewer brown trout, especially large brown trout, were captured than in most previous years (Figure 4, GEI 2008a). Brown trout biomass was higher in 2009 and 2010 in comparison to 2008, but remained on the low end of the range observed since 2001. The dominant species, as measured by biomass, has shifted from brown trout in 2001 and 2002 to brook trout in all years since then. Brown trout have been collected in a more limited size range than brook trout at Site AC-3-BIO. While a small number of YOY brown trout were collected in 2010, they were absent in 2009 and some previous years (GEI 2010a; *in progress*[a]). The lower density and biomass of brown trout and the absence of YOY in some years indicates that the brown trout population is less stable

than the brook trout population and likely is subsidized by brown trout from Spearfish Creek. Brown trout maintain resident populations in Spearfish Creek, which is approximately 200 m downstream of Site AC-3-BIO, thus fish likely move between the two streams. Mountain suckers were not detected during late summer or autumn sampling at Site AC-3-BIO after the 1995 sampling event (Figure 4); however, one mountain sucker was collected at this site in June 2008.

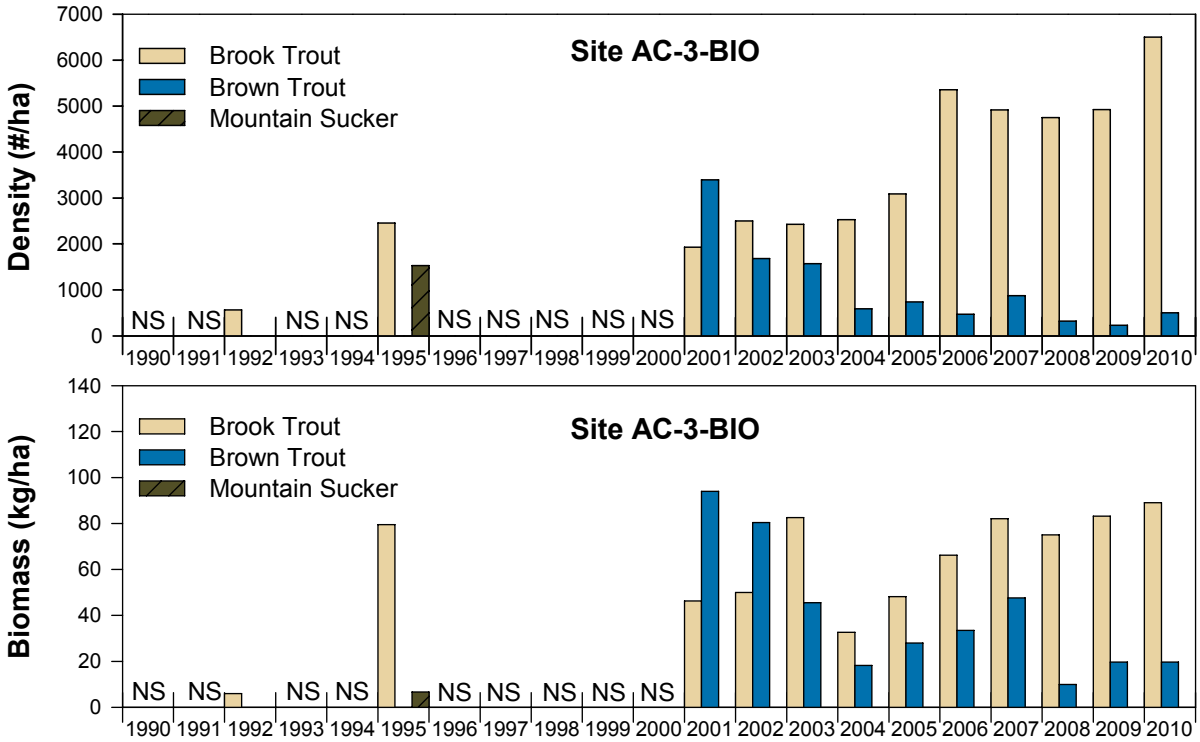

Figure 4: Density and biomass of brook trout, brown trout, and mountain suckers collected at Site AC-3-BIO in Annie Creek, 1990 - 2010. NS = Not Sampled.

4.2.1.2 Ross Valley

No fish were collected in this stream during sampling at Site RV-2-BIO from 2006 through 2010 (GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). The stream size and habitat in this headwaters reach of Ross Valley are apparently not suitable for fish.

4.2.1.3 Lost Camp Gulch

Site LC-1-BIO on Lost Camp Gulch was added to the study plan in 2010 to better characterize the area potentially affected by the Wharf mine expansion areas. No fish were collected from this site in 2010 (GEI *in progress*[a]). However, the location of this site immediately upstream of the Annie Creek confluence near Site AC-2-BIO indicates that if the sucker population in this reach of Annie Creek were to increase, some of these fish could potentially move upstream into Lost Camp Gulch.

4.2.1.4 Deadwood Creek

The streambed at the upstream Site DC-1-BIO on Deadwood Creek site was dry from 2000 to 2008 (CEC 2001a, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a). While limited water was present in August 2009 and 2010, no fish were collected (GEI 2010a, *in progress*[a]). No fish were found in this stream reach when it was sampled during 1995 either, indicating that limited aquatic habitat and low, interrupted flows present in this reach of Deadwood Creek are unsuitable for fish populations (CEC 1996c).

Site DC-2-BIO, downstream of Site DC-1-BIO, has perennial flows and supports a brook trout population. This reach of Deadwood Creek was sampled in 2001 through 2005, but was then dropped from the sampling plan. To provide more recent data for the proposed mine expansion areas, it was sampled again in 2010. Density and biomass were more than five times higher in 2010 in comparison to the highest values observed in 2001 through 2005 (Figure 5; Appendix C, Table C-3). Multiple size classes of brook trout, including YOY trout, were also present in 2010 (GEI *in progress*[a]) and in the previous years in which this site was sampled (CEC 2001a, 2002a, 2003a, 2004a, 2005a, 2006a), indicating brook trout are likely naturally reproducing in this reach of Deadwood Creek.

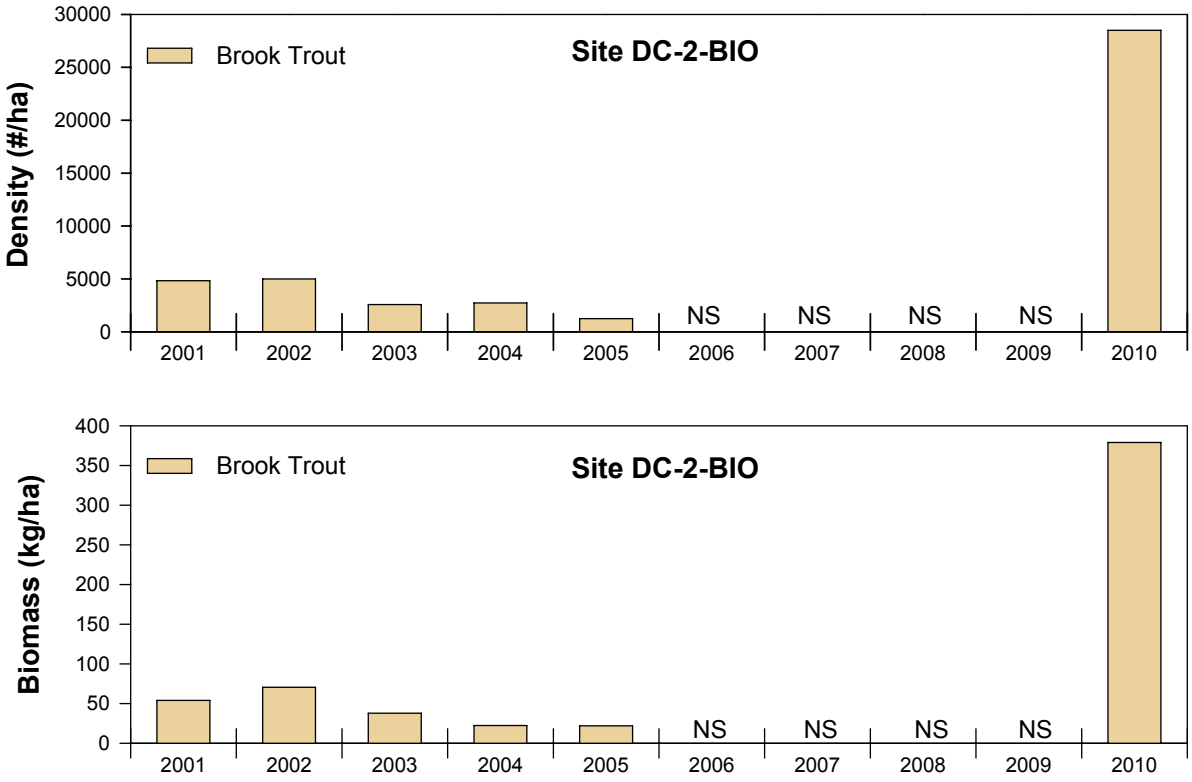

Figure 5: Density and biomass of brook trout collected at Site DC-2-BIO in Deadwood Creek, 2001 - 2010. NS = Not Sampled.

4.2.1.5 False Bottom Creek

Brook trout have been the only fish species collected at Site FB-1-BIO on False Bottom Creek over the course of the study (CEC 1996c, 1997b, 1999b, 2002a, 2003a, 2004a, 2005a, 2006a; GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). Brook trout density and biomass at Site FB-1-BIO were generally low from 2001 through 2008 compared to sampling conducted in the mid to late 1990s (Figure 6; Appendix C, Table C-3), with a general declining trend observed in both density and biomass of brook trout at this site through 2005. In 2006, there was an increase in both parameters, but they both declined again in 2007. In 2009, density reached the highest value observed at this site since sampling began in 1995, and biomass was higher than it had been since 1998. A high number of YOY brook trout contributed to the increases in density and biomass in 2009. Density and biomass in 2010 were lower than in 2009, but remained higher than in all other years since 2001.

The presence of YOY brook trout over the years of the study has been variable. In 2008, YOY fish were absent, with the population consisting of only juvenile and adult fish, while in 2007, a few YOY were present but adults were absent (GEI 2008a, 2009a). YOY and adult fish were also present in 2009 and 2010, and YOY fish were the most numerous size class in 2010 (GEI 2010a, *in progress*[a]). This type of size distribution in 2007 through 2010 suggests that the population is maintained over time, but successful recruitment may be limited in some years. Adult fish may move upstream from lower sections of False Bottom Creek to spawn in some years.

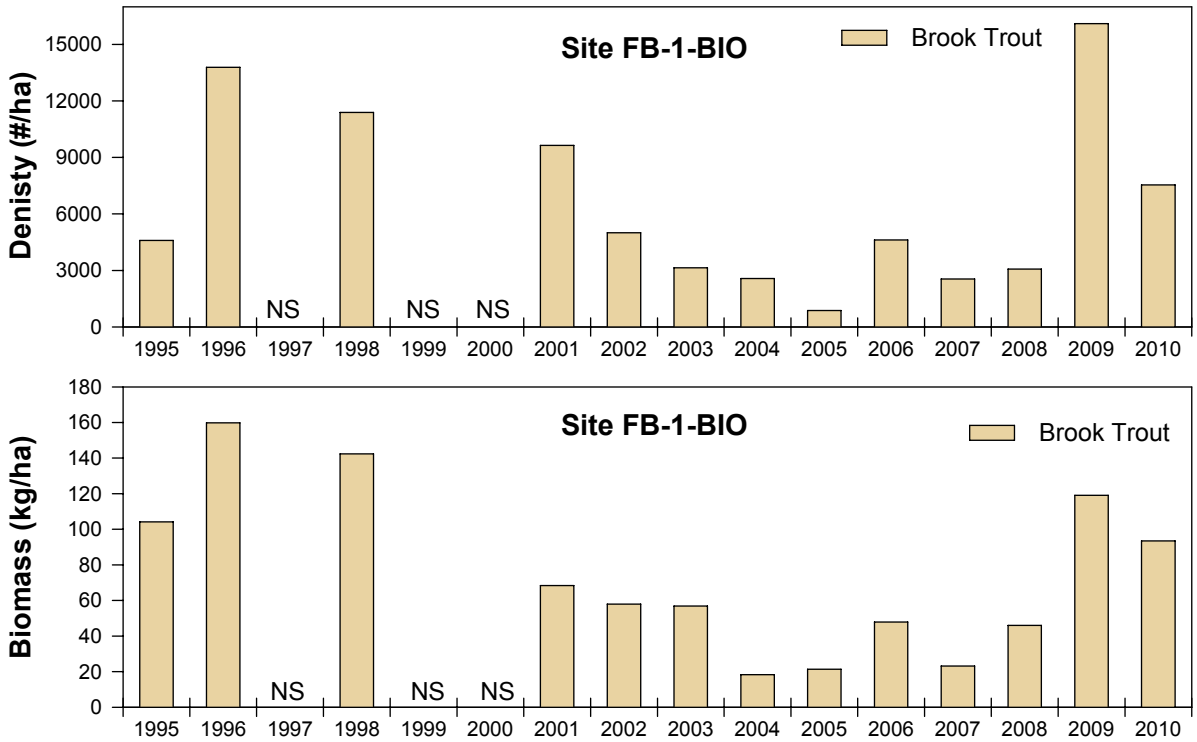

Figure 6: Density and biomass of brook trout collected during sampling at Site FB-1-BIO in False Bottom Creek, 1995 - 2010. NS = Not Sampled.

4.2.1.6 Cleopatra Creek

No fish were collected during annual sampling at Site CC-1A-BIO from 2006 through 2010 (GEI 2007a, 2008a, 2009a, 2010a; *in progress*[a]). Historically, fish density and biomass had been very high at the former Cleopatra Creek site, CC-1-BIO (CEC 2004a, 2005a, 2006a). However, the new site location is upstream in the headwaters of Cleopatra Creek where the stream size and habitat are apparently not suitable for fish.

4.2.1.7 Summary

No fish have been collected at the upstream Annie Creek site over the course of the study. Mountain suckers were collected in low densities from Site AC-2-BIO from 2001 through 2006, but were absent in 2007 and 2009, with only a few mountain suckers present in 2008. A single mountain sucker was observed in 2010. Their absence from Site AC-2-BIO in 2007 and limited presence since then may be due to either a high flow event that occurred in June 2007 or from the low dissolved oxygen levels that also occurred through fall 2007 due to a release of high BOD water. Mountain suckers were abundant in the early 1990s at this site, but their numbers have been reduced since 1995. Recovery of the mountain sucker population has likely been hampered by the elevated ammonia levels observed in February 2002 and April 2004, as well as the events that occurred in 2007. In addition, there does not appear to be any upstream sources of these fish, and movement of fish from the most downstream reach of Annie Creek is barred by Annie Creek falls.

Both brook trout and brown trout likely maintain resident populations at Site AC-3-BIO; however, brown trout populations are less stable with fewer individuals and the absence of YOY trout during some years. The brown trout population at this site is likely subsidized by the influx of fish from Spearfish Creek. Brook trout density has increased at Site AC-3-BIO since 2001 while brown trout density has decreased. Brook trout density and biomass were higher in 2010 than the range observed in previous years of the study. Mountain suckers were not detected during late summer or autumn sampling at Site AC-3-BIO from 1995 to 2010; however, one mountain sucker was collected at this site in June 2008.

The streambed at the upstream Site DC-1-BIO on Deadwood Creek site was dry from 2000 to 2008. While limited water was present in 1995, 2009, and 2010, no fish were collected, indicating that limited aquatic habitat and low, interrupted flows present in this reach of Deadwood Creek are unsuitable for fish populations. Site DC-2-BIO, downstream of Site DC-1-BIO, was surveyed from 2001 through 2005, and then again in 2010. It has perennial flows and appears to support a naturally reproducing brook trout population, with multiple size classes present in 2010.

The site on False Bottom Creek contains a population of brook trout. Trout density and biomass in 2009 and 2010 were higher than in all other years since 2001 at this site. The presence of YOY, juvenile, and adult brook trout in 2010 and some earlier years indicates that natural reproduction is occurring in this reach of False Bottom Creek. However, in other

past years, YOY or adult fish have been absent, suggesting that, while the population is maintained over time, successful recruitment may be limited in some years. Adult fish may move upstream from lower sections of False Bottom Creek to spawn in some years.

No fish have been collected from the site on Ross Valley or the current Cleopatra Creek site over the course of the study. Brook trout are common in the lower reaches of Cleopatra Creek (CEC 2004a, 2005a, 2006a). These streams are small, and the sites are in the headwaters, apparently upstream of suitable fish habitat. Lost Camp Gulch was surveyed for the first time in 2010, but no fish were present in this stream either.

4.2.2 Golden Reward

4.2.2.1 Fantail Creek

Six brook trout were collected in Fantail Creek in 1998, but fish have not been collected at this site in any other year. The presence of fish in 1998 was probably due to higher than normal summer flows, which allowed fish to move upstream during the late summer sampling period (CEC 1999c).

4.2.2.2 Nevada Gulch

Similar to Fantail Creek, the only year in which fish were present in Nevada Gulch was 1998, when a single brook trout was collected at the Lower Nevada Gulch site. The higher flows in that year likely allowed this fish to move upstream into Nevada Gulch (CEC 1999c). Sampling in 2010 was conducted at both the upper and lower sites on Nevada Gulch, but no fish were observed (GEI *in progress*[b]).

4.2.2.3 Stewart Gulch

The reach of Stewart Gulch sampled for the Golden Reward monitoring project supports a brook trout population, with this fish species collected from this site during all ten sampling events that have occurred since 1986 (Figure 7, GRMC 1987, 1992; CEC 1995a, 1998c, 1999c, 2002b, 2005b, 2006b; GEI 2009b, *in progress*[b]). No other fish species have been collected from this site over the course of the monitoring period. Brook trout density and biomass were high in 1986, 2005, 2008, and 2010, with the highest density value over the monitoring period occurring in 2008, while the highest biomass value occurred in 1986 (Appendix C, Table C-4). Brook trout density and biomass in 2010 were similar to values for these parameters in 2008, and values for both parameters were substantially higher in Stewart Gulch than in the Whitetail Creek reference site in 2010. YOY fish were abundant in 2010, with juvenile and adult fish also present. YOY fish have also been collected in high numbers in other years of the study as well (GEI 2008c), indicating that the brook trout are naturally reproducing in Stewart Gulch.

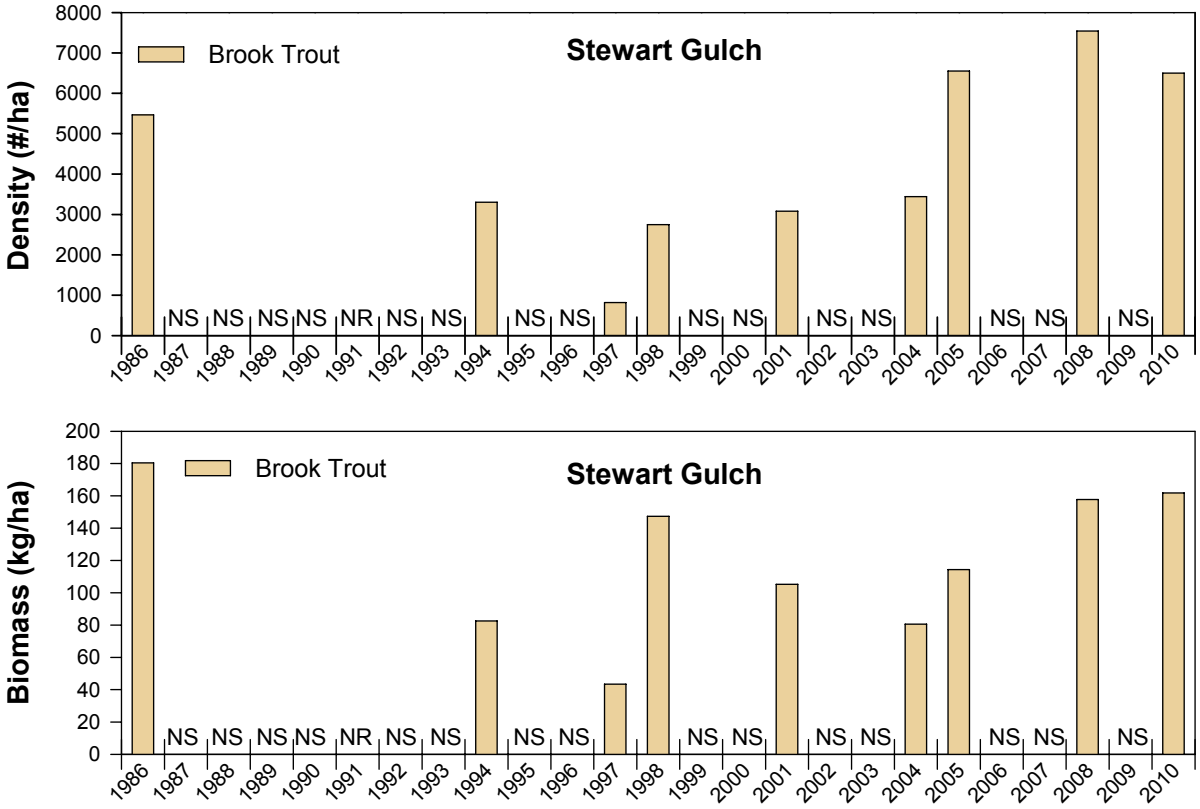

Figure 7: Density and biomass of brook trout collected during sampling at the Stewart Gulch Site, 1986 - 2010. NR = Not Reported. NS = Not Sampled.

In comparison to the reference site on Whitetail Creek, the brook trout population in this reach of Stewart Gulch has been stable over the monitoring period, indicating that the habitat and water quality conditions have been suitable to sustain their population. The long-term population parameters indicate that mining activities have had no apparent effect on trout populations in Stewart Gulch.

4.2.2.4 Whitetail Creek

The reach of Whitetail Creek sampled for the Golden Reward monitoring study represents a reference site unaffected by potential mining impacts. Similar to Stewart Gulch, only brook trout have been collected from this stream, with these fish collected in nine of the ten years of fish population monitoring at this site since 1987 (Figure 8; GRMC 1987, 1992; CEC 1995a, 1998c, 1999c, 2002b, 2005b, 2006b; GEI 2009b, *in progress*[b]). The brook trout population in Whitetail Creek has generally been more abundant during sampling events since 1998 than prior to 1998 (Appendix C, Table C-4). Density values observed in 2008 and 2010 were near the highest value recorded during the monitoring period, with values in 2001 slightly higher for Whitetail Creek. Biomass values peaked in 2008, with biomass in 2010 being lower than in 2008 but similar to or higher than values during the previous years of the study. Only a few fish were present in 1987 and 1991, and no fish were collected from this site in 1994. YOY, juvenile, and adult fish have been present during most sampling events at this site,

including in the sampling that occurred in 2010, indicating that the brook trout population in this reach of Whitetail Creek is naturally reproducing.

In comparison to Stewart Gulch, the brook trout population in Whitetail Creek, the reference site, has been less abundant and more variable. This is probably due to annual variations in flow, lower average depths, lower percentages of undercut banks, and other less suitable habitat within this small stream.

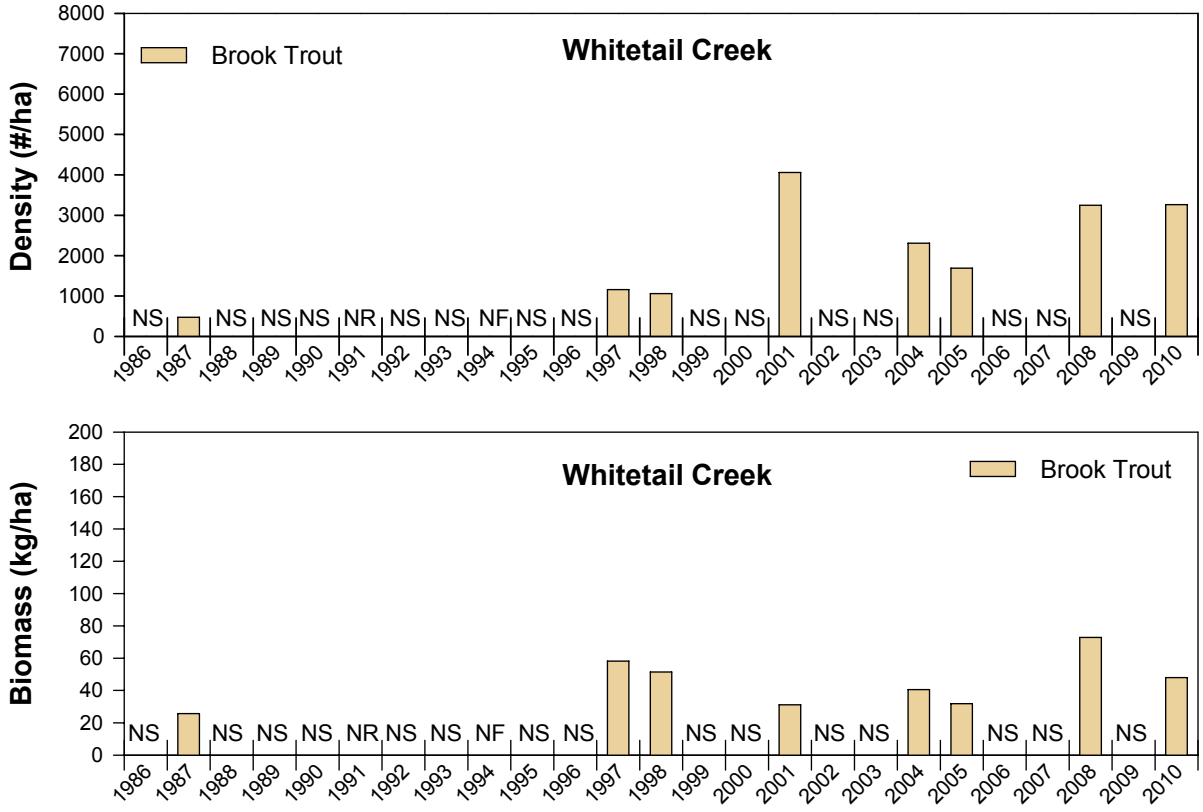

Figure 8: Density and biomass of brook trout collected during sampling at the Whitetail Creek Site, 1986 - 2010. NR = Not Reported. NS = Not Sampled.

4.2.2.5 Summary

The reaches of Stewart Gulch and Whitetail Creek sampled for the Golden Reward monitoring project both support a brook trout population. YOY, juvenile, and adult fish have been collected from both sites in many of the years of the study, indicating that these populations are naturally reproducing. Brook trout density and biomass have been variable in Stewart Gulch and Whitetail Creek, but both sites have had high trout densities and biomass in 2008 and 2010 in comparison to many earlier years of the study. In comparison to the reference site on Whitetail Creek, the brook trout population in this reach of Stewart Gulch has been stable over the monitoring period, indicating that mining activities have had no apparent effect on the trout populations and that the habitat and water quality conditions present at this site are suitable to sustain this population.

A small number of brook trout were collected from the Fantail Creek and Lower Nevada Gulch sites in 1998, but no fish have been observed at either site since then. The higher than normal flows that year likely allowed fish to move upstream into these reaches.

4.3 Benthic Macroinvertebrate Populations

4.3.1 Wharf

4.3.1.1 Annie Creek

Site AC-1-BIO

Densities, number of taxa, and number of EPT taxa have exhibited a large degree of variability over the course of the study at Site AC-1-BIO, the first sampling site on Annie Creek downstream of Outfall 006A/006B (Figures 9 and 10, Appendix D, Table D-1). Ephemeropterans (mayflies) have been present at this site in all years of the study except 1997 and 2007, but abundances have frequently been low (Figure 9). Diversity index values have been greater than 2.50 in all years except 2002 and 2007, indicating a diverse macroinvertebrate community has been present at this site in most years (Appendix D, Table D-1).

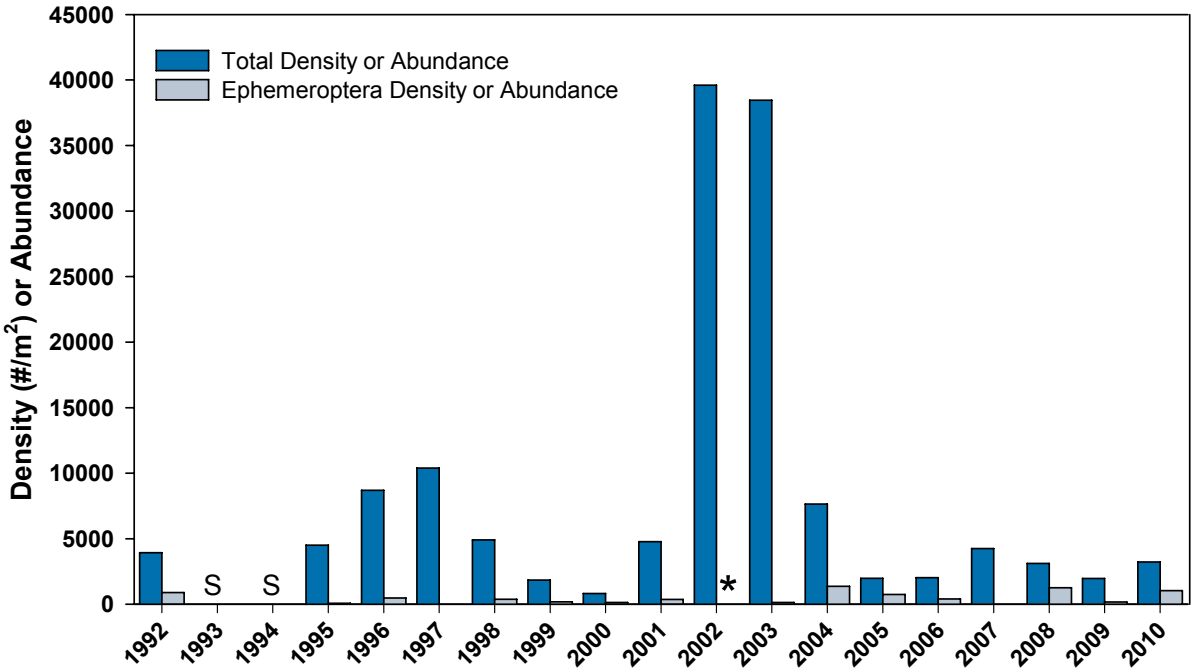

Figure 9: Benthic invertebrate density (1992 – 2005) and abundance (2006 – 2010) data for Site AC-1-BIO on Annie Creek. S = Sampled but results not presented as methods not comparable. * = Ephemeroptera were present at densities < 40 organisms/m^2.

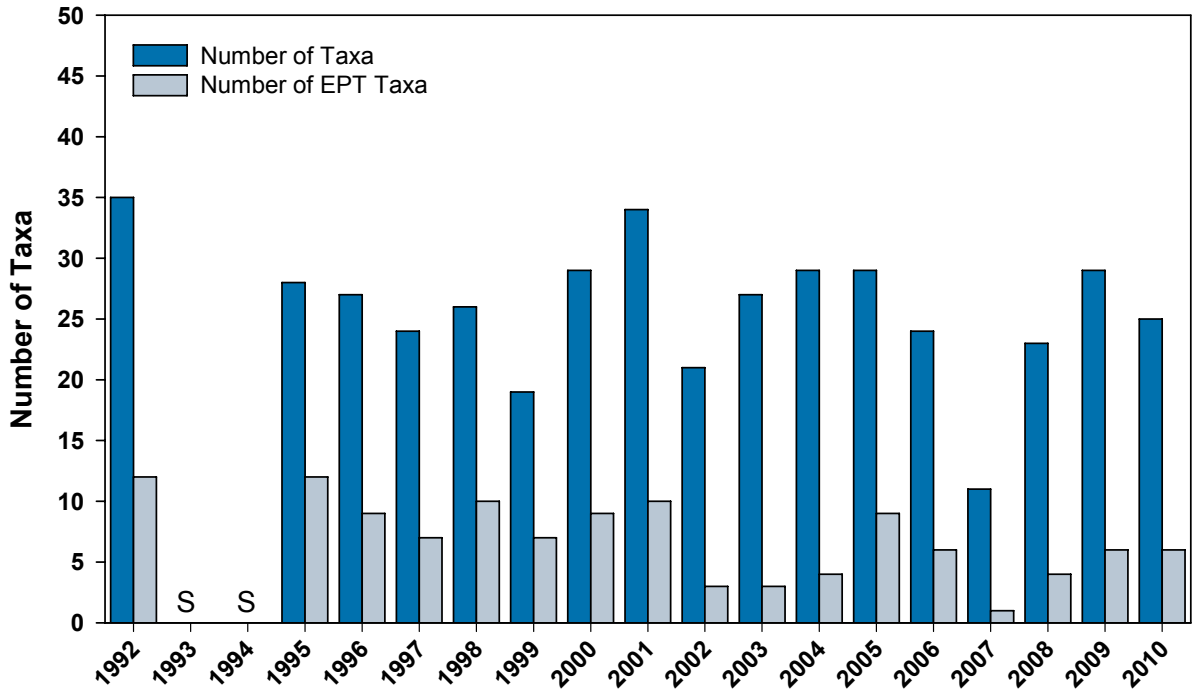

Figure 10: Total number of invertebrate taxa and EPT taxa for Site AC-1-BIO on Annie Creek, 1992 – 2010. SDDENR sampling protocols were followed in 2006 – 2010, while other sampling protocols were used prior to 2006. S = Sampled but results not presented as methods not comparable.

After the elevated ammonia levels in February 2002, macroinvertebrate populations at Site AC-1-BIO in April 2002 showed low diversity and densities (203 organisms/m^2, CEC 2003a). Number of taxa and number of EPT taxa were likewise reduced. In contrast, by August 2002, densities were extremely high (39,612 organisms/m^2), primarily due to the high densities of the chironomid midges *Eukiefferiella* sp. and *Micropsectra* sp., and the blackfly *Simulium* sp. (CEC 2003a). These midges were also present in high densities in August 2003, along with another early-colonizing midge *Pseudodiamesa* sp. (CEC 2004a). These true fly (Diptera) taxa are multivoltine (i.e., with many generations/year; Merritt et al. 2008) and were likely able to quickly colonize the area affected by the elevated ammonia (Williams and Hynes 1976; Williams 1980; Ledger and Hildrew 2001). Density then decreased through 2005. In 2006, abundance was also at the low end of the range for this site, likely reflecting the change in sampling methods and indicating that current data for this metric are not directly comparable to past data. However, levels of most other invertebrate population parameters in 2006 were similar to those seen prior to 2002 (Figures 9 and 10).

After the low dissolved oxygen levels occurred in 2007, the number of taxa, number of EPT taxa, and diversity dropped at this site, and no mayflies were present (Figures 9 and 10, Appendix D, Table D-1). The invertebrate community was again dominated by midges, similar to what had occurred in April 2002 at Site AC-1-BIO. As Site AC-1-BIO represents the headwaters of the drainage, there were limited upstream populations to repopulate the area by downstream drift. Upstream colonization by dispersing adult insects was likely

responsible for returning populations at Site AC-1-BIO to conditions similar to those prior to the elevated ammonia events in past years (Williams and Hynes 1976; Williams 1980; Hawkins and Sedell 1990; Johnson and Vaughn 1995).

In 2008, the invertebrate community was no longer dominated by midges, but the abundance, number of taxa, and number of EPT taxa remained low compared to many past years (Figures 9 and 10, GEI 2009a). Ephemeroptera abundance was the second highest over the monitoring period in 2008, but the increase resulted from high numbers of the single mayfly taxon present at Site AC-1-BIO in that year, *Baetis tricaudatus*, which is a common mayfly that is not considered sensitive to pollution (Barbour et al. 1999). Data from 2009 and 2010 indicate that Site AC-1-BIO has recovered to some extent, with number of taxa, number of EPT taxa, and the diversity values that were above or equal to the values that occurred in 2006 in both these years. However, it was still largely a pollution tolerant community.

Long-term trend analysis using data since 1992 indicated that there was no significant trend in total number of taxa over time ($p = 0.17$), but a significant decrease in the number of EPT taxa over time was detected ($p < 0.01$). Long-term comparisons between Site AC-1-BIO and the Lower Nevada Gulch reference site indicated that the total number of taxa and EPT taxa were significantly higher ($p < 0.01$ and $p = 0.02$, respectively) at the reference site than at SiteAC-1-BIO. These data indicate that while there are signs that the invertebrate populations are recovering at the upstream Annie Creek site, the population is less healthy than in the past and compared to the reference site.

Site AC-2-BIO

As at Site AC-1-BIO, density has varied considerably at Site AC-2-BIO, from less than 1,000 organisms/m^2 in 1998 to over 10,000 organisms/m^2 in 1992 and 2001 (Figure 11, Appendix D, Table D-1). Abundance in most years from 2006 through 2010 was lower than the density in previous years, which likely resulted from the change in sampling methods between 2005 and 2006. Abundance in 2009 was considerably higher than in the previous three years, and was within the low end of the range observed at this site from 1992 through 2005. Ephemeroptera abundance was highest in 1996, when this invertebrate group comprised almost 70% of the total abundance. Ephemeropterans continued to comprise a substantial proportion of the total abundance for the next two years, but lower relative abundances have been observed since 1999.

Similar to the abundance parameters, interannual variation in the number of taxa and EPT taxa was also considerable from 1992 through 2010. The number of taxa ranged from 17 taxa in 1998 to 48 taxa in 2003 (Figure 12, Appendix D, Table D-1), while the number of EPT taxa ranged from 4 taxa in 2006 to 17 taxa in 1992. Values for both parameters increased from 2006 through 2008, but have decreased in the two years since then. Diversity values have been greater than 2.50 in all years since 1998.

The elevated ammonia levels in February 2002 also affected benthic invertebrate populations at Site AC-2-BIO, but not as severely as at Site AC-1-BIO (CEC 2003a). By August 2002, most parameters were within the range observed in previous years, as were values from 2003 through 2005 (Figures 11 and 12, Appendix D, Table D-1). While chironomid midges and aquatic segmented worms (Oligochaeta) were abundant in some years at this site, they generally did not dominate the invertebrate assemblage (CEC 2003a). In 2006, most parameters were lower, likely due to the higher flows and the change in the methods in this year. In 2007, total abundance and ephemeropteran abundance was low, and chironomids dominated the community, indicating that Site AC-2-BIO was affected by the high BOD water released into Annie Creek. As was the case with the previous discharges into Annie Creek and subsequent recoveries, the benthic invertebrate community appeared largely recovered at SiteAC-2-BIO in August 2008 and 2009. However, the number of taxa and number of EPT taxa in 2010 were lower than they had been in the past three years, and were similar to values that occurred in 2006 (Figures 11 and 12).

Long-term trend analysis using data since 1992 indicated that there was no significant trend in the total number of taxa or number of EPT taxa over time (p = 0.84 and 0.07, respectively). Long-term comparisons between Site AC-2-BIO and the Whitetail Creek reference site indicated that the mean number of taxa and mean number of EPT taxa were significantly higher (p = 0.03 and 0.01, respectively) at the reference site than at Site AC-2-BIO.

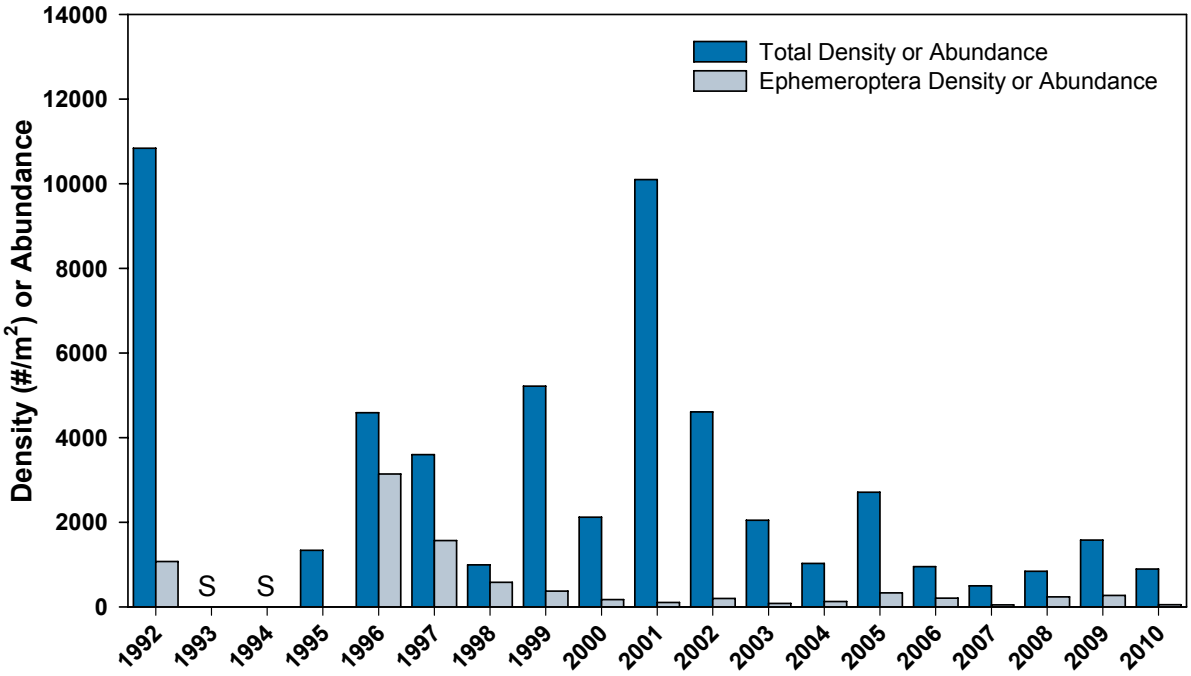

Figure 11: Benthic invertebrate density (1992 – 2004) and abundance (2005 – 2010) data for Site AC-2-BIO on Annie Creek. S = Sampled but results not presented as methods not comparable.

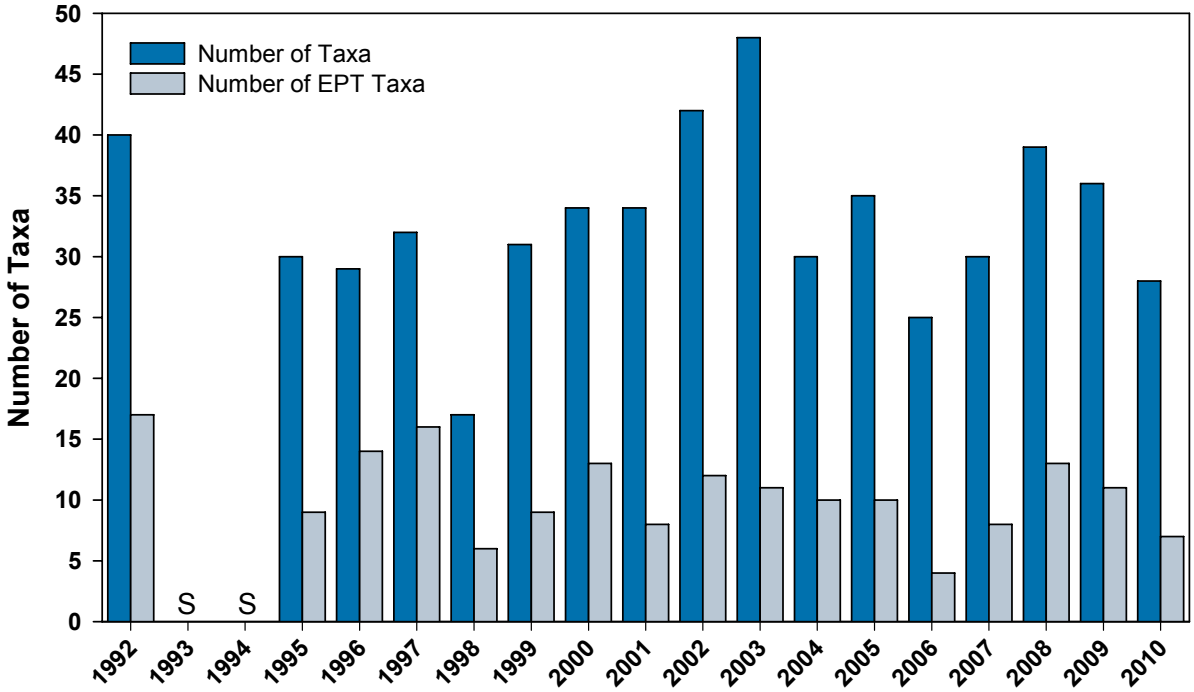

Figure 12: Number of taxa and number of EPT taxa for Site AC-2-BIO on Annie Creek, 1992 - 2010. SDDENR sampling protocols were followed in 2006 – 2010, while other sampling protocols were used prior to 2006. S = Sampled but results not presented as methods not comparable.

Site AC-3-BIO

The long-term record for Site AC-3-BIO is less consistent in terms of sampling events than at the other two Annie Creek sites because no data were collected between 1996 and 1999. Invertebrate density has varied since 1992, but has generally shown a decreasing trend since it peaked in 2001 at 12,598 organisms/m^2 (Figure 13, Appendix D, Table D-1). The abundance values for 2006 through 2009 were low compared to many density values in the past, likely as a result of the change in methods that occurred in 2006. However, abundance in 2010 was higher than it had been since 2003. Ephemeroptera abundance has been low in most years (Figure 13), but they have comprised a slightly higher percentage of the total abundance since 2006 than in most previous years. Ephemeroptera abundance was higher in 2010 than it has been since 1992. Diversity values have been well above the 2.50 threshold during all years of the study at Site AC-3-BIO, indicating diverse invertebrate communities are present.

The number of taxa and EPT taxa at Site AC-3-BIO were highest in the first year of sampling in 1992, and then peaked again in 2003 (Figure 14, Appendix D, Table D-1). Values for these two parameters have generally been lower since 2003, but increased from 2006 to 2008. The number of taxa and EPT taxa in 2009 and 2010 were similar to the values observed in 2006 and 2007.

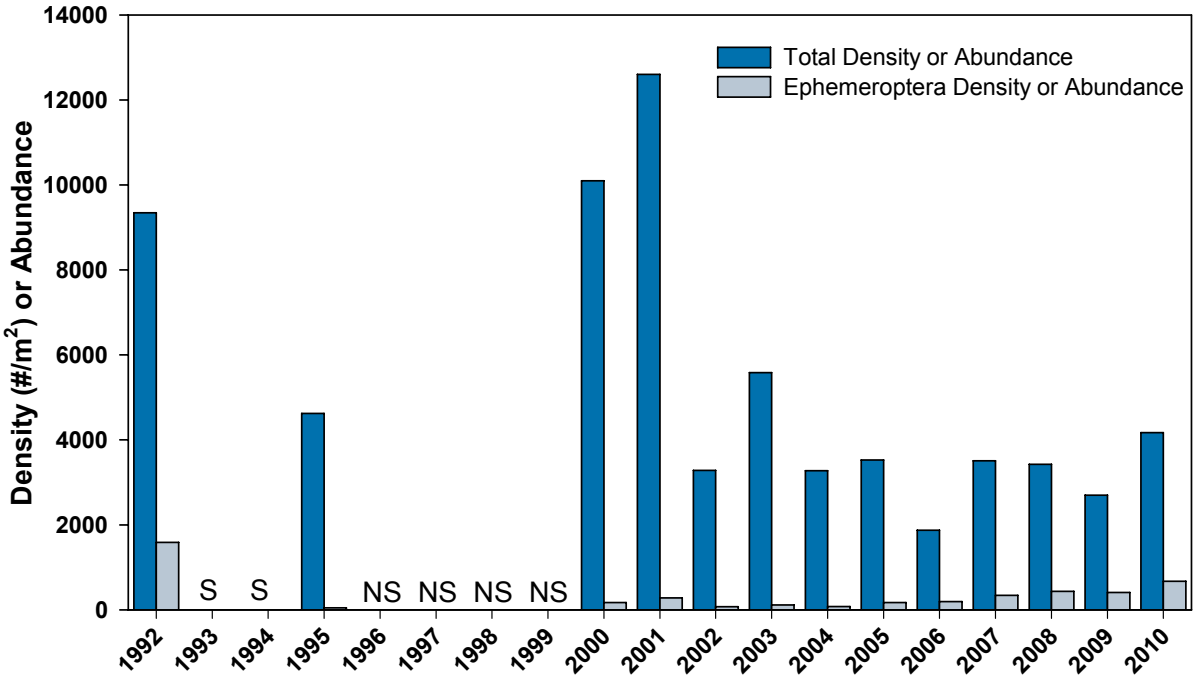

Figure 13: Benthic invertebrate density (1992 – 2005) and abundance (2006 – 2010) data for Site AC-3-BIO on Annie Creek. S = Sampled but results not presented as methods not comparable. NS = Not Sampled.

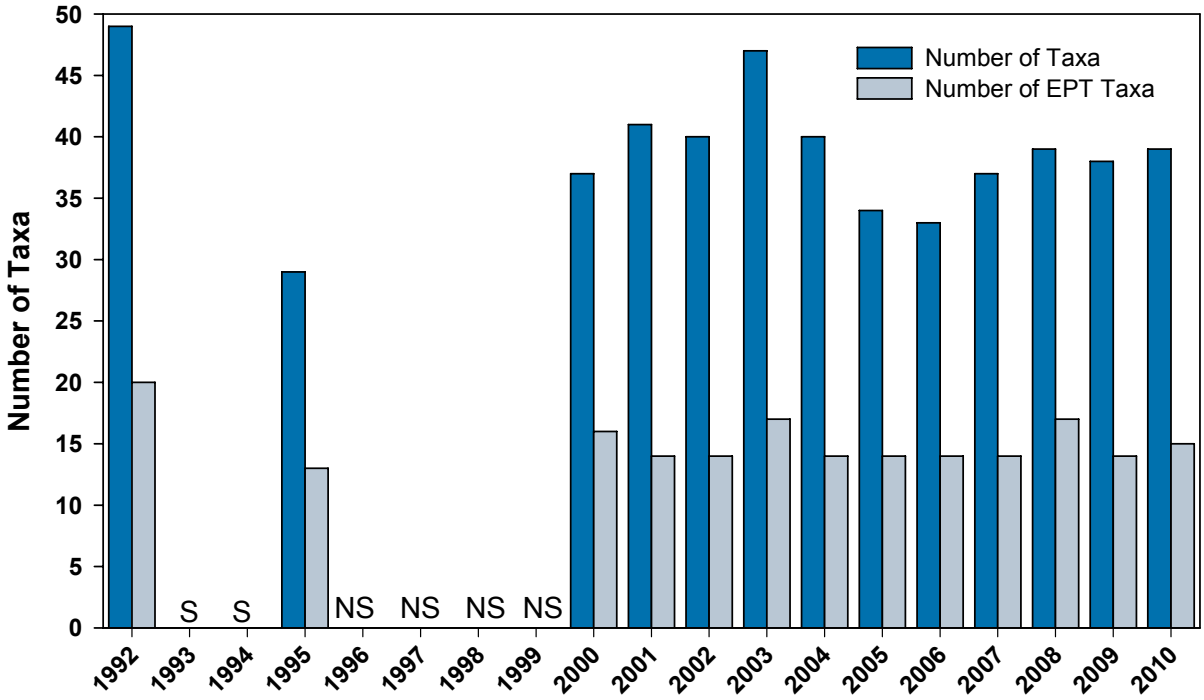

Figure 14: Number of taxa and number of EPT taxa for Site AC-3-BIO on Annie Creek, 1992 - 2010. SDDENR sampling protocols were followed in 2006 – 2010, while other sampling protocols were used prior to 2006. S = Sampled but results not presented as methods not comparable. NS = Not Sampled.

While invertebrate density at Site AC-3-BIO was low in April and August 2002 (Figure 13. CEC 2003a), possibly as a result of the elevated ammonia levels that occurred in February of that year, all other parameters were within the range observed previously at this site (Appendix D, Table D-1). Likewise, metric values in August 2007 were similar to previous values, indicating that the high BOD water released into Annie Creek in that year had less effect on the invertebrate communities at this site than at the two sites further upstream. The invertebrate community at this site was dominated by stoneflies (Plecoptera) or mayflies during all sampling events from 2007 through 2009 (GEI 2008a, 2009a, 2010a). While chironomid midges were observed in increased relative abundances in 2010 than in the past few years, the high numbers of chironomids and worms observed during some sampling events at the upstream Annie Creek sites have rarely occurred at Site AC-3-BIO over the course of the study.

Statistically, the number of taxa and number of EPT taxa at Site AC-3-BIO have remained stable since 1992 ($p = 0.50$ and $p = 0.22$, respectively). Long-term comparisons between Site AC-3-BIO and the Whitetail Creek reference site indicated that the mean number of taxa did not differ significantly ($p = 0.99$), but mean number of EPT taxa was significantly higher ($p = 0.04$) at Site AC-3-BIO than at the reference site. These results suggest that Site AC-3-BIO is not affected by Wharf mining activities, as the invertebrate assemblages at Site AC-3-BIO are at least as healthy as at the Whitetail Creek site.

4.3.1.2 Ross Valley

The monitoring site on Ross Valley, Site RV-2-BIO, was sampled for the first time in 2006. Sites upstream and downstream of the present site were sampled in April 2004 in response to the release of ammonia in that month. Values from 2004 differ substantially from 2006 through 2010 values, but the 2004 data were collected in a different season, at different locations, and with different methods. Thus, they are only comparable in a general sense to the data collected since 2006. In the spring of 2004, total invertebrate density was 15,650 organisms/m^2 (CEC 2005a), whereas in the August 2006 through 2010, abundance was much lower (Figure 15, Appendix D, Table D-2). Over these last five years, abundance was highest in 2010, when 1,648 organisms/sample were collected. Abundance in 2008 was similar to that in 2010, but abundances were substantially lower in all other years since 2006.

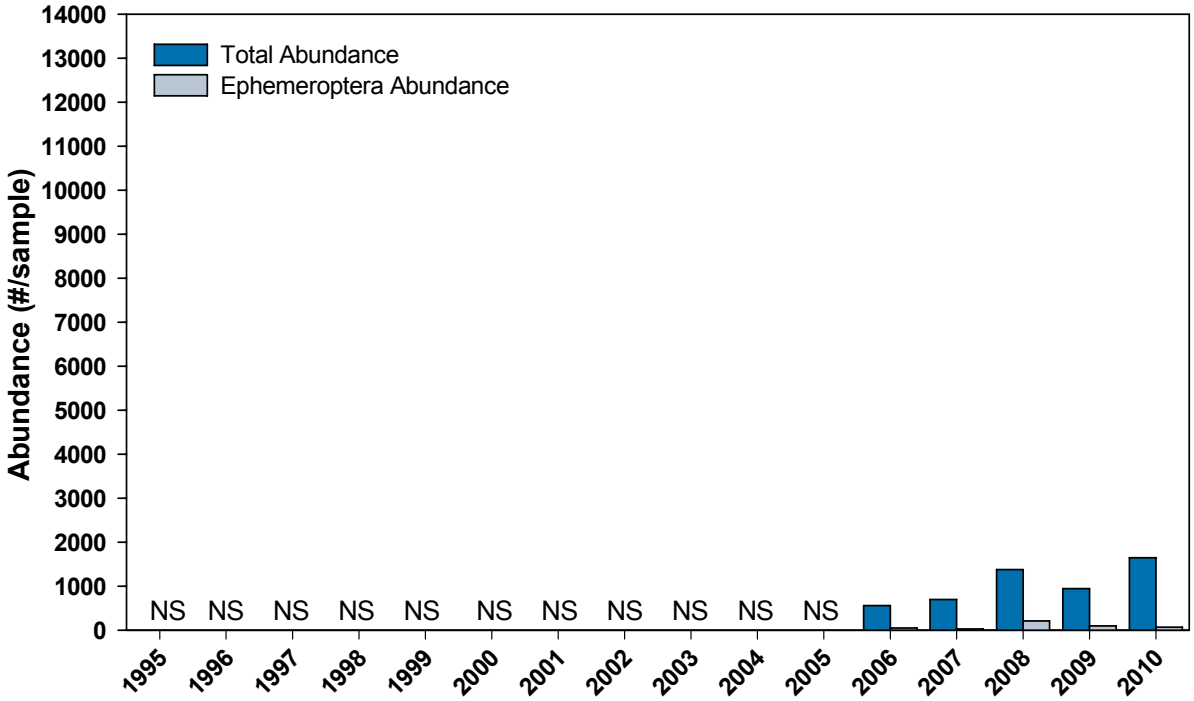

Figure 15: Benthic invertebrate abundance (2006 – 2010) data for Site RV-2-BIO on Ross Valley. NS = Not Sampled.

Despite the high density of invertebrates in 2004, only 17 taxa were collected and none of these taxa were sensitive EPT taxa, resulting in values of zero for the EPT index and the Ephemeroptera abundance metric (CEC 2005a). This is in contrast to the relatively healthy assemblage of benthic invertebrates present in most samples taken from 2006 through 2010 samples, with numerous sensitive species and EPT taxa collected each year (Figure 16, Appendix D, Table D-2). The present community is also more diverse than the stressed community present in 2004, with all diversity values since 2006 well over the 2.50 threshold that indicates diverse invertebrate assemblages are present. The number of taxa, number of EPT taxa, and diversity were highest at this site in 2007 and 2010 (Figure 16, Appendix D, Table D-2).

While limited to only five years of data, no significant increasing or decreasing trends in the number of taxa or number of EPT taxa have been observed since 2006 ($p = 0.85$ and 0.36, respectively). In addition, the mean number of taxa and number of EPT taxa at Site RV-2-BIO were statistically similar to values for these metrics at the Lower Nevada Gulch reference site ($p = 0.33$ and 0.35, respectively).

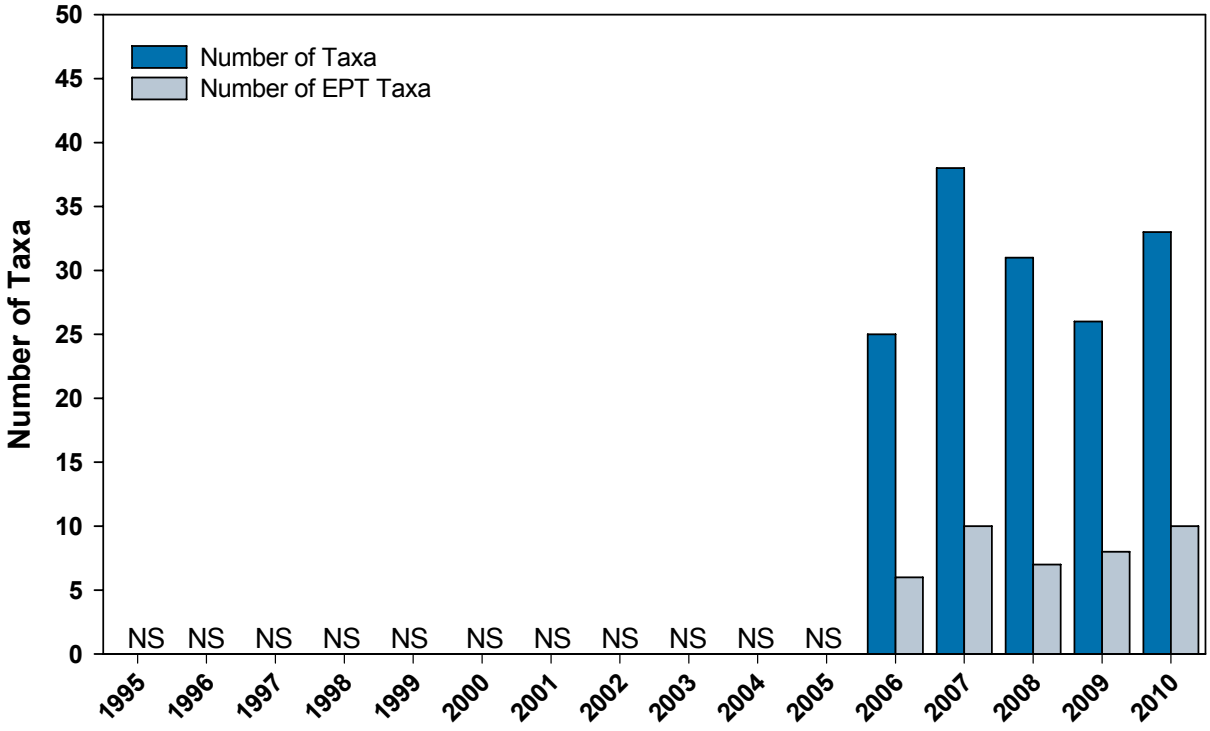

Figure 16: Number of taxa and number of EPT taxa for Site RV-2-BIO on Ross Valley, 2006 - 2010. SDDENR sampling protocols were followed in all years. NS = Not Sampled.

4.3.1.3 Lost Camp Gulch

As Site LC-1-BIO on Lost Camp Gulch was added to the study plan in 2010, only a single year of benthic invertebrate sampling has been conducted. Most metric values for this site were similar to those for the nearby Site AC-2-BIO on Annie Creek, with a total of 16 taxa and 11 EPT taxa collected (Appendix D, Table D-2). Ephemeropterans comprised 24% of the total density, and a common mayfly species, *Baetis tricaudatus*, was the dominant taxon at this site (GEI *in progress*[a]). Stoneflies, caddisflies, and true flies made up substantial proportions of the invertebrate assemblage as well, and beetles and aquatic worms were also present in low numbers. Diversity was well over the 2.50 threshold indicating a diverse community was present at this site in 2010. Other than abundance, all other metrics values for Site LC-1-BIO were higher that at the Lower Nevada Gulch reference site in 2010.

4.3.1.4 Deadwood Creek

Site DC-1-BIO

The monitoring site on Deadwood Creek, Site DC-1-BIO, was sampled in 1995 through 1999, but was dry between 2000 and 2008 (Appendix D, Table D-3). Sufficient water was present in 2009 and 2010 to collect a sample. Abundance in 2009 was substantially higher than from 1995 through 1999, but it was within the range observed in the earlier years in 2010. The high abundance in 2009 was largely due to a high numbers of chironomid midges

that were collected (Figure17). The number of taxa, number of EPT taxa, and percent Ephemeroptera abundance in 2009 and 2010 were either below or at the low end of the range observed from 1995 through 1999, with no mayflies collected at this site in 2010 (Figure 17 and 18; Appendix D, Table D-3). While the diversity index value was above the 2.50 threshold in 2010, it was substantially lower in 2009.

The low diversity in 2009 was largely due to a single chironomid taxon, *Micropsectra* sp. that dominated the invertebrate population, comprising 69% of the total abundance at this site (GEI 2010a). While diversity was higher in 2010, the same midge taxon was again dominant, comprising 60% of the total abundance (GEI *in progress* [a]). The intermittent flows and limited habitat present at this site would restrict the ability of some invertebrate taxa to flourish at this site, but taxa such as *Micropsectra* sp. and some of the other true fly taxa are able to colonize streams quickly in low flows or when flows resume (Grzybkowski 1995). While chironomid taxa were commonly present in the samples collected from 1995 to 1999 as well (CEC 2000a), they were present at lower relative abundances.

As no sampling occurred from 2000 to 2008 due to the lack of water at Site DC-1-BIO, statistical analysis of trends or comparison to reference sites is not appropriate. The range of values observed for the number of taxa and number of EPT taxa metrics at this site for the years in which water was present from 1995 through 2010 was lower than the range of values observed at the Lower Nevada Gulch during the same time period.

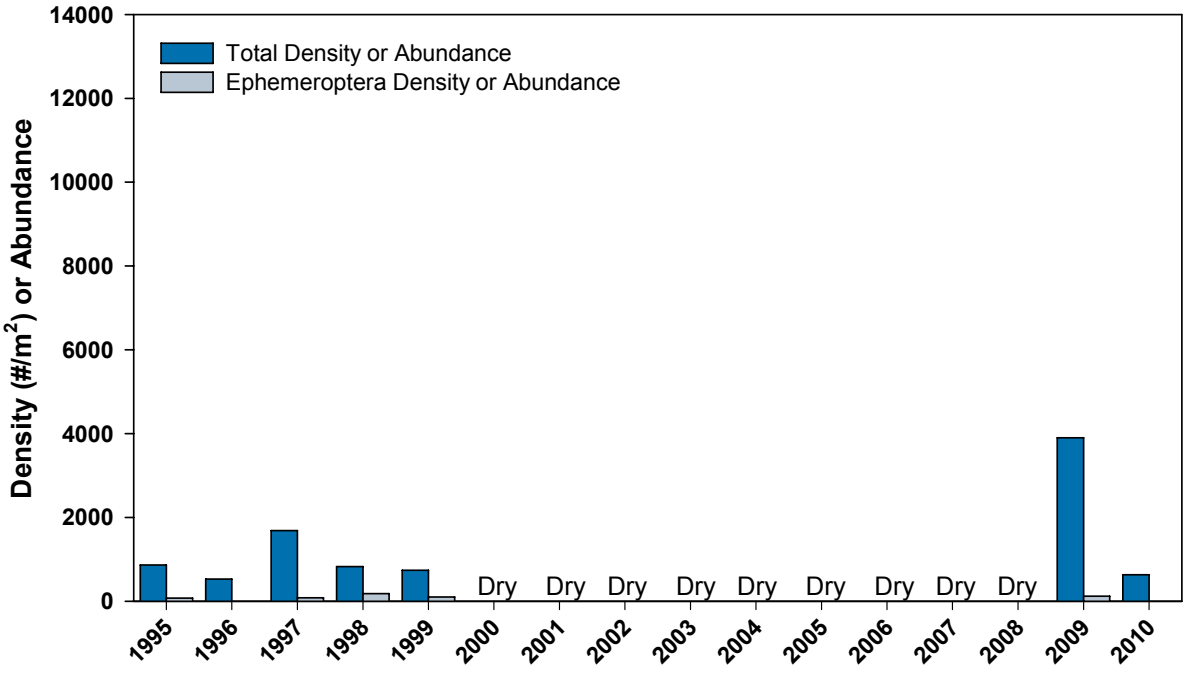

Figure 17: Benthic invertebrate density (1992 – 1999) and abundance (2009 - 2010) data for Site DC-1-BIO on Deadwood Creek.

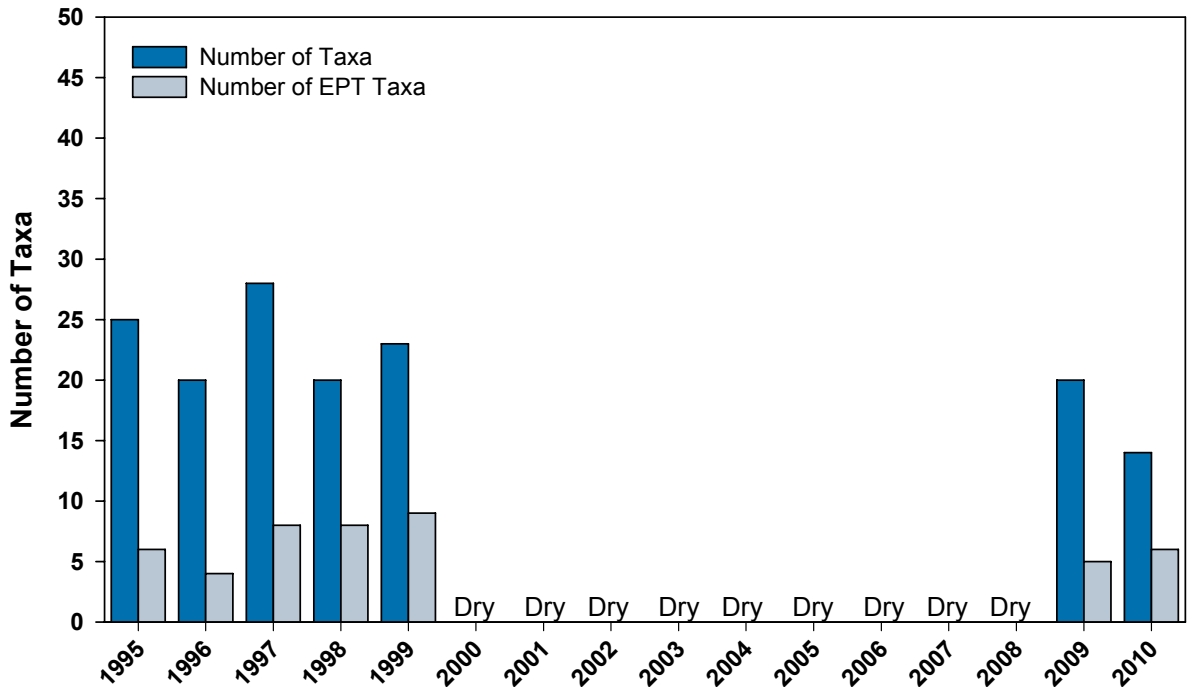

Figure18: Number of taxa and number of EPT taxa for Site DC-1-BIO on Deadwood Creek, 1995 - 2010. SDDENR protocols were followed for sample collection in 2009 and 2010, while other sampling protocols were used from 1995 – 1999.

Site DC-2-BIO

Invertebrate populations at Site DC-2-BIO were sampled from 2000 through 2005, this site was discontinued from the sampling program in 2006. This site was again sampled in August 2010 as part of the supplemental sampling conducted for the potential mine expansion areas. Invertebrate density generally showed an increasing trend from 2000 through 2005 at Site DC-2-BIO, with the highest density recorded in 2005, when 7,951 organisms/m^2 were collected (Figure 19, Appendix D, Table D-3). Abundance in 2010 was within the range of density values observed in the earlier years, but was substantially lower than in 2005. Ephemeropteran abundance varied more over the same time period, but also peaked in 2005, and was lower in 2010. In most years, ephemeropterans comprised 10% or less of the total density.

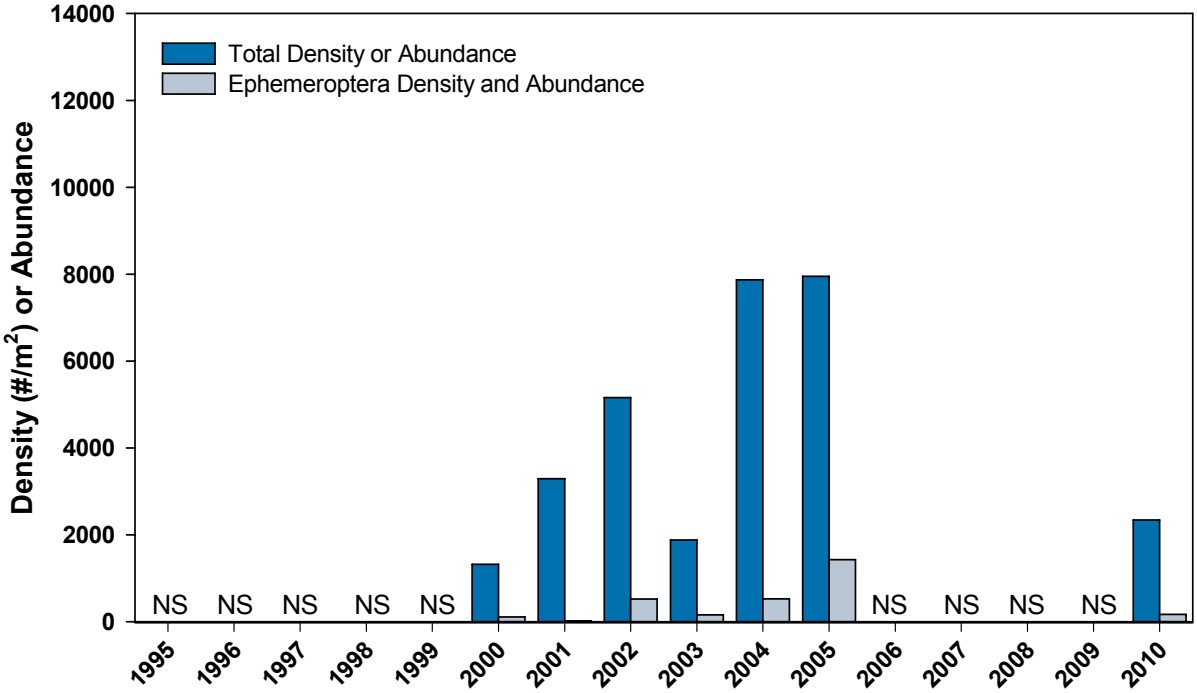

Figure 19: Benthic invertebrate density (2000 – 2005) and abundance (2010) data for Site DC-2-BIO on Deadwood Creek, 2000 - 2010. NS = Not Sampled.

The total number of taxa collected at this site ranged from 27 taxa collected in 2001 to 43 taxa collected in 2002 (Figure 20, Appendix D, Table D-3). EPT taxa comprised from 30% to 40% of those taxa in most years, with up to 16 EPT taxa collected. Values for both these metrics in 2010 were within the range observed from 2000 through 2005. While true fly taxa as a whole were more abundant in 2001, 2002, 2004, and 2005 at Site DC-2-BIO, a stonefly taxon from the Nemouridae family was the dominant taxon in most years at this site, including 2010, and comprised up to 43% of the total abundance (CEC 2002a, 2003a, 2004a, 2005a; GEI *in progress* [a]). Diversity values were well above the 2.50 threshold during all six years, indicating that diverse invertebrate populations inhabit this reach of Deadwood Creek.

While statistical analysis was not conducted on the limited and discontinuous data available for this site, qualitative evaluation of the data indicated that no consistent trends in the number of taxa and number of EPT taxa were apparent (Figure 20). Qualitative comparison of the number of taxa and number of EPT taxa data from Site DC-2-BIO with the data for the Whitetail Creek reference site showed that values for these metrics at the Deadwood Creek site were within the range observed at the Whitetail Creek site for all years except 2001.

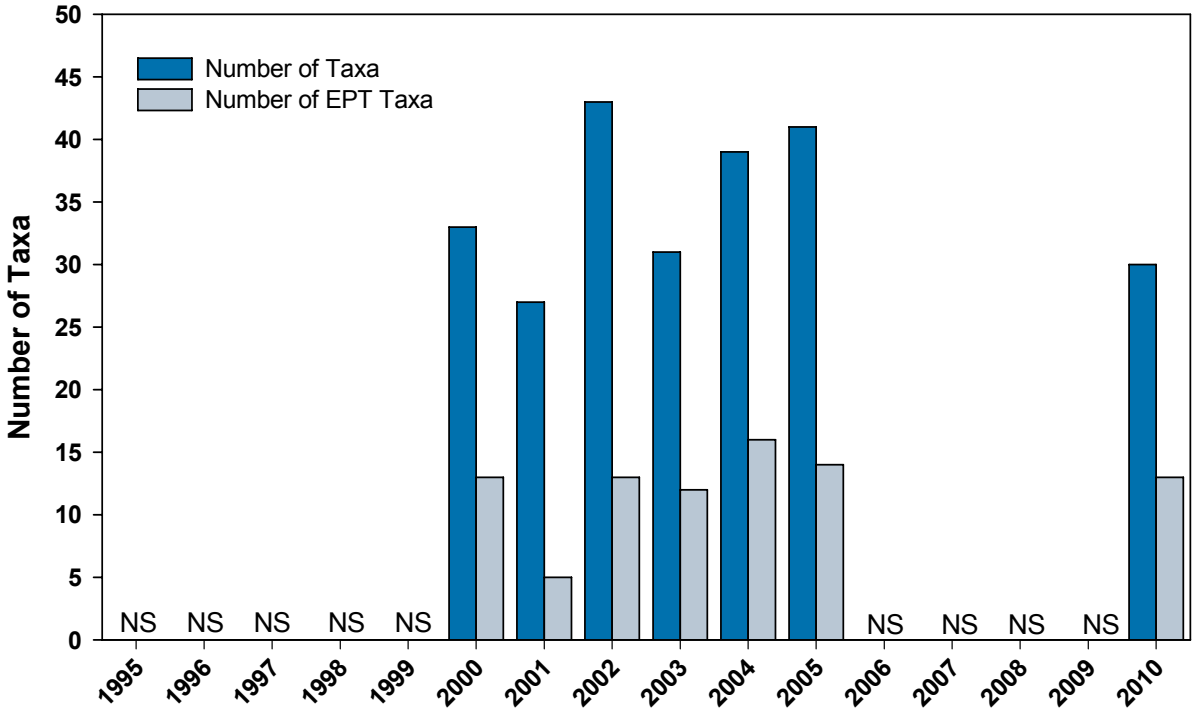

Figure 20: Number of taxa and number of EPT taxa for Site DC-2-BIO on Deadwood Creek, 2000 – 2010. SDDENR protocols were followed for sample collection in 2010, while other sampling protocols were used from 2000 - 2005. NS = Not Sampled.

4.3.1.5 False Bottom Creek

Site FB-1-BIO on False Bottom Creek has been sampled annually since 1995, which allows for investigation of temporal trends. Through 2005, there was generally an increasing trend in density observed at this site, but abundance in 2006 through 2010 was lower than the 2005 density value, which was the highest recorded value for this site (Figure 21, Appendix D, Table D-3). Likely the change in sampling methods that occurred in 2006 was a factor in the lower abundances observed since then. Since 2006, abundances have varied slightly from year to year, being higher in 2006, 2008, and 2010, and lower in the intervening years. Ephemeroptera abundance also reached its highest value in 2005 concurrently with the high total density. Despite the sampling differences, Ephemeroptera abundance was within the range observed in previous years in 2006, but then decreased substantially in 2007 and remained low in 2008 and 2009 before increasing considerably in 2010.

The invertebrate community composition has differed from year to year at Site FB-1-BIO, with tolerant aquatic worm or true fly taxa comprising the majority of the populations in some years, while stonefly taxa were more abundant in other years (CEC 1996c, 1997b, 1998b, 1999b, 2000a, 2001a, 2002a, 2003a, 2004a, 2005a, 2006a, GEI 2007a, 2008a, 2009a, 2010a, *in progress* [a]). However, generally no single taxon strongly dominated the invertebrate community. Diversity values have remained well over the 2.50 threshold since

1995, indicating diverse invertebrate communities are present in this reach of False Bottom Creek.

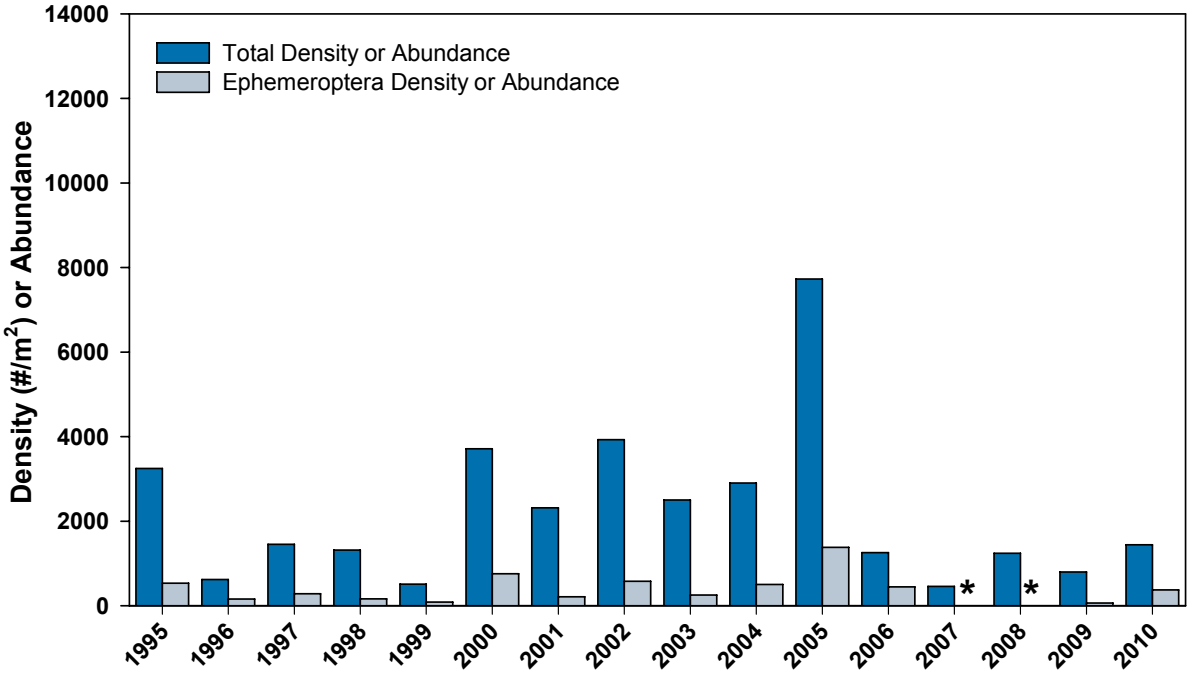

Figure 21: Density (1995 – 2005) and abundance (2006 – 2010) parameters for Site FB-1-BIO on False Bottom Creek. * = Ephemeroptera were present at abundances ≤ 5 organisms/sample.

The number of taxa and number of EPT taxa peaked in 2004 and have been lower in all years since then (Figure 22). However, values for both metrics have been relatively stable during this time period, with no significant increasing or decreasing trends in the total number of taxa or number of EPT taxa at Site FB-1-BIO since 1995 ($p = 0.10$ and 0.19, respectively). At Site FB-1-BIO, the stream size is intermediate between the size of Nevada Gulch and Whitetail Creek. However, Whitetail Creek has been utilized as the Golden Reward reference site for this stream (CEC 2006a). Long-term comparisons between Site FB-1-BIO and the Whitetail Creek reference site indicated that the number of taxa and number of EPT taxa were significantly higher ($p \leq 0.01$ for both) at the reference site than at Site FB-1-BIO. The larger size of the Whitetail Creek reference stream in comparison to False Bottom Creek which may contribute to this difference.

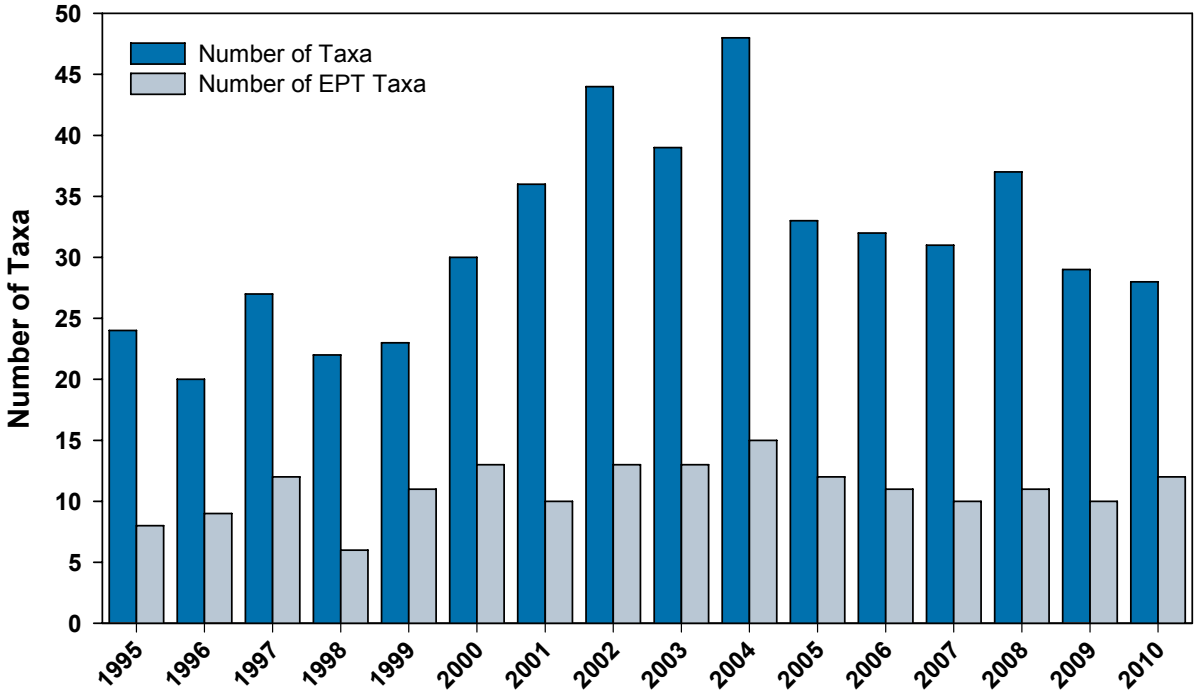

Figure 22: Number of taxa and number of EPT taxa for Site FB-1-BIO on False Bottom Creek, 1995 - 2010. SDDENR protocols were followed for sample collection in 2006 – 2010, while other sampling protocols were used prior to 2006.

4.3.1.6 Cleopatra Creek

The monitoring site on Cleopatra Creek was established at a new location in 2006 that is immediately downstream of the headwaters and the Wharf Mine. The site previously sampled through 2005 on Cleopatra Creek was downstream of Site CC-1A-BIO, and had higher water levels and more consistent flows (CEC 2006a). As a result, Site CC-1A-BIO and the former Cleopatra Creek Site CC-1-BIO are not comparable. Thus, only comparisons of Site CC-1A-BIO from 2006 through 2010 were assessed.

Invertebrate abundance was higher at this site in 2008 and 2009 than in the other years since 2006, but ephemeropterans were either absent or comprised 1% or less of the total abundance each year since 2006 (Figure 23, Appendix D, Table D-2). The number of taxa collected at Site CC-1A-BIO has ranged from 11 taxa in 2006 to 22 taxa in 2008. The highest number of EPT taxa was also collected in 2008, when seven of these taxa were present (Figure 24, Appendix D, Table D-2).

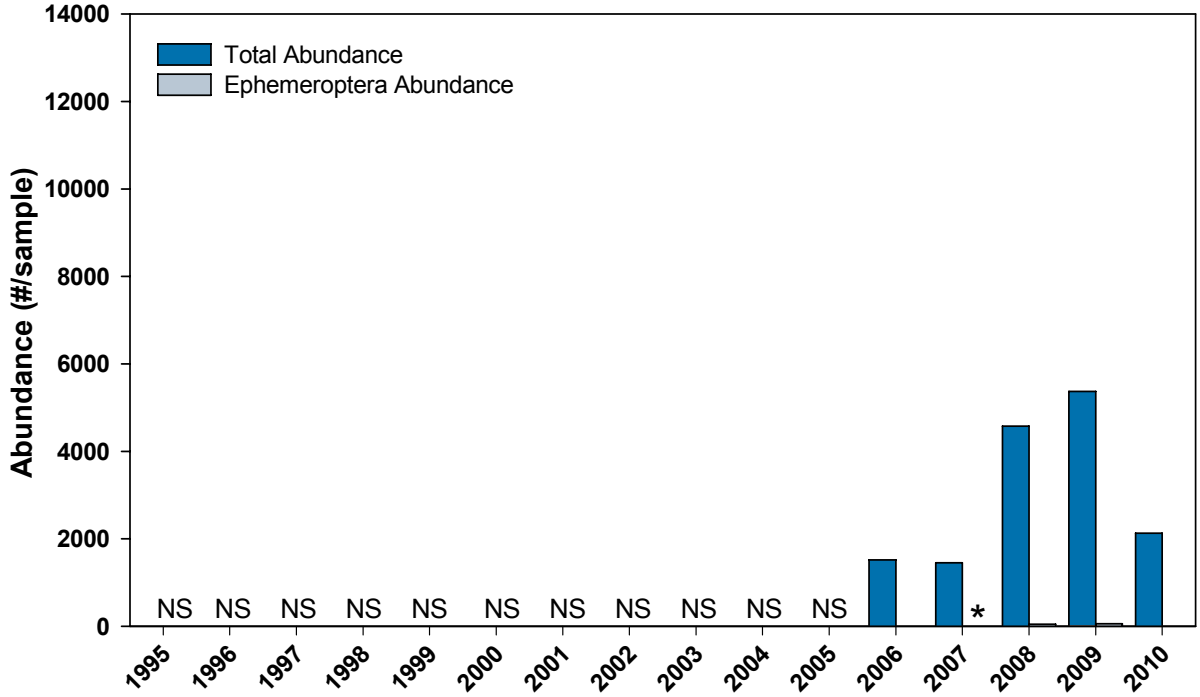

Figure 23: Benthic invertebrate abundance (2006 – 2010) data for Site CC-1A-BIO on Cleopatra Creek. NS = Not Sampled. * = Ephemeroptera present at abundances ≤ 15 organisms/sample.

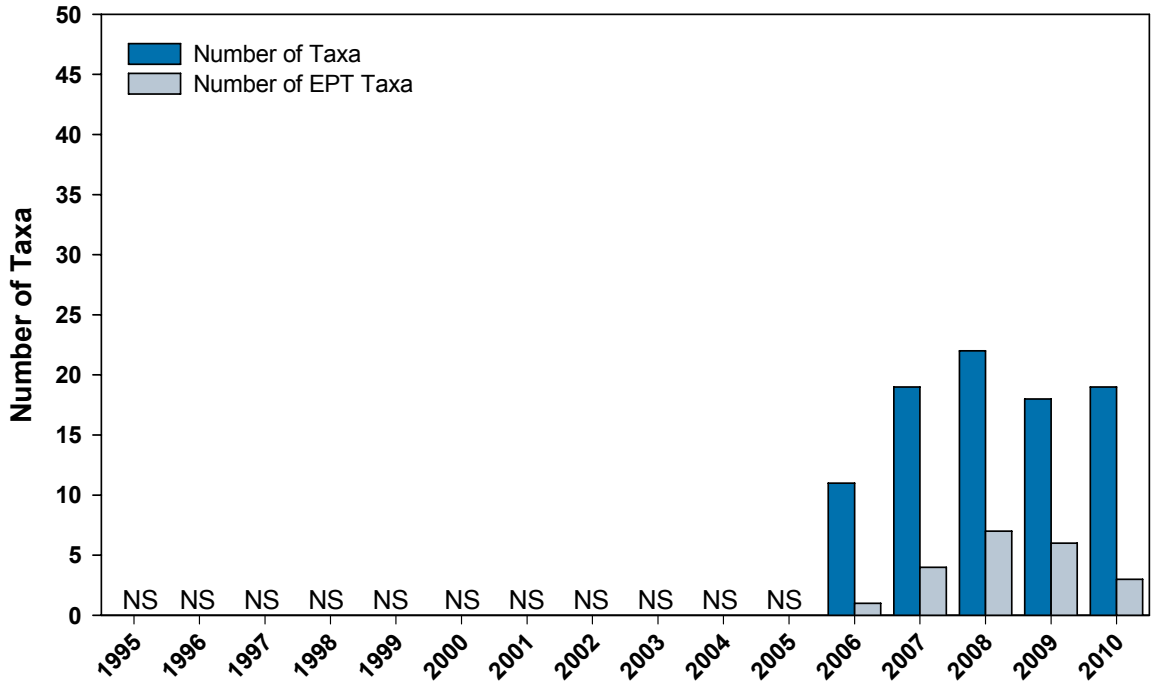

Figure 24: Number of taxa and number of EPT taxa for Site CC-1A-BIO on Cleopatra Creek, 2006 - 2010. SDDENR sampling protocols were followed in all years. NS = Not Sampled.

Hydrologic regime can influence benthic community structure (Zale et al. 1989; Grzybkowska 1995), and often streams with limited flows are dominated by chironomids, which are able to colonize streams very quickly in low flows or when flows resume after a dry period (Grzybkowska 1995). In 2006, the community was dominated by chironomid midges, which comprised 97% of the abundance, and only had a single EPT taxa present (GEI 2007a; Appendix D, Table D-2). In 2007, the community contained only 39% chironomids, and most other metrics were more favorable as well. The benthic invertebrate community in 2008 was similar to in 2007, but chironomids again dominated the community in 2009 and 2010, although at slightly lower percentages than in 2006 (GEI 2008a, 2009a, 2010a). Diversity values indicate that the population was less diverse in 2006 and 2009 than in the intervening years and 2010. Based on the higher flows that occurred in Annie Creek in 2007 and 2008 (Figure 2), more water was likely present in Cleopatra Creek in some of those years also, which may account for the healthier communities.

While data for Cleopatra Creek is more limited than at many of the other sites, with five years of data collected, there were no trends detected in the number of taxa or number of EPT taxa since 2006 ($p = 0.31$ and 0.51, respectively). Statistical comparisons between Site CC-1A-BIO and the Lower Nevada Gulch reference site indicate that the number of taxa and number of EPT taxa were significantly lower at Site CC-1A-BIO ($p < 0.01$ for both), likely reflecting the limited flows present in this reach of Cleopatra Creek.

4.3.1.7 Summary

Macroinvertebrate data collected since 1992 indicate that invertebrate populations at the two downstream Annie Creek sites generally have been diverse and balanced over the course of the study. However, invertebrate assemblages at the upstream Annie Creek site, Site AC-1-BIO, have shown signs of stress in some years. After the elevated ammonia levels and low dissolved oxygen levels that occurred in Annie Creek in 2002 and 2007, respectively, the total number of taxa, number of EPT taxa, and diversity index values at this site decreased substantially. Density initially was also low in the spring 2002 sampling event, but high numbers of midge and other true fly larvae were observed in the fall 2002 sampling event. These pollution-tolerant midges again dominated the invertebrate community in 2007, and no mayflies and only a single EPT taxon were collected. The data from 2009 and 2010 indicated that the invertebrate community at Site AC-1-BIO was beginning to recover, although some signs of stress persisted. While there was no trend in total number of taxa over time at this site, the number of EPT taxa has significantly decreased since 1995. Site AC-1-BIO also had a significantly lower mean number of taxa and mean number of EPT taxa than the Lower Nevada Gulch reference site. These trends indicate that the population is less healthy than it has been in the past and compared to reference sites.

Sites AC-2-BIO and AC-3-BIO did not appear to be as affected by the elevated ammonia levels that occurred in 2002 as the site upstream was, as most metric values in that year were similar to or higher than those that occurred in the previous year. The invertebrate community composition at Site AC-2-BIO was dominated by chironomids in 2007, possibly as a result of the low dissolved oxygen levels that occurred that year, but the population has since appeared to be largely recovered. The invertebrate community at Site AC-3-BIO appeared to be affected little by the low dissolved oxygen levels, and the invertebrate population at this site was dominated by mayflies or stoneflies in most of the years from 2007 through 2010, as it was in some previous years. The two downstream Annie Creek sites have shown no significant trends in the number of taxa or number of EPT taxa over time. However, Site AC-2-BIO had a significantly lower mean number of taxa and number of EPT taxa over time in comparison to the Whitetail Creek reference site, while Site AC-3-BIO had similar or more favorable long-term values for these parameters in comparison to the reference site. Metric values at this site and the favorable comparisons to reference site values suggest that Site AC-3-BIO is not affected by mining activities.

While sensitive taxa have been present at sites DC-1-BIO and CC-1A-BIO over the course of the study, the invertebrate assemblages at these two sites were often numerically dominated by chironomid midges, a group that is generally tolerant of disturbance and often colonizes streams quickly after a disturbance occurs. The limited aquatic habitat and low to intermittent flows that occur at these two sites likely allow such taxa to thrive while limiting other groups. Many of the metric values at these two sites compared unfavorably to values at the Lower Nevada Gulch reference site, which is of similar size to these streams but appears to have more consistent flows.

True fly taxa continued to be abundant at the downstream Deadwood Creek site as they were at the upstream site, but stoneflies were also numerous, and EPT taxa comprised 30% to 40% of the total number of taxa each year, indicating that this reach of Deadwood Creek supports many sensitive species. Site DC-2-BIO and Site RV-2-BIO on Ross Valley both compared more favorably to the reference sites, with most metric values being similar to or higher than those at their respective reference sites, indicating that healthy, diverse invertebrate assemblages are present at these sites. The invertebrate populations at Site LC-1-BIO on Lost Camp Gulch were sampled for the first time in 2010, and most metric values for this site were similar to those for the nearby Site AC-2-BIO on Annie Creek. Other than abundance, all other metrics values for Site LC-1-BIO were higher that at the Lower Nevada Gulch reference site in 2010.

Diversity index values have been high at the site on False Bottom Creek since 1995, but the invertebrate community has often been numerically dominated by pollution tolerant taxa such as aquatic worms and true flies. However, sensitive EPT taxa have been collected at Site FB-1-BIO during every sampling event, and the number of taxa and number of EPT taxa appears to have been stable since 1995. Analyses indicate that the long term mean number of taxa and number of EPT taxa at this site were statistically lower than at the Whitetail Creek

reference site; however, the smaller size of False Bottom Creek compared to Whitetail Creek may account for some of these differences.

4.3.2 Golden Reward

4.3.2.1 Fantail Creek

The site on Fantail Creek has been sampled annually from 1995 through 2010 (CEC 1996d, 1997c, 1998c, 1999c, 2000c, 2001b, 2002b, 2003b, 2004b, 2005b, 2006b; GEI 2007b, 2008c, 2009b, 2010b, *in progress* [b]). This site was moved upstream approximately 1.0 km in 2005 from its former location near the mouth of the stream. The new location is just downstream of the Yenter Sand Filter Dam and has different characteristics than the former site, namely that the new location is in a section that may have occasionally gone dry, and the dam probably limits the drift of benthic invertebrates from upstream. The data collected between 2005 and 2010 are statistically similar to that collected prior to 2005, indicating that the change in location had no effect (GEI *in progress* [b]). However, the data since 2005 tend to be on the low end of the range of data collected since 1995 suggesting that there may be an effect over time.

Total invertebrate density and abundance has varied substantially over this time period. Density was highest in 2000 and 2001, but was considerably lower in 2002 (Figure 25, Appendix E, Table E-1). It then increased again from 2003 through 2004, but remained lower from 2005 through 2008. The decrease observed between 2004 and 2005 likely resulted at least in part from the change in sampling methods that occurred between those two years, but may also have been an effect of the change in location. However, abundances in 2009 and 2010 were higher than in the preceding four years, and were similar to the values observed in 1995 and 1996. Ephemeropteran abundance was generally low in most years in Fantail Creek, particularly in 1997, 2002, and 2004 (Figure 25). The relative abundance of Ephemeroptera has been higher since 2005 than in most of the previous years.

The number of taxa and number of EPT taxa have varied less over time (Figure 26, Appendix E, Table E-1). Both parameters had high values in 2000, 2003, and 2008. The number of taxa and number of EPT taxa collected in Fantail Creek in 2009 and 2010 were on the low end of the range of values observed for each parameter since 1995. Data over the entire study show no significant long-term trend in the number of taxa or number of EPT taxa from 1995 to 2010 ($p = 0.85$ and 0.97, respectively). The lack of any increasing or decreasing trends indicates that the variability in the benthic invertebrate community is due to natural variation.

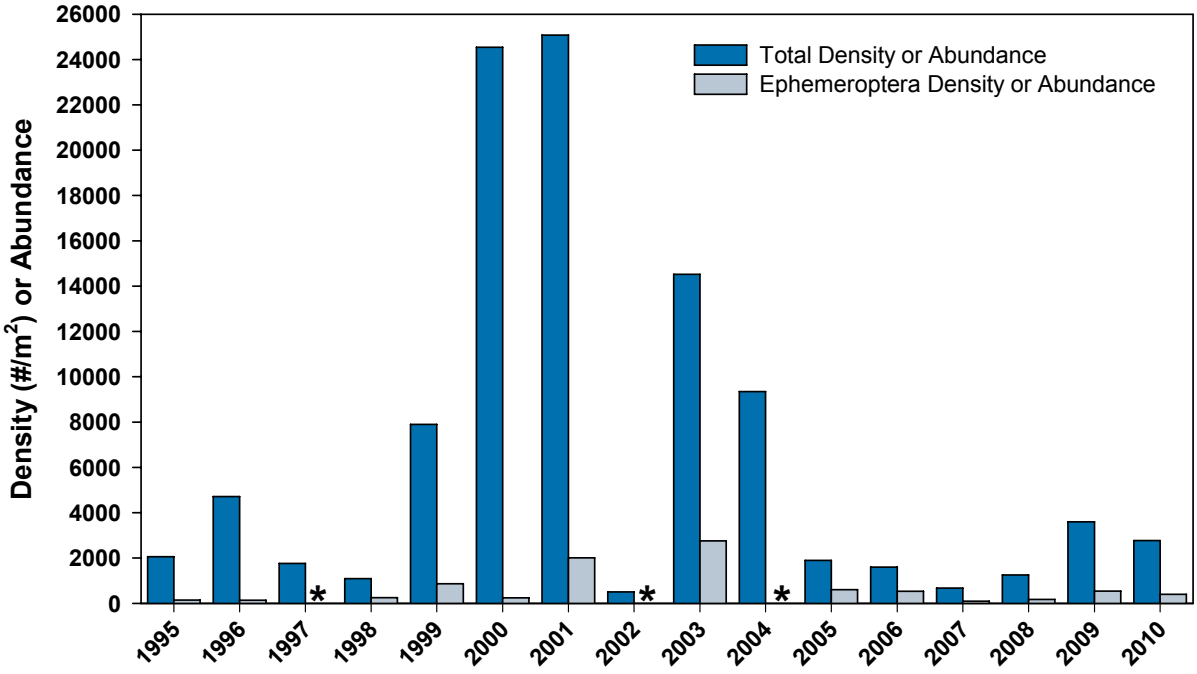

Figure 25: Density (1995 – 2004) and abundance (2005 – 2010) data for the Fantail Creek site. * = ephemeropteran abundance ≤ 18 organisms.

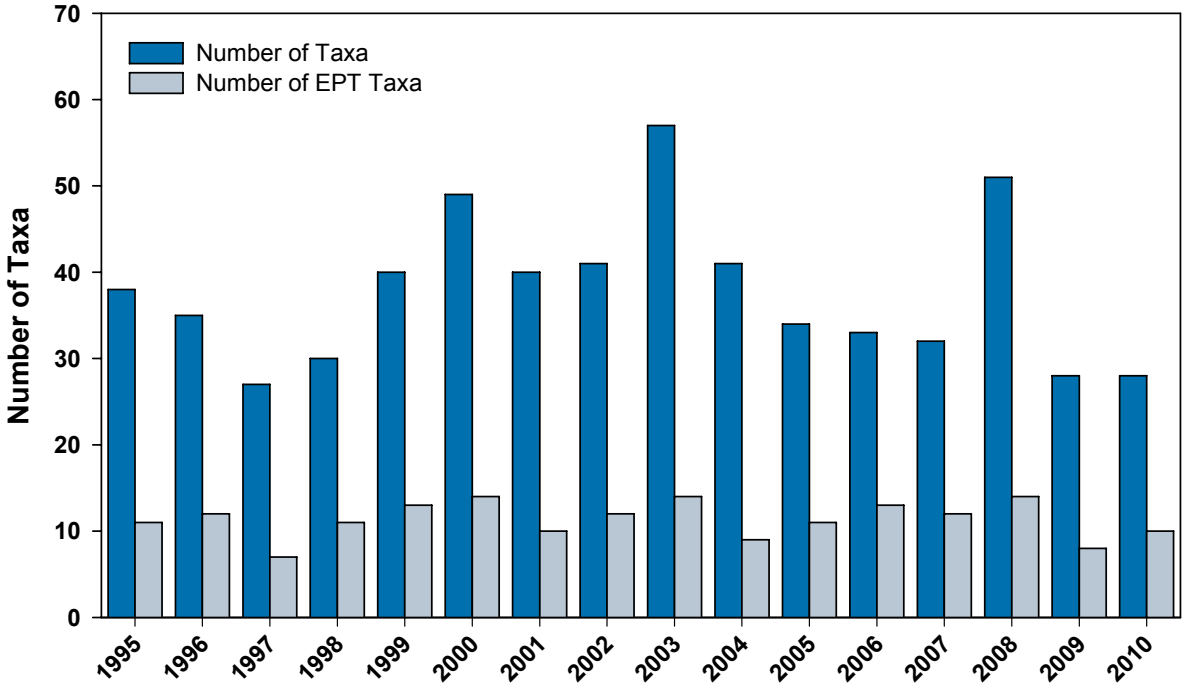

Figure 26: Number of taxa and number of EPT taxa parameters for Fantail Creek, 1995 - 2010. SDDENR protocols were followed for sample collection in 2005 through 2010, while other sampling protocols were used prior to 2005.

The invertebrate community composition varied among years in Fantail Creek. The more tolerant true fly taxa were the dominant group of invertebrates in most years since 1995 and in the qualitative kick samples since 1986 (GRMC 1987, 1990, 1992, 1993; CEC 1994a, 1995a, 1996d, 1997c, 1998c, 1999c, 2000c, 2001b, 2002b, 2003b, 2004b, 2005b, 2006b; GEI 2007b, 2008c, 2009b, 2010b). However, the more sensitive stoneflies were dominant in approximately a third of the samples since 1996, and mayflies, caddisflies (Trichoptera), beetles (Coleoptera), or snails (Gastropoda) were instead the most abundant group in a few years. These results illustrate the high amount of natural variability associated with the benthic invertebrate communities. Using the data from 1995 through 2010, there was no significant differences in the mean number of taxa or number of EPT taxa between the Fantail Creek site and either of the reference sites ($p = 0.11$ and > 0.05, respectively).

Baseline data were collected in 1986 and 1987 at all four Golden Reward sites with kick-net samples. This method is different than the current method and makes comparisons difficult. However, at Fantail Creek and the other three sites, the current methods collected a higher number of invertebrates and roughly twice as many taxa as the baseline data (Appendix E, Tables E-1 and E-3). In Fantail Creek, the baseline samples were dominated by true fly and beetle taxa, while the more recent data indicate higher proportions of sensitive species. This suggests that water quality in Fantail Creek in recent years is as good as or better than baseline conditions and is suitable for supporting sensitive species.

4.3.2.2 Nevada Gulch

4.3.2.3 Upper Nevada Gulch

The Upper Nevada Gulch site was sampled from 1995 through 2005 (CEC 1996d, 1997c, 1998c, 1999c, 2000c, 2001b, 2002b, 2003b, 2004b, 2005b, 2006b), and was originally used as one of the reference sites. After 2005, sampling at this site was discontinued; however, it was sampled again in 2010 as part of the supplemental sampling for the potential mine expansion areas.

Abundance at Upper Nevada Gulch varied little from 1995 through 1999, but was substantially higher in 2000 (Figure 27, Appendix E, Table E-1). In most years from 2001 through 2005, as well as in 2010, density or abundance was lower than in 2000, but was higher than had been observed in the earlier years of the study. Ephemeropteran abundance was low at this site in 2010 and throughout most of the course of the study, and no ephemeropterans were collected in 2004. True flies were the most abundant invertebrate group collected in 1997, 1998, 2002, 2004, and 2005, while stone flies dominated the invertebrate community in all other study years (CEC 1996d, 1997c, 1998c, 1999c, 2000c, 2001b, 2002b, 2003b, 2004b, 2005b, 2006b; GEI *in progress* [b]).

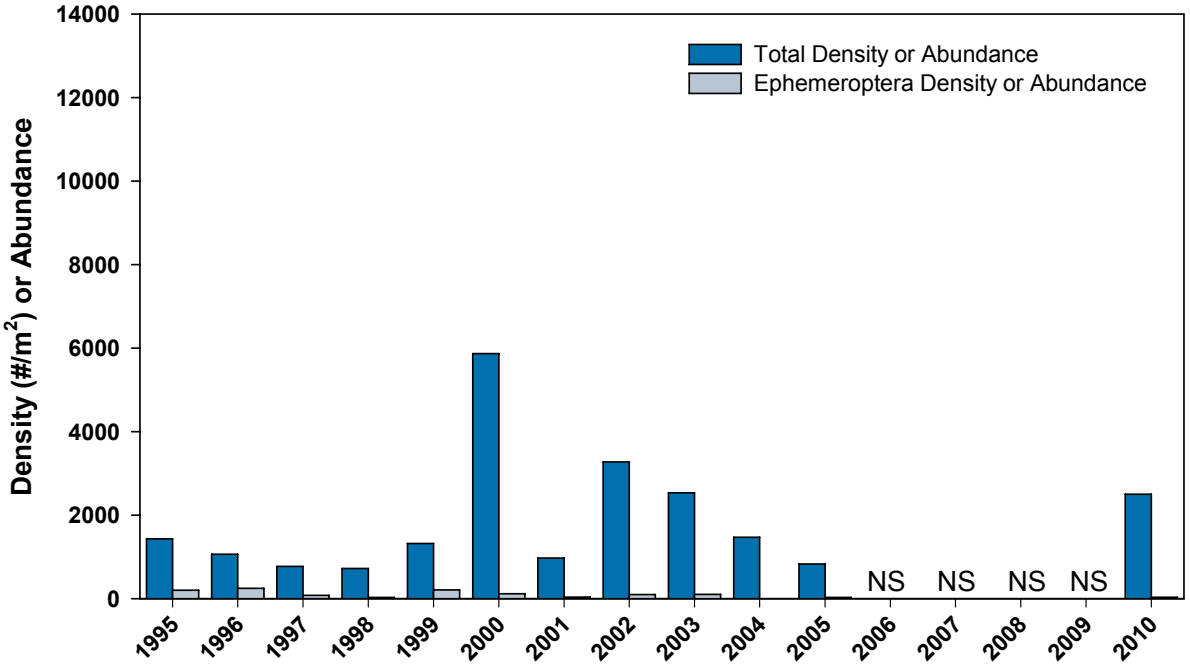

Figure 27: Density (1995 – 2004) and abundance (2005 and 2010) data for Upper Nevada Gulch. NS = Not Sampled.

The number of taxa and number of EPT taxa were relatively constant from 1995 through 2002, and then peaked at this site in 2003, when 55 total taxa and 15 EPT taxa were collected (Figure 27, Appendix E, Table E-1). Both parameters then decreased substantially in 2004 to levels more similar to those observed in the earlier years of the study. The number of taxa and number of EPT taxa collected in 2010 were similar to values for these metrics in 2004 and 2005. There were no significant trends in number of taxa or number of EPT taxa at this site from 1995 through 2010 ($p = 0.36$ and 0.67, respectively).

The mean number of taxa at the Upper Nevada Gulch site was not significantly different from mean values for the other Golden Reward sites using data since 1995 ($p = 0.12$). The mean number of EPT taxa at the Upper Nevada Gulch site was also not significantly different from the Lower Nevada Gulch site, but was significantly lower than the mean number of EPT taxa at the remaining Golden Reward sites ($p < 0.05$). These significant differences and the low values observed for some of the population parameters at the Upper Nevada Gulch site may be related to the low flows, small stream size, and sedimentation from non-mining related causes (CEC 2005b).

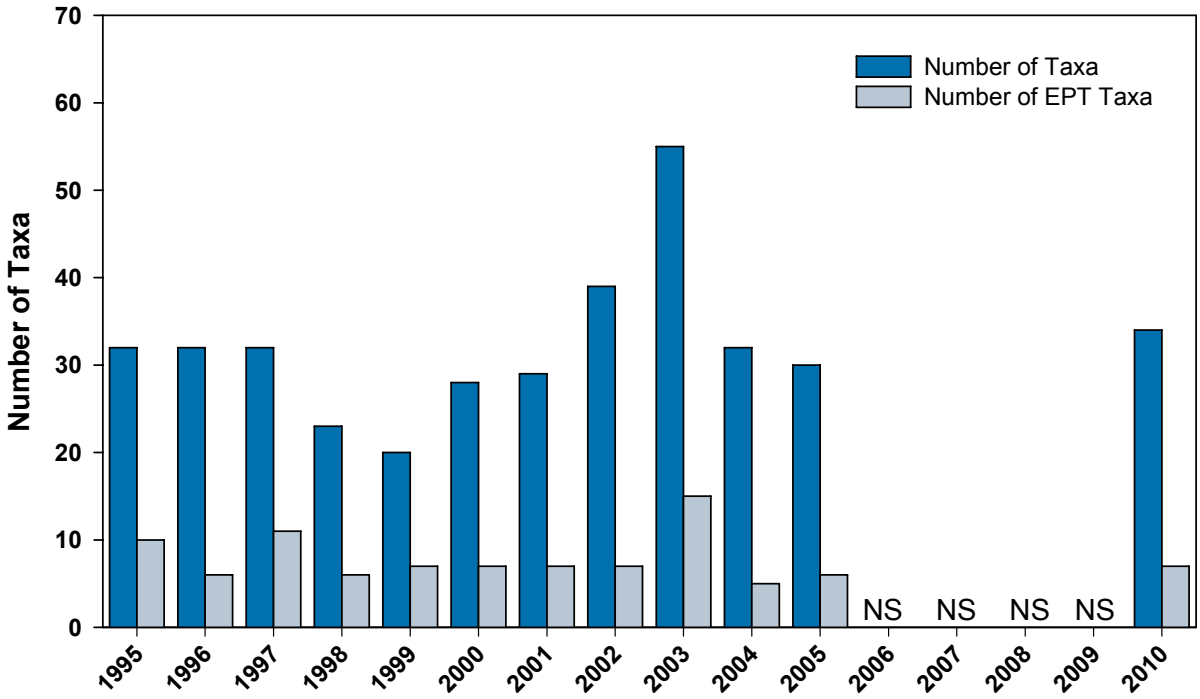

Figure 28: Number of taxa and number of EPT taxa parameters for Upper Nevada Gulch, 1995 - 2010. SDDENR protocols were followed for sample collection in 2005 and 2010, while other sampling protocols were used prior to 2005.

4.3.2.4 Lower Nevada Gulch

The Lower Nevada Gulch reference site has exhibited high variability in all benthic invertebrate parameters since 1995 (Figures 29 and 30; Appendix E, Table E-1). Total abundance was highest in 2002, and was generally at the low end of the range observed previously from 2005 through 2010 (Figure 29). However, the change in sampling methods that occurred in 2005 likely affected values for this parameter. Ephemeropteran abundance was low in most years, but these organisms comprised 20% or more of the total number of invertebrates collected in 2005 and 2006.

The highest number of taxa collected from this site over the course of the study occurred in 2003, when a total of 47 taxa were present (Figure 30, Appendix E, Table E-1). Only a little over half as many taxa were collected in 2000, the lowest over the monitoring period for this site. The number of taxa collected from 2005 to 2010 was variable and generally in the middle of the range of values that occurred in the previous years. The number of EPT taxa fluctuated more at Lower Nevada Gulch than the other Golden Reward sites, ranging from four EPT taxa collected in 2002 to 15 EPT taxa collected in both 1996 and 1999 (Figure 30, Appendix E, Table E-1). The number of EPT taxa has been near the middle or high end of the data range since 2006. No significant long-term trends in the number of taxa or number of EPT taxa have been detected using data since 1995 ($p = 0.47$ and 0.23, respectively). The lack of any consistent increasing or decreasing trends indicates that changes in the benthic

invertebrate community are mainly the result of natural variation. The mean number of EPT taxa at this site is substantially lower than the mean number collected at the other reference site on Whitetail Creek ($p < 0.05$), but is statistically similar to the number of EPT taxa collected at the other sites.

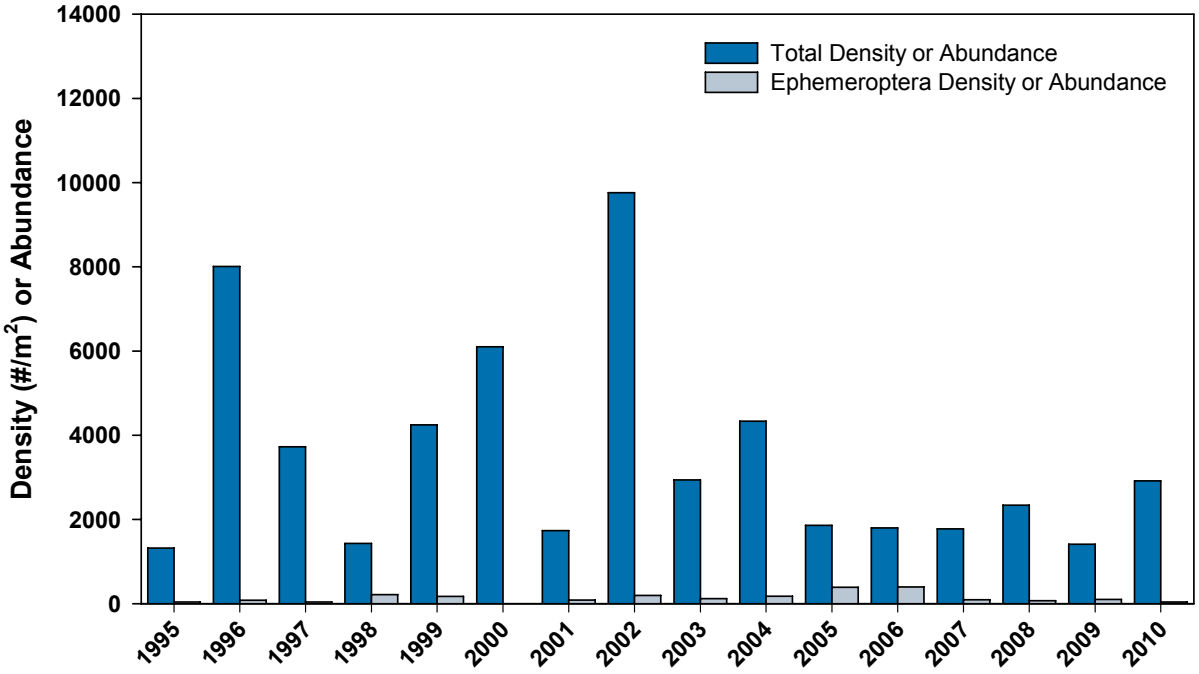

Figure 29: Density (1995 – 2004) and abundance (2005 – 2010) data for the Lower Nevada Gulch site.

True flies have dominated the invertebrate community composition in Lower Nevada Gulch in eleven of the sixteen years in which this site has been sampled, with stoneflies dominating in most of the remaining years (GRMC 1987, 1990, 1992, 1993; CEC 1994a, 1995a, 1996d, 1997c, 1998c, 1999c, 2000c, 2001b, 2002b, 2003b, 2004b, 2005b, 2006b; GEI 2007b, 2008c, 2009b, 2010b). Low flows in some past years in this small stream may have decreased the abundance of EPT taxa, as true flies have been the dominant group each year since 2002. These taxa are generally considered more tolerant of drought conditions than other insect groups and are able to become locally very abundant when flows return. The benthic invertebrate community at this small stream site has apparently not recovered entirely from the low flows and habitat conditions that allowed true fly taxa to become dominant during the drought.

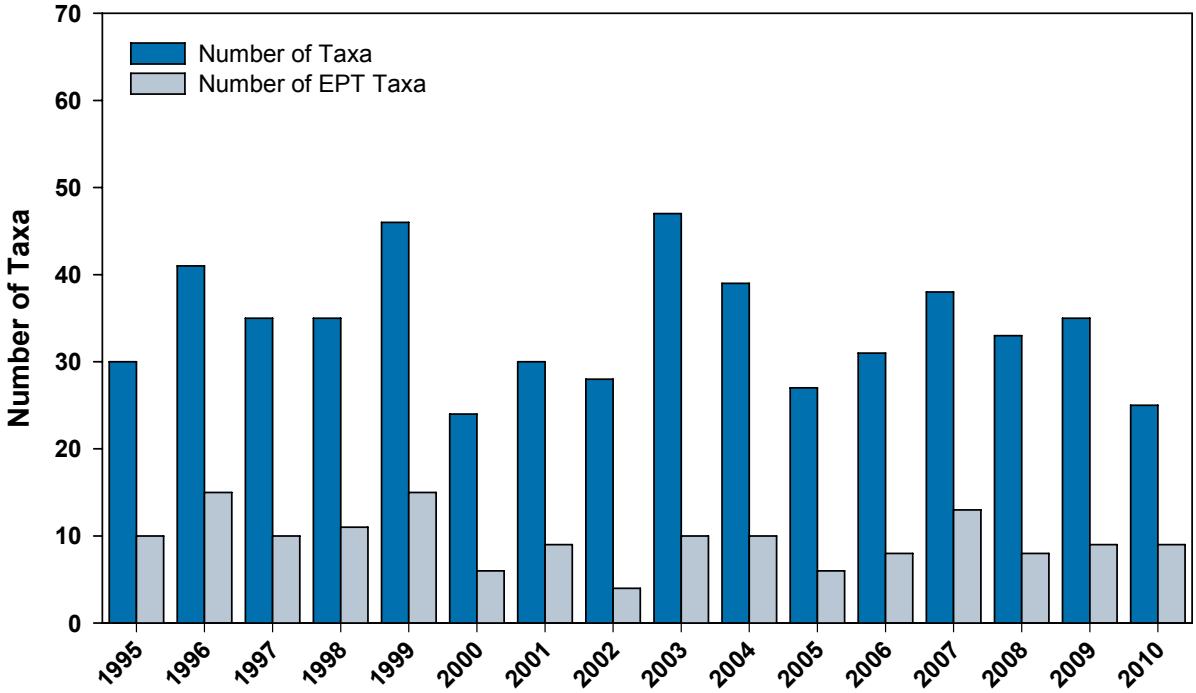

Figure 30: Number of taxa and number of EPT taxa for the Lower Nevada Gulch site, 1995 - 2010.

4.3.2.5 Stewart Gulch

The number of invertebrates collected in Stewart Gulch ranged from 467 organisms/m^2 collected in 1998 to 13,225 organisms/m^2 collected in 2002 (Figure 31, Appendix E, Table E-2). A high number of organisms were collected in 2000 and 2005 as well. Since 2005, total abundance has varied less, with abundances in each year falling within the range observed previously. Ephemeropterans frequently comprised a substantial proportion of the total number of invertebrates collected annually at the Stewart Gulch site, and made up almost 50% of the total number collected in 1998, the year in which total density was lowest. Ephemeropterans have comprised 20% or more of the total abundance in four of the six years since 2005 (Figure 31, Appendix E, Table E-2).

The number of taxa increased in most years from 1998 to 2004 at the Stewart Gulch site, before fluctuating near the middle of the range in 2005 through 2010 (Figure 32, Appendix E, Table E-2). This appears to be natural variability, since no significant, long-term trend in the number of taxa was detected ($p = 0.28$). Data from Stewart Gulch exemplify the utility of long-term monitoring to insure the full degree of natural variation within a system is captured. Total number of taxa from this site increased for six consecutive years from 1998 to 2003. Evaluation of the data through 2003 concluded that a significant increasing trend in the number of taxa was apparent in Stewart Gulch (CEC 2004), but this trend was subsequently shown not to exist over a longer period.

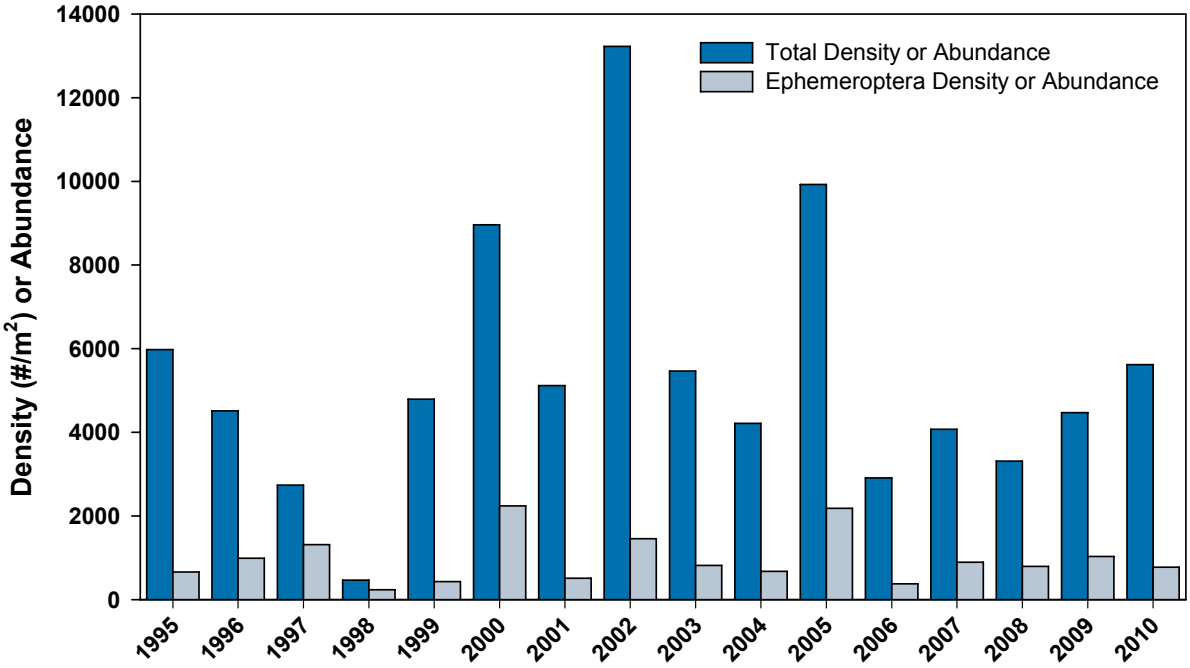

Figure 31: Density (1995 – 2004) and abundance (2005 – 2010) data for the Stewart Gulch site.

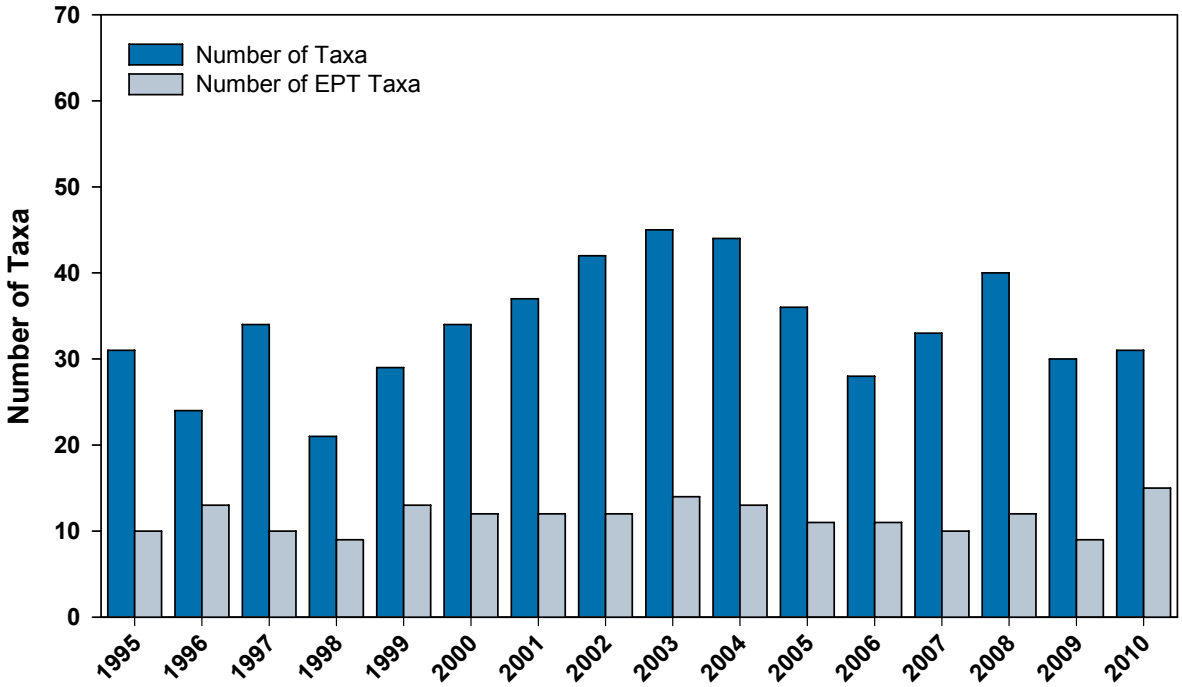

Figure 32: Number of taxa and number of EPT taxa for the Comparison of richness parameters for the Stewart Gulch site, 1995 - 2010. SDDENR protocols were followed for sample collection in 2005 through 2010, while other sampling protocols were used prior to 2005.

The number of EPT taxa has varied little since 1995, from a low of nine in 1998 and 2009 to a high of 15 in 2010 (Figure 32; Appendix E, Table E-2). No significant long-term trend in the number of EPT taxa was detected ($p = 0.55$). The lack of significant long-term trends and similar numbers of EPT taxa detected from year to year indicates that the variability observed in other parameters is likely related to natural flow or habitat conditions rather than to mining activities.

The invertebrate community in Stewart Gulch was generally dominated by sensitive insect groups such as stoneflies and mayflies between 1994 and 2003 (CEC 1995a, 1996d, 1997c, 1998c, 1999c, 2000c, 2001b, 2002b, 2003b, 2004b). In recent years, this site has had a more even balance in abundance among the major groups than the other sites (CEC 2005b, 2006b, GEI 2007b, 2008c, 2009b, 2010b, *in progress* [b]). Mayflies and caddisflies were the dominant group in 2009. True fly taxa were abundant during several years of the study, and were the dominant invertebrate group from 2004 through 2008, and again in 2010. They were also dominant in some of the kick samples collected during the earlier years of the study in 1986 through 1993. The dominance of true fly taxa in recent years may be related to drought than to mining impacts, as this invertebrate group has also been dominant at the two reference sites during recent years as well.

There was no significant difference in the mean number of taxa among sites using data from 1995 through 2010 ($p = 0.12$). Stewart Gulch had a significantly higher mean number of EPT taxa over time in comparison to the Upper Nevada Gulch site ($p < 0.05$), but had a statistically similar number of EPT taxa collected as the other sites, including both reference sites. As at the other Golden Reward sites, when data collected from 2005 through 2010 using the current methods was qualitatively compared to the baseline data collected in 1986 and 1987 using kick-net samples, many more individuals invertebrates and roughly twice as many taxa were collected in the most recent data as in the baseline data (Appendix E, Table E-3). The baseline samples in Stewart Gulch were also dominated by true fly larvae and beetles while the recent samples have higher relative abundances of sensitive species, especially mayflies and caddisflies, than the baseline samples, suggesting that the water quality in Stewart Gulch in recent years is as good or better than baseline conditions and is suitable for supporting sensitive species.

4.3.2.6 Whitetail Creek

Invertebrate abundance in Whitetail Creek was generally higher in most years from 1999 through 2003 than it was in the previous or more recent years of the study (Figure 33; Appendix E, Table E-2). Density peaked in 2003, when 23,110 organisms/m^2 were collected. The number of invertebrates collected since 2004 has been lower but within or higher than the range observed in the earlier years of the study from 1995 through 1998. Ephemeropteran abundance was highest in 2002, when these invertebrates comprised 17% of the total

abundance (Figure 33; Appendix E, Table E-2). Since 2006, abundances have been lower, but mayflies have comprised a similar or higher proportion of the total abundance.

The number of taxa at the reference site on Whitetail Creek was variable among years reaching a maximum of 62 taxa in 2003, and then decreasing through 2006 (Figure 34; Appendix E, Table E-2). During the most recent sampling event in 2010, the number of taxa was 38, near the middle of the range observed previously. There was no significant long-term trend in the number of taxa ($p = 0.25$). The number of EPT taxa was more consistent throughout the monitoring period, varying from 11 to 18 (Figure 34), with no significant long-term trend ($p = 0.52$).

The composition of the invertebrate community in Whitetail Creek has been more evenly balanced among the insect groups than at some of the other sites. Since 1987, stoneflies, beetles, caddisflies, and true flies have been common in most years, with one or two of these groups being dominant in any year (GRMC 1987, 1990, 1992, 1993; CEC 1994a, 1995a, 1996d, 1997c, 1998c, 1999c, 2000c, 2001b, 2002b, 2003b, 2004b, 2005b, 2006b; GEI 2007b, 2008c, 2009b, 2010b). True fly and caddisfly taxa were the two most abundant groups in 2009 and 2010, but other groups were also common. Comparisons of abundance and number of taxa data since 2000 to data from the baselines samples in 1986 and 1987 at this site show that many more individuals invertebrates and at least twice as many taxa have been collected since 2000 (Appendix E, Tables E-2 and E-3). This suggests that the water quality in Whitetail Gulch, as at the other Golden Reward sites, is as good or better in recent years than baseline conditions.

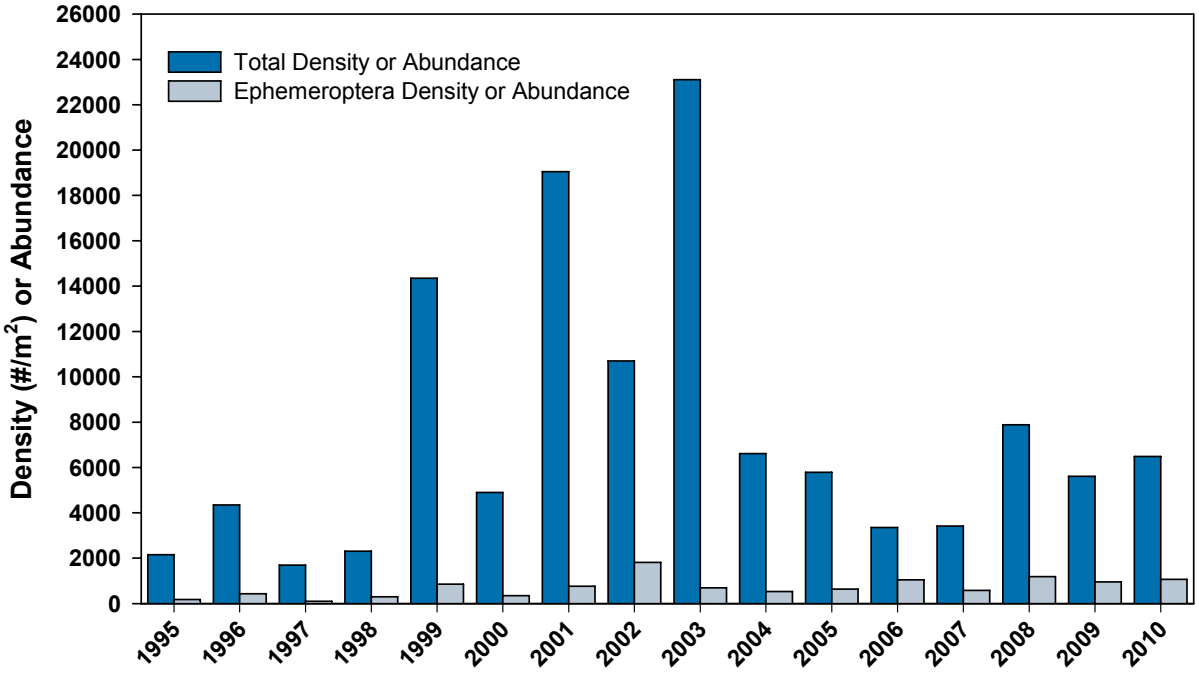

Figure 33: Density (1995 – 2004) and abundance (2005 – 2010) data for the Whitetail Creek site.

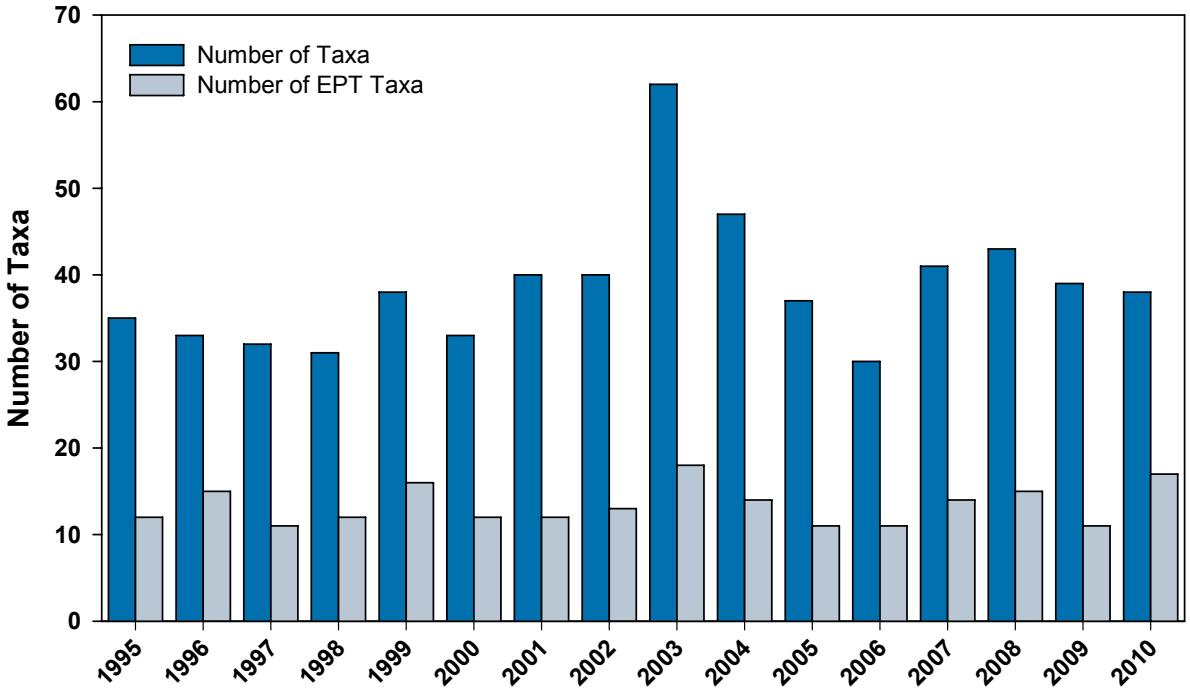

Figure 34: Number of taxa and number of EPT taxa for the Whitetail Creek site, 1995 – 2010. SDDENR protocols were followed for sample collection in 2005 through 2010, while other sampling protocols were used prior to 2005.

4.3.2.7 Summary

Invertebrate data collected since 1986 with various sampling methods indicate the presence of healthy, balanced populations that include sensitive taxa at all sites. Long-term trend analyses using data since 1995 did not detect any significant increases or decreases in the number of taxa or number of EPT taxa for any of the study sites. There were no significant differences in the number of taxa among sites using data from 1995 through 2010; however, the Upper Nevada Gulch site had a significantly lower mean number of EPT taxa over time than Fantail Creek, Stewart Gulch, and Whitetail Creek. Additionally, the Lower Nevada Gulch reference site had a significantly lower mean number of EPT taxa than the Whitetail Creek reference site. There were no other significant differences between sites, indicating that those sites downstream of mining have a similar number of total taxa and EPT taxa as the two reference sites. The Nevada Gulch sites tended to have less robust population parameters than the other sites, likely due to variations in natural conditions such as weather and flow, which apparently had a greater effect on this small stream than in the other three streams that have perennial flow.

Baseline data were collected in 1986 and 1987 with kick-net samples at these sites. This method is different from the current method, making comparisons difficult. However, at all four sites, the current methods collect many more individual invertebrates and roughly twice as many taxa as the baseline data (Appendix E, Tables E-1, E-2, and E-3). In Fantail Creek, the baseline samples were dominated by true flies and beetles while the more recent data

indicate higher proportions of sensitive species. In Stewart Gulch, the baseline sample in 1987 was also dominated by true flies and beetles, while the recent samples have higher relative abundances of sensitive species, especially mayflies and caddisflies, than the baseline samples. This suggests that water quality in Fantail Creek and Stewart Gulch in recent years is as good as or better than baseline conditions and is suitable for supporting sensitive species.

4.4 Periphyton Populations

Substantial differences in density at the Wharf and Golden Reward sites between the PhycoTech data from 2000 and 2001 and the data from Aquatic Analysts in 2002 through 2010 indicate that the differences are likely related to the changes in the laboratories and identification techniques and therefore do not represent true changes in the periphyton communities. The number of periphyton taxa collected in 2000 and 2001, the years when PhycoTech analyzed the samples, was higher than the range observed since then at most of the Wharf sites and all of the Golden Reward sites (Appendices F and G). The changes in methods also probably underestimate the number of blue-green algae (Cyanophyta), which have small cells. The periphyton communities at most of the Wharf and Golden Reward sites have been comprised almost entirely of diatoms (Bacillariophyta) since 2002, with other algal groups less common than in 2000 and 2001 (Appendices F and G). This suggests that the number of taxa and community composition are likely affected to some degree by the different identification methods. Therefore, trends were statistically evaluated for the period from 2002 through 2010 and only qualitatively evaluated for the data collected before 2002. Chlorophyll *a* and AFDW assessments were initiated in 2006 and 2005 for the Wharf and Golden Reward sites, respectively, as part of the SDDENR protocols; therefore, only five or six years of data for these two parameters are available (Appendix F, Table F-4; Appendix G, Table G-3).

4.4.1 Wharf

4.4.1.1 Annie Creek

Site AC-1-BIO

Since 2002, the number of taxa at Site AC-1-BIO has ranged from 10 taxa collected in 2010 to 29 taxa collected in 2006 (Figure 35, Appendix F, Table F-1). The number of taxa collected from 1992 through 2001 was either lower than or within the range observed from 2006 to 2010, indicating that recent conditions for periphyton are as good as or better than conditions in the past. Data collected from 2002 to 2010 showed no significant increasing or decreasing trend in the number of taxa over time at this site ($p = 0.76$), and the long-term mean number of taxa at Site AC-1-BIO was not significantly different from the mean number of taxa at the Lower Nevada Gulch reference site ($p = 0.12$).

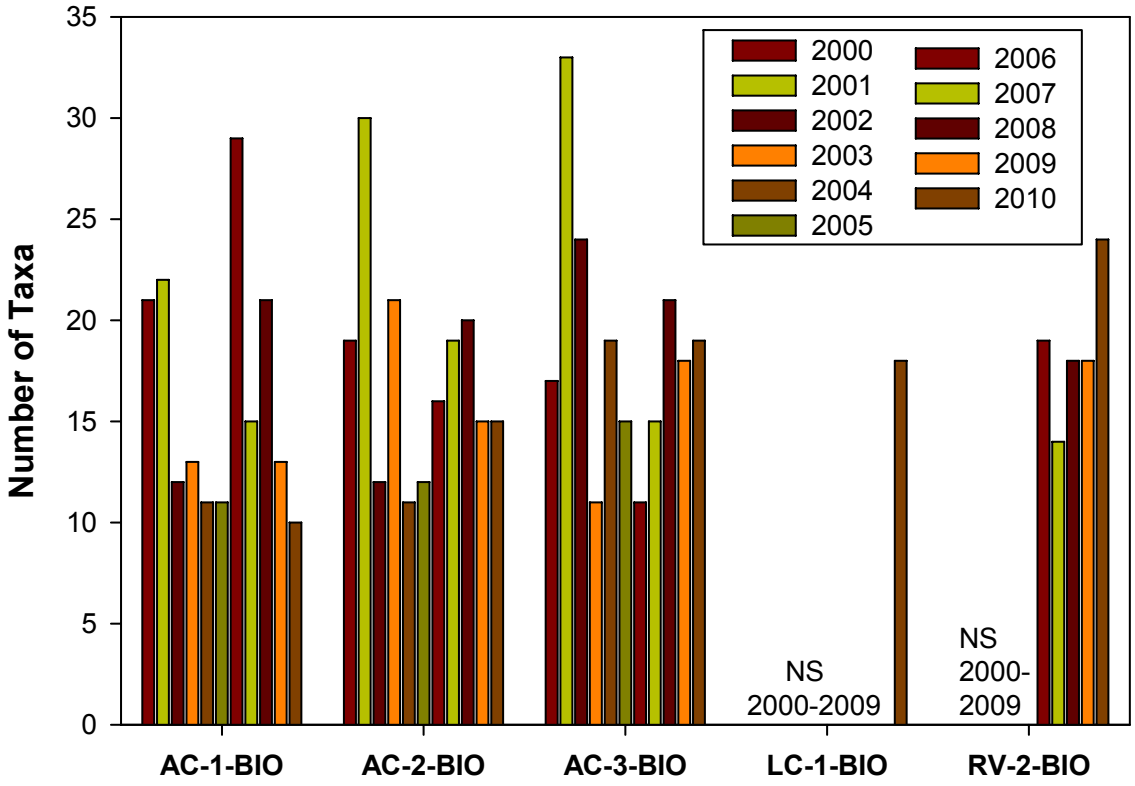

Figure 35: Number of periphyton taxa for sites on Annie Creek, Lost Camp Gulch, and Ross Valley near the Wharf Mine, 2000 - 2010. NS = Not Sampled

Total density at Site AC-1-BIO has been highly variable since 2002, ranging from 44 cells/mm^2 in 2010 to 19,324 cells/mm^2 in 2007 (Appendix F, Table F-1). As the same sampling and identification methods were used in 2006 through 2010, such variation cannot be attributed to changes in methodology. This increase from year to year illustrates the extreme interannual variability in periphyton densities that can occur. Density in 2008 and 2009 were within the range of data from 2006 and 2007, but density in 2010 was lower, as was observed at several other sites as well.

At Site AC-1-BIO, the site nearest Outfall 006A/006B, blue-green algae were dominant in terms of relative abundance in six of the previous 18 years, the last time in 2001, while green algae (Chlorophyta) were dominant from 2002 to 2004, and again in 2010 (Appendix F, Table F-1). Diatoms were dominant in 1992, 1994, 1995, 1998, and from 2005 through 2009. Other periphyton taxa collected rarely at this site since 1992 included yellow-green algae (Chrysophyta), cryptomonads (Cryptophyta), euglenoids (Euglenophyta), and red algae (Rhodophyta). The changes in periphyton community composition, specifically the lack of blue-green algae since 2001, may be related at least in part to the changes in identification methods. However, the changing conditions of the water discharged from the water treatment facility and/or the collection ponds over the years, and the releases of ammonia and higher BOD water may have contributed to changes in the periphyton community composition as well.

Site AC-2-BIO

The number of taxa collected at this site since 2002 ranged from 11 taxa collected in 2004 to 21 taxa collected in 2003 (Figure 35; Appendix F, Table F-1). The number of taxa collected since 2006 has generally been higher than the number observed from 1991 to 1999, but less than or similar to values in 2000 and 2001 when the identification methods presumably differed. There were no significant increasing or decreasing trends in the number of taxa over time at Site AC-2-BIO since 2002 ($p = 0.54$). However, the long-term mean number of taxa was significantly lower at Site AC-2-BIO than at the Whitetail Creek reference site ($p < 0.01$).

As at Site AC-1-BIO, density has varied substantially from year to year at Site AC-2-BIO. Periphyton density in 2010 was lower than it had been since 2002 (Appendix F, Table F-1). Blue-green algae were dominant at this site in terms of relative density from 1993 to 1997 and again in 2000, while green algae dominated in 2001, 2003, and 2004 (Appendix F, Table F-1). Pennate diatoms were the dominant periphyton group in 1991, 1992, 1998, 1999, 2002, and the last six years. Yellow-green algae, cryptomonads, euglenoids, and red algae were collected in one or two years since 1991. As at the site upstream, changes in the discharge of water from the treatment facility and/or collection ponds may have contributed to the observed changes in the periphyton community over the years, but the community composition has likely also been affected by the different identification methods.

Site AC-3-BIO

Periphyton populations have been monitored at Site AC-3-BIO since 2000. The number of taxa collected was highest in 2001, when 33 taxa were observed (Figure 35; Appendix F, Table F-1). Values for this parameter remained relatively high in 2002, but have been lower in the years since then. The number of taxa collected at this site has shown no significant increasing or decreasing trend over time since 2002 ($p = 0.89$), but the mean number of taxa is significantly lower than at the Whitetail Creek reference site ($p = 0.02$).

Density at Site AC-3-BIO, like the two upstream sites, has varied substantially since 2000, ranging from 83 cells/mm^2 to 54,113 cells/mm^2 in 2005 and 2000, respectively (Appendix F, Table F-1). Density was low in 2010, but was similar to the density observed in 2006. Diatoms have been dominant in terms of relative abundance in all years except 2000 and 2001, when blue-green algae were more numerous at this site (Appendix F, Table F-1). Cryptomonads and red algae were each collected in one year from 2000 through 2010, and green algae were present from 2000 through 2004, as well as in 2010.

4.4.1.2 Ross Valley

Ross Valley was previously sampled in April 2004 in response to a release of ammonia into Ross Valley (CEC 2005a). The sampling season, locations, and methods differed from those of the 2006 through 2010 monitoring events, limiting the ability to compare data among

years. However, the assemblage in 2004 was similar to that in 2006 through 2010, in terms of the dominance in relative density by pennate diatoms (CEC 2005a; GEI 2007a, 2008a, 2009a, 2010a). The assemblage was more balanced in 2006 through 2010 than in 2004. Two diatoms made up 77% of the density in 2004 (CEC 2005a), whereas in 2006 through 2010, the two most common diatoms made up 42% or less of the density (Appendix F, Table F-3; GEI 2007a, 2008a, 2009a, 2010a, *in progress*(a)). Green algae have been present in most samples collected since 2006 as well, while blue-green algae were observed in 2008 and 2010.

The number of periphyton taxa at Site RV-2-BIO was highest in 2010 and lowest in 2007 (Figure 35; Appendix F, Table F-3). While data available for this site is limited to the past five years, no significant increasing or decreasing trend in the number of taxa has been apparent since 2006 ($p = 0.27$). The number of taxa collected at Site RV-2-BIO since 2006 is statistically similar to the number of taxa collected at the Lower Nevada Gulch reference site over time ($p = 0.99$). Density was highest in 2008 and 2009, and decreased in 2010. However, the density in 2010 was higher than during the first two years of surveys (Appendix F, Table F-3).

4.4.1.3 Lost Camp Gulch

The Lost Camp Gulch site was established in 2010; therefore, periphyton populations have only been surveyed once. A total of 18 periphyton taxa were collected at this site, a number similar to or higher than was observed at the Annie Creek sites in 2010 (Figure 35, Appendix F, Table F-3), and within the range observed at the Lower Nevada Gulch reference site since 2002. Although there are no values from previous years to compare to, the periphyton density appeared low at this site, with 80 cells/mm^2 collected. Similar low values occurred at several of the Wharf and Golden Reward sites in 2010. The periphyton community was dominated by pennate diatoms, with these taxa comprising 98% of the assemblage. A cryptomonad taxon was also present in 2010 at a low abundance.

4.4.1.4 Deadwood Creek

The upstream site on Deadwood Creek was dry from 2000 through 2008, but was sampled from 1995 through 1999, and again in 2009 and 2010 (Appendix F, Table F-2). Due to the discontinuous and limited data available for this site, statistical analysis of trends or comparisons to reference sites were not conducted. In all five of the earlier years of sampling, blue-green algae dominated the algal community at Site DC-1-BIO, with pennate diatoms present in lower abundances. In comparison, pennate diatoms were dominant in 2009 and 2010, with no blue-green algae observed. However, a yellow-green algal taxon was present in 2010 that was not observed during the earlier sampling events. Eight and sixteen taxa were collected from this site in 2009 and 2010, respectively, which were higher values than was observed in 1995 through 1999, when between two and six taxa were collected (Figure 36; Appendix F, Table F-2). Density was also substantially higher in 2009 than in the earlier sampling period, with 3,030 cells/mm^2 collected in 2009, compared to

878 cells/mm^2 or less being collected from 1995 through 1999 (CEC 1999c). However, similar to other Wharf sites, density in 2010 was lower than had been observed previously over the monitoring period.

The periphyton community at Site DC-2-BIO was sampled from 2000 through 2005, and again in 2010. Over this time period, the number of taxa ranged from 14 taxa collected in 2002 to 24 taxa collected in 2004 (Figure 36; Appendix F, Table F-2). As at the other sites, density was highly variable from year to year, peaking in 2000, when 243,000 cells/mm^2 were collected, and being lowest in 2010, when 673 cells/mm^2 were collected (Appendix F, Table F-2). Blue-green algae dominated the periphyton community in 2000 and 2001, while pennate diatoms were dominant from 2002 through 2005, and again in 2010. Green algae, yellow-green algae, and red algae were also collected in one or more years at lower relative abundances. Due to the discontinuous and limited amount of data available for this site, statistical analysis of trends or comparisons to reference sites were not conducted.

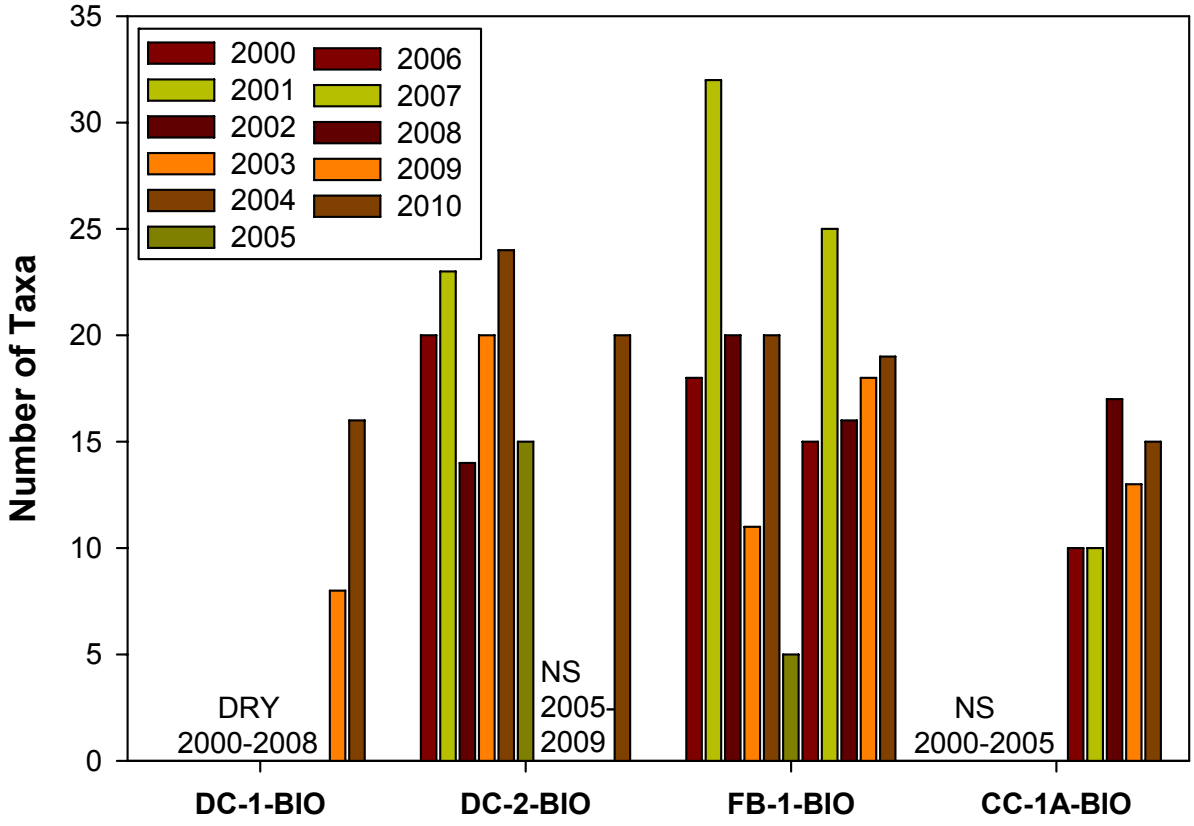

Figure 36: Number of periphyton taxa for sites on False Bottom Creek, Cleopatra Creek, and Deadwood Creek near the Wharf Mine, 2000 - 2010. NS = Not Sampled

4.4.1.5 False Bottom Creek

Since 2002, the number of taxa varied from five taxa in 2005 to 25 taxa in 2007 at Site FB-1-BIO. The number of taxa collected peaked in 2001, similar to what was observed at some of the other Wharf and Golden Reward sites, when 32 taxa were collected (Figure 36, Appendix F, Table F-3). However, the number of taxa collected in the earlier years of the study from 1995 to 1999 tended to be lower than in more recent years. There was no significant increasing or decreasing trend in the number of taxa over time in data from 2002 through 2010 ($p = 0.56$). However, Site FB-1-BIO had a significantly lower long-term mean number of taxa collected than at the Whitetail Creek reference site ($p = 0.04$).

Blue-green algae dominated samples in terms of relative density in all years from 1995 through 2001, except for 1999 (Appendix F, Table F-3). Blue-green algae were also present in low densities in 2010. Diatoms dominated the periphyton assemblage in 1999 and every year after 2001. Green and red algae have also been collected at this site in lower abundances in one or more years since 1995. Density has been highly variable since 1995, and was lower in 2009 and 2010 than has been observed at this site since 2003. However, as at the other sites, differences in sampling methods limit the ability to compare density data.

4.4.1.6 Cleopatra Creek

Site CC-1A-BIO was established in 2006, with no data available from previous years. In all years except 2010, pennate diatoms have comprised the entire periphyton assemblage. While diatoms dominated in 2010, blue-green algae were also present in lower abundances (Appendix F, Table F-2). The number of taxa collected peaked in 2008 (Figure 36), when 17 taxa were collected, and was lowest in 2006 and 2007, when 10 taxa were collected. The value for this parameter in 2010 was within the range observed since 2006 (Figure 36), but the density was lower than in the previous four years. Density peaked in 2007 at 30,019 cells/mm^2 and remained high in 2008 (Appendix F, Table F-2). Density in 2009 and 2010 dropped substantially to 838 cells/mm^2 or less, but, as noted at the other sites, interannual variability in periphyton density is often high. Using the data available from 2006 through 2010, no increasing or decreasing trends in the number of taxa over time were apparent at Site CC-1A-BIO ($p = 0.22$), and the number of taxa at this site was not significantly different from the number of taxa at the Lower Nevada Gulch reference site ($p = 0.08$).

4.4.1.7 Summary

Changes in the identification and sampling methods over the course of the study have complicated the evaluation of any long-term trends in the periphyton communities. Periphyton density from year to year has shown extreme interannual variation at all of the Wharf sites, even in those years in which sampling and identification methods were the same. Algae are opportunistic and sporadic in their population levels, often exhibiting extreme variability over time and space, which may account for some of the heterogeneity in algae

populations in these streams. Disturbance (e.g., floods and low flows), nutrient supply, shading, temperature, and grazing by invertebrates all cause variability in periphyton populations (Hynes 1970; Pritchard and Bradt 1984; Reiter 1986; Robinson and Rushforth 1987; Allan 1995; Biggs 1996; Peterson 1996). Within a site, patchy distribution of periphyton can also occur due to spatial variations in localized flow conditions (Biggs and Hickey 1994; Biggs and Stokseth 1996).

No significant increasing or decreasing trends in the number of taxa collected over time at the Annie Creek, Ross Valley, False Bottom Creek, or Cleopatra Creek sites were observed using the available data from 2002 through 2010. However, the mean number of taxa over time at sites AC-2-BIO, AC-3-BIO, and FB-1-BIO was significantly lower than at the Whitetail Creek reference site. There was no significant difference in mean number of taxa between site AC-1-BIO, RV-2-BIO, and CC-1A-BIO and the Lower Nevada Gulch reference site. Due to the limited or discontinuous data available for sites on Lost Camp Gulch and Deadwood Creek, statistical analysis of trends or comparisons to reference sites were not conducted.

Diatoms have dominated the periphyton assemblages at most Wharf sites since at least 2006, while the blue-green algae that were often the dominant group at sites sampled prior to 2002 have been detected less frequently and in lower numbers since then. This is probably in part a result of changes in laboratory analyses, but if these algae were currently common they would probably be detected. Thus, it is reasonable to assume that despite changes in laboratory techniques, blue-green algae are less common now than in previous years. At the Annie Creek sites, the changing conditions of the water discharged from the water treatment facility and collection ponds over the years, as well as the releases of ammonia and higher BOD water, may have contributed to the observed changes in the periphyton community composition and the differences observed between two downstream Annie Creek sites and the reference site.

4.4.2 Golden Reward

4.4.2.1 Fantail Creek

Since 2002, the number of taxa at Fantail Creek declined to a low of seven in 2005, the year of the change to the SDDENR procedure. Number of taxa at this site has increased or remained the same each year since then , with 17 taxa collected in 2010 (Figure 37). Data collected from 2002 to 2010 show no significant long-term trend in the number of taxa ($p = 0.97$). The number of taxa reported since 2007 has been higher than that from samples in 1993 through 1999 (Appendix G, Table G-1), suggesting that conditions for periphyton now are as good as or better than conditions in the past. However, statistical analysis using data from 2002 through 2010 indicated that while the mean number of taxa collected at the Fantail Creek site is statistically similar to the mean for the Lower Nevada Gulch reference site, it is significantly lower than the mean for the Whitetail Creek reference site ($p < 0.05$).

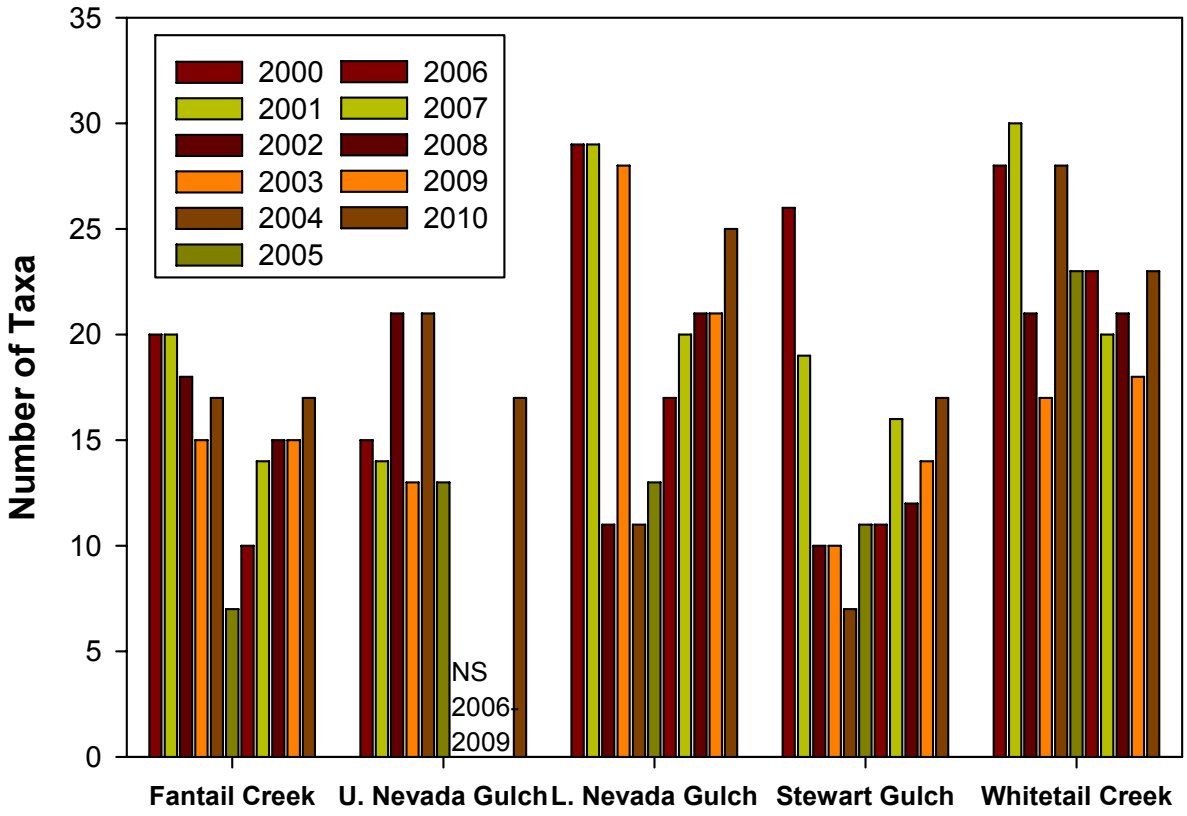

Figure 37: Number of periphyton taxa for sites in streams in the vicinity of the Golden Reward Mine, 2000 - 2010.

As at the Wharf sites, periphyton density has been highly variable over the course of the study, ranging from 21 cells/mm^2 collected in 2010 to 171,137 cells/mm^2 in 2001 (Appendix G, Table G-1). The periphyton community has been comprised entirely of diatoms since 2002. Blue-green algae comprised a large proportion of the periphyton in all samples collected prior to 2002, and green algae and yellow-green algae have been collected on two occasions each from 1993 through 2010. This change in composition may be an artifact of the changes in identification methods over the years as this appears to be the case for all of the monitoring sites.

4.4.2.2 Nevada Gulch

The Upper Nevada Gulch site was sampled from 1993 through 2005 and again in 2010. Since 2002, the number of taxa varied from 13 taxa collected in 2003 and 2005 to 21 taxa collected in 2002 and 2004 (Figure 37; Appendix G, Table G-1). As only five years of data were available since 2002 for this site, no statistical analysis was conducted to determine trends or to compare to reference sites. However, the number of taxa collected each year since 2002 at the Upper Nevada Gulch site has been within the range observed at the Lower Nevada Gulch reference site (Appendix G, Table G-1). The number of taxa collected in

2010 and from 2002 through 2005 was higher than or similar to the number of taxa collected in the previous years.

Density has been highly variable over the course of the study, like the other sites, peaking in 2000 (Appendix G, Table G-1). Similar to the Fantail Creek site, density in 2010 was lower than it had been since 1999. Green algae comprised most of the algal density in 2002 and 2003, with pennate diatoms being dominant in 2004, 2005, and 2010. In the earlier years of the study from 1993 through 2001, blue-green algae were dominate in six of the nine years of sampling, and pennate diatoms were dominant in the remaining years. Cryptomonads and red algae were also present in low relative abundances in one year each since 1993.

At the Lower Nevada Gulch reference site, the number of taxa in 2010 was higher than it had been since 2003, as the number of taxa increased or remained the same in each year since then (Figure 37, Appendix G, Table G-2). No significant trend was observed in the data from 2002 to 2010 ($p = 0.20$) probably due to the high value in 2003. The number of taxa in the last few years is higher than in all years between 1993 and 1999, possibly due to changes in the methods used.

Algal density at the Lower Nevada Gulch site ranged from 242 cells/mm^2 in 2010 to 62,062 cells/mm^2 in 2001. Green algae were present in 2001, 2002, and 2009, but diatoms have been the dominant group in all years since 2001 (Appendix G, Table G-2). As at the other sites, blue-green algae have been rare since 2001, but dominated the periphyton populations for many of the years from 1993 to 2001.

4.4.2.3 Stewart Gulch

In Stewart Gulch, the number of periphyton taxa present in 2010 was higher than in all years since 2001 (Figure 37; Appendix G, Table G-2), and a significant increasing trend was observed in data from 2002 to 2010 ($p = 0.01$). The number of taxa since 2005 has been equal to or higher than in all years between 1994 and 1999. In only one year, 1993, was the number higher than in the last few years. The mean number of taxa collected at the Stewart Gulch site using data since 2002 was significantly lower than the mean number of taxa collected at both the Whitetail Creek or Lower Nevada Gulch reference sites ($p < 0.05$).

Density was highly variable from 1993 through 2001, peaking in 2000 when 58,605 cells/mm^2 were collected, but has remained more stable in recent years. Diatoms were the only group of periphyton present in Stewart Gulch in six of the last nine years, with blue-green algae present in low proportions in 2003 and 2005 and green algae present in low proportions in 2009 (Appendix G, Table G-2). Blue-green algae were more common prior to 2002, and often dominated the periphyton community. Red algae were collected at this site in low abundances in 2000 as well.

4.4.2.4 Whitetail Creek

In Whitetail Creek the number of taxa declined from 2004 through 2009, but then increased in 2010 (Figure 37). No significant trend was observed in 2002 to 2010 data ($p = 0.83$). The number of taxa collected in recent years is higher than that in the period from 1993 to 1999 (Appendix G, Table G-2). Density has been highly variable over the course of the study, with high densities recorded in 2000 and 2005. Densities were substantially lower than the peak 2005 value from 2006 through 2010. The density in 2010 was lower than it has been over the course of the study.

Blue-green algae were present in Whitetail Creek from 1993 through 2004 and have been absent since. Green algae were present in 2000 and 2001 as well. Diatoms have comprised 100% of the periphyton community since 2005, and have been the dominant group for every year from 2002 through 2010.

4.4.2.5 Summary

Changes in the identification and sampling methods over the course of the study have complicated the evaluation of any long-term trends in the periphyton communities. Using data since 2002, a significant increasing trend in the number of taxa at the Stewart Gulch site was apparent, but no trends in this parameter were observed for the sites on Fantail Creek, Lower Nevada Gulch, and Whitetail Creek. Additionally, the number of taxa collected in recent years at these sites has generally been higher than the number of taxa present in samples from 1993 through 1999, suggesting that conditions for periphyton now are as good as or better than conditions in the past. However, the changes in methods used over the monitoring period complicate such comparisons. Statistical analysis of the 2002 through 2010 data indicated that the mean number of taxa collected at the Fantail Creek site was significantly lower than the mean for the Whitetail Creek reference site, and the mean number of taxa collected at the Stewart Gulch site was significantly lower than the mean number of taxa collected at both reference sites.

As at the Wharf sites, periphyton density has been highly variable over the course of the study at all Golden Reward sites. Most sites had low densities in 2010 relative to previous years. With the exception of the Upper Nevada Gulch site, the periphyton community at these sites has been dominated by diatoms in each year since 2002, with blue-green algae often comprising a large proportion of the periphyton in samples collected prior to that year. This pattern was also observed in the sites sampled for Wharf. As discussed previously for those sites, this change in composition may be an artifact of the changes in identification methods over the years. However, if blue-green algae were currently common in these streams, they would probably be detected. Thus, it is reasonable to assume that despite changes in laboratory techniques, blue-green algae are less common now than in previous years.

The reason for the higher number of taxa at the two reference sites is not apparent. Overall, it appears that periphyton populations at all four sites are functioning normally and exhibiting a great deal of interannual variability. All four sites sustain diatom communities that include many species in common and many sensitive species, suggesting that water quality is sufficient at all four sites. The two sites on Fantail Creek and Stewart Gulch are more heavily shaded with riparian vegetation than the two reference sites, which may affect algal community composition.

5.0 Conclusions

Wharf is submitting a large-scale mine permit in anticipation of expanding their existing heap-leach gold operations near Lead, South Dakota. Prior to this expansion, baseline environmental studies describing the existing aquatic ecology in the proposed mining area are to be completed. GEI has conducted aquatic species and habitat surveys for multiple years on streams that flow through or have drainages within the expansion areas, with the most recent data collected in 2010. The results of these surveys, as summarized in this report, provide recent and historical data on fish populations, benthic invertebrate populations, periphyton populations, and habitat for the relevant streams and also evaluate any potential effects of current and past mining activities by Wharf and Golden Reward on these populations.

5.1 Habitat

Habitat data are available for some of the Wharf sites dating back to 1990, while other sites were added to the monitoring program in 2006. All of the Annie Creek sites have been dominated by fast water habitat types such as riffles and runs, with smaller pools present at most sites and years as well. Habitat characteristics at the three Annie Creek sites were stable from 2000 through 2006, likely as the result of a stable channel configuration and the lack of high flows. A high flow event in June 2007 appears to have caused some minor changes in habitat characteristics, with some evidence of debris movement, scouring, and an increase in the percent of exposed bank, particularly at Site AC-3-BIO. However, no exposed banks were observed at any of the sites in 2009 and 2010, indicating riparian vegetation has been recovering at this site.

The remaining Wharf sites on Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, and Cleopatra Creek have also typically been dominated by riffle habitat. A diverse mixture of substrate sizes has been present at each site, with gravel or rubble being abundant at some sites. Fine sediment was common at the upstream Deadwood Creek site, which has had water present for the past two years after being dry from 2000 through 2008. Banks have generally been stable at most of these sites, but eroded banks were more common at sites DC-2-BIO and FB-1-BIO. The increase in eroded and exposed banks observed at the False Bottom Creek site is thought to have resulted from scouring from high spring flow events in 2007. However, no exposed banks were present at this site in the past two years.

Similar to the Wharf sites, all of the Golden Reward sites have been dominated by riffle habitat over the course of the study, with pools comprising a smaller proportion of the habitat at each site. Substrate at each site was heterogeneous, but rubble or gravel was often the most abundant substrate size category. Habitat conditions at these sites have varied considerably since monitoring began in 1986, and, in many cases, the variations appear to be

related to changes in flow conditions between years. Water widths at some sites were greatest in 1998 and 2008, likely as a result of higher flows in late summer at the time of measurement than in most other years. In general, although habitat characteristics have been variable, few trends have been observed other than an increase in the percentage of fine substrate at the Fantail Creek site.

5.2 Fish

Of the streams near the Wharf expansion areas, no fish have been collected over the course of the study at the upstream Annie Creek site, the upstream Deadwood Creek site, the Ross Valley site, and the Cleopatra Creek site. These sites are in the headwaters of the streams, apparently upstream of suitable fish habitat. In addition, the streambed at the upstream Site DC-1-BIO on Deadwood Creek was dry from 2000 to 2008. While limited water was present in 1995, 2009, and 2010, no fish were collected, indicating that limited aquatic habitat and low, interrupted flows present in this reach of Deadwood Creek are unsuitable for fish populations. Lost Camp Gulch was surveyed for the first time in 2010, but no fish were present in this stream either.

Mountain suckers were collected in low densities from Site AC-2-BIO on Annie Creek from 2001 through 2006, but were absent in 2007 and 2009, with only a few mountain suckers present in 2008 and 2010. Their absence from Site AC-2-BIO in 2007 and limited presence since then may be due to either a high flow event that occurred in June 2007 or from the low dissolved oxygen levels that also occurred in 2007 due to a release of high BOD water. Mountain suckers were abundant in the early 1990s at this site, but their numbers have been substantially reduced since 1995. Recovery of the mountain sucker population has likely been hampered by the elevated ammonia levels observed in February 2002 and April 2004, as well as the events that occurred in 2007. In addition, there does not appear to be any upstream sources of these fish, and movement of fish from the most downstream reach of Annie Creek is barred by Annie Creek falls.

Both brook trout and brown trout appear to maintain resident populations at Site AC-3-BIO; however, brown trout populations are less stable with fewer individuals and the absence of YOY trout during some years. The brown trout population at this site is likely subsidized by the influx of fish from Spearfish Creek. Brook trout density has increased at Site AC-3-BIO since 2001, while brown trout density has decreased.

The downstream reach surveyed on Deadwood Creek and the reach surveyed on False Bottom Creek both support brook trout populations. Site DC-2-BIO was surveyed from 2001 through 2005, and then again in 2010. It has perennial flows, and the brook trout population present at this site appears to be naturally reproducing, with multiple size classes present. Multiple size classes of brook trout were also present at Site FC-1-BIO in 2010 as well as some other years. However, YOY or adult fish have occasionally been absent; suggesting

that, while the population is maintained over time, successful recruitment may be limited in some years.

Of the four streams surveyed for the Golden Reward monitoring plan, only Stewart Gulch and Whitetail Creek support brook trout populations. YOY, juvenile, and adult fish have been collected from both sites in many years, indicating that these populations are naturally reproducing. Brook trout density and biomass have been variable in Stewart Gulch and Whitetail Creek, but both sites had high trout densities and biomass in 2008 and 2010 in comparison to many earlier years of the study. In comparison to the reference site on Whitetail Creek, the brook trout population at the Stewart Gulch site has been stable over the monitoring period, indicating that mining activities have had no apparent effect on the trout populations and that the habitat and water quality conditions present at this site are suitable to sustain this population.

A small number of brook trout were collected from the Fantail Creek and Lower Nevada Gulch sites in 1998, but no fish have been observed at either site since then. The higher than normal flows that year likely allowed fish to move upstream into these reaches.

5.3 Benthic Macroinvertebrates

Macroinvertebrate data collected since 1992 with various sampling methods indicate that the invertebrate populations at the two downstream Annie Creek sites have generally been diverse and well balanced. The upstream Annie Creek site, Site AC-1-BIO, has shown some signs of stress over the course of the study, specifically after the elevated ammonia levels and low dissolved oxygen levels that occurred in Annie Creek in 2002 and 2007, respectively. After these two events, the total number of taxa, number of EPT taxa, and diversity index values at this site decreased substantially, and pollution tolerant chironomid midges dominated the community. The data from 2009 and 2010 indicated that the invertebrate community at Site AC-1-BIO was beginning to recover, but continues to show some signs of stress. While there was no trend in total number of taxa over time at this site, the number of EPT taxa has decreased since 1992, and this site has a significantly lower mean number of taxa and mean number of EPT taxa than the Lower Nevada Gulch reference site using data from 1992 through 2009. These trends indicate that the population is less healthy than it has been in the past and compared to reference sites.

Sites AC-2-BIO and AC-3-BIO did not seem to be as affected by the elevated ammonia levels that occurred in 2002 as the site upstream was, with most metric values in fall of that year being similar to or higher than in previous years. The invertebrate assemblage at Site AC-2-BIO was dominated by chironomids in 2007, possibly as a result of the low dissolved oxygen levels that occurred that year, but the population appeared to have largely recovered in 2008 and 2009. The invertebrate community at Site AC-3-BIO appeared to be affected little by the low dissolved oxygen levels, and the invertebrate population at this site has been dominated by mayflies or stoneflies in most years since 2007, as it was in some

previous years. The two downstream Annie Creek sites have shown no significant trends in the number of taxa or number of EPT taxa over time. However, Site AC-2-BIO had a significantly lower mean number of taxa and number of EPT taxa over time in comparison to the Whitetail Creek reference site, while Site AC-3-BIO had similar or more favorable long-term values for these parameters in comparison to the reference site. Metric values at this site, and comparisons to the reference site, indicate that Site AC-3-BIO is not affected by mining activities.

While some sensitive taxa have been present at sites DC-1-BIO and CC-1A-BIO over the course of the study, the invertebrate assemblages at these two sites were often numerically dominated by chironomids, a group that is generally tolerant of disturbance and often colonizes streams quickly after a disturbance occurs. The limited aquatic habitat and low to intermittent flows that occur at these two sites likely allow such taxa to thrive while limiting other groups. Many of the metric values at these two sites compared unfavorably to values at the Lower Nevada Gulch reference site, which is of similar size to these streams but appears to have more consistent flows.

True fly taxa continued to be abundant at the downstream Deadwood Creek site as they were at the upstream site, but EPT taxa also comprised a substantial proportion of the total number of taxa each year, indicating that this reach of Deadwood Creek also supports a substantial number of sensitive species. Site DC-2-BIO and Site RV-2-BIO on Ross Valley both compared favorably to the reference sites, with most metric values being similar to or higher than those at their respective reference sites, indicating that healthy, diverse invertebrate assemblages are present at these sites. The invertebrate populations at Site LC-1-BIO on Lost Camp Gulch were sampled for the first time in 2010, and most metric values for this site were similar to those for the nearby Site AC-2-BIO on Annie Creek. Other than abundance, all other metrics values for Site LC-1-BIO were higher that at the Lower Nevada Gulch reference site in 2010.

Diversity index values have been high at the site on False Bottom Creek since 1995, but the invertebrate community has often been numerically dominated by pollution tolerant taxa such as true flies and aquatic worms. However, sensitive EPT taxa have been collected at Site FB-1-BIO during every sampling event, and the number of taxa and number of EPT taxa collected each year have been stable since 1995. Analyses indicate that the long term mean number of taxa and number of EPT taxa at this site were statistically lower than at the Whitetail Creek reference site; however, the smaller size of False Bottom Creek compared to Whitetail Creek may account for some of these differences.

Invertebrate data collected since 1986 with various sampling methods indicate the presence of healthy, balanced populations that include sensitive taxa at all sites surveyed for Golden Reward. Long-term trend analyses using data since 1995 did not detect any significant increases or decreases in the number of taxa or number of EPT taxa for any of the study sites. There were no significant differences among sites in the mean number of taxa

using data from 1995 through 2010, indicating that the sites downstream of mining, Fantail Creek and Stewart Gulch, had similar mean numbers of taxa collected to the reference sites. Additionally, there were no significant differences between the long-term mean number of EPT taxa at these two sites and the reference sites. However, both Nevada Gulch sites had a significantly lower mean number of EPT taxa over time in comparison to the Whitetail Creek reference site. The sites on Nevada Gulch appear to be more affected by variations in natural conditions such as weather and flow than the other larger streams. Comparisons of recent data to data from the baseline samples collected in 1986 and 1987 from all four streams suggest that recent samples have higher relative abundance of sensitive species, especially mayflies and caddisflies. Any changes observed in the invertebrate assemblages in these four streams from year-to-year are not consistent and appear to represent natural variation in these streams. These analyses indicate that streams near the Golden Reward Mine demonstrate no short-term or long-term impacts from mining activities.

5.4 Periphyton

Changes in the identification and sampling methods over the course of the study have complicated the evaluation of any long-term trends in the periphyton communities for the Wharf and Golden Reward sites. Additionally, there is limited or discontinuous data available for the sites on Deadwood Creek and Lost Camp Gulch. Periphyton density from year to year has shown extreme interannual variation at all sites, with many of the Wharf and Golden Reward sites having low densities of periphyton in 2010. Algae are opportunistic and sporadic in their population levels, often exhibiting extreme variability over time and space, which may account for some of the heterogeneity in algae populations in these streams. Diatoms have dominated the periphyton assemblages at most Wharf sites since at least 2006, while the blue-green algae that were often the dominant group at sites sampled prior to 2002 have been detected less frequently and in lower numbers since then. No significant increasing or decreasing trends in the number of taxa collected over time at the Annie Creek, Ross Valley, False Bottom Creek, and Cleopatra Creek sites were observed using the available data from 2002 through 2010. However, the mean number of taxa over time at sites AC-2-BIO, AC-3-BIO, and FB-1-BIO was significantly lower than at the Whitetail Creek reference site. At the Annie Creek sites, the changing conditions of the water discharged from the water treatment facility and collection ponds over the years, as well as the releases of ammonia and higher BOD water, may be contributing to the differences observed between two downstream Annie Creek sites and the reference site.

The periphyton populations within the four streams surveyed for Golden Reward appear to have been healthy and diverse throughout the monitoring period. Diatoms have been the dominant group of algae since 2002 at most sites, compared to years prior to 2002, when blue-green algae were often the dominant group. These changes in composition may have resulted at least in part from the changes in sample analysis methods. Evaluations in number of taxa have demonstrated interannual variation but no significant long-term trends over time for the sites on Fantail Creek, Nevada Gulch, or Whitetail Creek. An increasing trend in the

number of taxa since 2002 was apparent at the Stewart Gulch site. The number of taxa collected in recent years at these sites has generally been higher than the number of taxa present in samples from 1993 through 1999, suggesting that conditions for periphyton now are as good as or better than conditions in the past. The number of periphyton taxa has generally been higher at the reference sites in Whitetail Creek and Nevada Gulch since 2002 compared to the two sites downstream of mining activities. The two sites on Fantail Creek and Stewart Gulch are more heavily shaded with riparian vegetation than the two reference sites, which may affect algal community composition.

6.0 References

Allan, J.D. 1995. Stream Ecology: Structure and Function of Running Waters. Chapman and Hall, London, England.

Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pp. 447-482 *in* Murphy, B. R., and D. W. Willis (eds). Fisheries Techniques, Second Edition. American Fisheries Society, Bethesda, MD.

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

Biggs, B.J.F. 1996. Patterns in benthic algae of streams. Pages 31-56 IN: Stevenson, R.J., M.L. Bothwell, and R.L. Lowe (eds.). Algal Ecology: Freshwater Benthic Systems. Academic Press, NY.

Biggs, B.J.F., and C.W. Hickey. 1994. Periphyton responses to a hydraulic gradient in a regulated river, New Zealand. *Freshwater Biology* 32:49-59.

Biggs, B.J.F., and S. Stokseth. 1996. Hydraulic habitat suitability for periphyton in rivers. Regulated Rivers: Research and Management 12:251-261.

Bukantis, R., 1998. *Rapid Bioassessment Macroinvertebrate Protocols: Sampling and Sample Analysis SOPs*. Working Draft. Montana Department of Environmental Quality, Planning Prevention and Assistance Division.

Carter, J. L., and V. H. Resh. 2001. After site selection and before data analysis: Sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by U.S.A. state agencies. Journal of the North American Benthological Society 20:658-682.

Chadwick & Associates, Inc. (C&A). 1993. Aquatic Biology Assessment, Annie Creek. Draft report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick & Associates, Inc. (C&A). 1994a. Aquatic Biology Assessment of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for the Golden Reward Mining Company, Lead, SD.

Chadwick & Associates, Inc. (C&A). 1994b. Annie Creek Biological Monitoring. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick & Associates, Inc. 1995a. (C&A). 1994 Aquatic Biology Assessment of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for the Golden Reward Mining Company, Lead, SD.

Chadwick & Associates, Inc. (C&A). 1995b. Annie Creek Biological Monitoring. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1996a. Response of the Fish, Benthic Macroinvertebrate, and Periphyton Communities of Annie Creek, South Dakota, to an Accidental Release of Ammonia and Cyanide. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1996b. Biological Monitoring of Annie Creek, South Dakota, 1995. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1996c. Baseline Aquatic Biology of Upper Deadwood Creek and False Bottom Creek, South Dakota, 1995. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1996d. The 1995 Aquatic Biology Assessment of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for the Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1997a. 1996 Aquatic Biological Monitoring of Annie Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1997b. Baseline Aquatic Biology of Upper Deadwood Creek and False Bottom Creek, South Dakota, 1996. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1997c. The 1996 Aquatic Biology Assessment of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for the Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1998a. 1997 Aquatic Biological Monitoring of Annie Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1998b. Aquatic Biology Baseline Monitoring of Upper Deadwood Creek and False Bottom Creek, South Dakota, 1997. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1998c. 1997 Aquatic Biology Assessment of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for the Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1999a. 1998 Aquatic Biological Monitoring of Annie Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1999b. Aquatic Biology Baseline Monitoring of Upper Deadwood Creek and False Bottom Creek, South Dakota, 1998. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 1999c. Aquatic Biology Assessment of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for the Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2000a. 1999 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, and False Bottom Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2000b. Aquatic Biological Monitoring Plan for Annie Creek, Deadwood Creek, False Bottom Creek, McKinley Gulch, and Squaw Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2000c. 1999 Aquatic Biology Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2001a. 2000 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, and McKinley Gulch, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2001b. 2000 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2002a. 2001 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, and McKinley Gulch, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2002b. 2001 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2003a. 2002 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, and McKinley Gulch, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2003b. 2002 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2004a. 2003 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2004b. 2003 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2005a. 2004 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2005b. 2004 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Report prepared for Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2006a. 2005 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2006b. 2005 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Prepared for Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2006c. Aquatic Biological Monitoring Plan for Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Prepared for Golden Reward Mining Company, Lead, SD.

Chadwick Ecological Consultants, Inc. (CEC). 2006d. Aquatic Biological Monitoring Plan for Annie Creek, Ross Valley, Upper Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

Clements, W.H., and P.M. Kiffney, 1994. Integrated laboratory and field approach for assessing impacts of heavy metals at the Arkansas River, Colorado. *Environmental Toxicology and Chemistry* 13:397-404.

Everhart, W.H., and W.D. Youngs. 1981. Principles of Fishery Science, 2nd Edition. Cornell University Press, Ithaca, NY.

GEI Consultants, Inc. (GEI). 2007a. 2006 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

GEI Consultants, Inc. (GEI). 2007b. 2006 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Prepared for Golden Reward Mining Company, Lead, SD.

GEI Consultants, Inc. (GEI). 2008a. 2007 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

GEI Consultants, Inc. (GEI). 2008b. Fish, benthic macroinvertebrate, and periphyton evaluation, June 2008 sampling. Memo prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

GEI Consultants, Inc. (GEI). 2008c. 2007 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Prepared for Golden Reward Mining Company, Lead, SD.

GEI Consultants, Inc. (GEI). 2009a. 2008 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

GEI Consultants, Inc. (GEI). 2009b. 2008 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Prepared for Golden Reward Mining Company, Lead, SD.

GEI Consultants, Inc. (GEI). 2010a. 2009 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

GEI Consultants, Inc. (GEI). 2010b. 2009 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Prepared for Golden Reward Mining Company, Lead, SD.

GEI Consultants, Inc. (GEI). *In progress*(a). 2010 Aquatic Biological Monitoring of Annie Creek, Upper Deadwood Creek, False Bottom Creek, McKinley Gulch, Lost Camp

Gulch, and Cleopatra Creek, South Dakota. Report prepared for Wharf Resources (U.S.A.), Inc., Lead, SD.

GEI Consultants, Inc. (GEI). *In progress*(b). 2010 Aquatic Biological Monitoring of Streams in the Vicinity of the Golden Reward Mine, Lawrence County, South Dakota. Prepared for Golden Reward Mining Company, Lead, SD.

Golden Reward Mining Company (GRMC). 1987. Golden Reward Mine: Aquatic Biology and Habitat Baseline Investigations. Report prepared by OEA Research, Inc.

Golden Reward Mining Company (GRMC). 1990. Golden Reward Mine: 1989 Aquatic Habitat, Macroinvertebrate, and Periphyton Surveys. Report prepared by OEA Research, Inc.

Golden Reward Mining Company (GRMC). 1992. Aquatic Biology and Habitat Survey, 1991, Golden Reward Mine. Report prepared by OEA Research, Inc.

Golden Reward Mining Company (GRMC). 1993. Aquatic Macroinvertebrate and Periphyton Survey, 1992, Golden Reward Mine. Report prepared by OEA Research, Inc.

Grzybkowska, M. 1995. Impact of human-induced flow perturbation on the chironomid communities in the first order stream section (central Poland). Pp. 247-253 *in* Cranston, P. (ed.). Chironomids: From Genes to Ecosystems. CSIRO Publications, Melbourne, Australia.

Hawkins, C. P., and J. R. Sedell. 1990. The role of refugia in the recolonization of streams devastated by the 1980 eruption of Mount St. Helens. Northwest Science 64:271-274.

Hintze, J.L. 2000. *NCSS 2001 Statistical Software System for Windows*. Number Cruncher Statistical Systems, Kaysville, UT.

Hynes, H. B. N. 1970. The Ecology of Running Waters. University of Toronto Press, Toronto, Canada.

Johnson, S. L., and C. C. Vaughn. 1995. A hierarchical study of macroinvertebrate recolonization of disturbed patches along a longitudinal gradient in a prairie river. *Freshwater Biology* 34:531-540.

Kiffney, P.M., and W.H. Clements, 1993. Bioaccumulation of heavy metals by benthic invertebrates at the Arkansas River, Colorado. *Environmental Toxicology and Chemistry* 12:1507-1517.

Klemm, D.J., P.A. Lewis, F. Fulk, and J.M. Lazorchak. 1990. Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters. EPA/600/4-90/030, U.S. Environmental Protection Agency, Washington, DC.

Knudson, K. 2003. An Evaluation of the Biological Communities of Squaw Creek, Labrador & Rubicon Gulches, Lawrence County near Lead, South Dakota. Report prepared for LAC Minerals (U.S.A.) LLC, Lead, SD.

Ledger, M. E., and A. G. Hildrew. 2001. Recolonization by the benthos of an acid stream following a drought. Archives für Hydrobiologie 152:1-17.

Lydy, M. J., C. G. Crawford, and J. W. Frey. 2000. A comparison of selected diversity, similarity, and biotic indices for detecting changes in benthic-macroinvertebrate community structure and stream quality. Archives of Environmental Contamination and Toxicology 39:469-479.

Mariah Associates, Inc. 1990. Aquatic Report for the Annie Creek-Spearfish Creek (Reliance Waste Dump) and Squaw Creek (Foley Ridge Waste Dump) Drainage Areas. Report prepared for Wharf Resources, (U.S.A.), Inc., Deadwood, SD.

Mariah Associates, Inc. 1992a. Results of Aquatic Sampling on Annie Creek, Lawrence County, South Dakota, 1991. Report prepared for Wharf Resources (U.S.A.), Inc., Deadwood, SD.

Mariah Associates, Inc. 1992b. Results of Aquatic Sampling on Annie Creek, Lawrence County, South Dakota, 1992. Report prepared for Wharf Resources (U.S.A.), Inc., Deadwood, SD.

Merritt, R.W., K. W. Cummins, and M.B. Berg. 2008. An Introduction to the Aquatic Invertebrates of North America, Fourth Edition. Kendall-Hunt Publishing Company, Dubuque, IA.

Omernik, J. M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers 77:118-125.

Omernik, J. M., and A. L. Gallant. 1987. Ecoregions of the West Central United States. EPA/600/D-87/317. U.S. Environmental Protection Agency, Corvallis, OR.

Overton, C. K., S. P. Wollrab, B. C. Roberts, and M. A. Radko. 1997. R1/R4 (Northern/Intermountain Regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. General Technical Report INT-GTR-346. U.S. Department of Agriculture Forest Service Intermountain Research Station, Ogden, UT.

Peck, D.V., J.M. Lazorchak, and D.J. Klemm (eds.). Unpublished Draft. Environmental Monitoring and Assessment Program - Surface Waters: Western Pilot Study Field

Operations Manual for Wadeable Streams. EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, DC.

Peterson, C.G. 1996. Responses of benthic algal communities to natural physical disturbance. pp. 375-402 IN: Stevenson, R.J., M.L. Bothwell, and R.L. Lowe (eds.). Algal Ecology: Freshwater Benthic Systems. Academic Press, NY.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for Evaluating Stream, Riparian, and Biotic Conditions. General Technical Report INT-138. U.S. Department of Agriculture Forest Service Intermountain Research Station, Ogden, UT.

Pritchard, H.N., and P.T. Bradt. 1984. Biology of Nonvascular Plants. Times Mirror/Mosby, St. Louis, MO.

Reiter, M.A. 1986. Interactions between the hydrodynamics of flowing water and development of a benthic algal community. *Journal of Freshwater Ecology* 3:511-517.

Robinson, C.T., and S.R. Rushforth. 1987. Effects of physical disturbance and canopy cover on attached diatom community structure in an Idaho stream. Hydrobiologia 154:49-59.

South Dakota Department of Environment and Natural Resources (SDDENR). 2002. Unpublished Draft. Field Operations Manual for Physical Habitat Characterization of Wadeable Streams. Version 1.0, July 2002.

South Dakota Department of Environment and Natural Resources (SDDENR). 2005. Standard Operating Procedures for Field Samplers, Volume II: Biological and Habitat Sampling. Version 1.2, Water Resources Monitoring Team, February 2005.

South Dakota Department of Game, Fish, and Parks (SDGFP). 1991. Wildlife Monitoring Guidelines for Large Scale Mines. Division of Wildlife, Rapid City, SD.

Stribling, J. B., S. R. Moulton, II, and G. T. Lester. 2003. Determining the quality of taxonomic data. Journal of the North American Benthological Society 22:621-631.

USGS (United States Geological Survey). 2010. Surface-water monthly data for South Dakota. United States Geologic Survey. Available: http://waterdata.usgs.gov/sd/nwis/monthly/?search_site_no=06430800&agency_cd=USGS&referred_module=sw&format=sites_selection_links. (October 2010).

Van Deventer, J. S., and W. S. Platts. 1983. Sampling and estimating fish populations for streams. Transactions of the North American Wildlife and Natural Resource Conference 48:349-354.

Van Deventer, J. S., and W. S. Platts. 1986. MicroFish Interactive Program, Version 3.0.

Vinson, M. R., and C. P. Hawkins. 1996. Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams. *Journal of the North American Benthological Society* 15:392-399.

Whittaker, R. H. 1975. Communities and Ecosystems, 2nd edition. Macmillan Publishing Co., New York, NY.

Wiederholm, T. 1984. Responses of aquatic insects to environmental pollution. Pp. 508-557 *in* Resh, V.H., and D.M. Rosenberg (eds.). The Ecology of Aquatic Insects. Praeger Scientific, New York, NY.

Wilhm, J. L. 1970. Range of diversity index in benthic macroinvertebrate populations. Journal of the Water Pollution Control Federation 42:R227-R234.

Williams, D. D., and H. B. N. Hynes. 1976. The recolonization mechanisms of stream benthos. Oikos 27:265-272.

Williams, D. D. 1980. Temporal patterns in recolonization of stream benthos. Archive für Hydrobiologia 90:56-74.

Zale, A. V., D. M. Leslie, Jr., W. L. Fisher, and S. G. Merrifield. 1989. The physicochemistry, flora, and fauna of intermittent prairie streams: a review of the literature. Biological Report 89(5). U.S. Fish and Wildlife Service.

Appendix A

Aquatic Biological Monitoring Activities for Wharf and Golden Reward

Table A-1: Aquatic biological monitoring summary for the Wharf monitoring sites from 1990 through 2010. Parameters: H = habitat, F = fish populations, B = benthic macroinvertebrate populations, and P = periphyton populations.

Date	Annie Creek			Ross Valley	Deadwood Creek		False Bottom Creek	Cleopatra Creek	Lost Camp Gulch
	AC-1-BIO	AC-2-BIO	AC-3-BIO	RV-2-BIO	DC-1-BIO	DC-2-BIO	FB-1-BIO	CC-1A-BIO	LC-1-BIO
1990	H, B	H, F, B	--	--	--	--	--	--	--
1991	--	B, P	--	--	--	--	--	--	--
1992	F, B, P	F, B, P	H, F, B	--	--	--	--	--	--
1993	H, B, P	H, B, P	--	--	--	--	--	--	--
1994	B, P	B, P	--	--	--	--	--	--	--
1995	H, F, B, P	H, F, B, P	F, B	--	H, F, B, P	--	H, F, B, P	--	--
1996	B, P	B, P	--	--	H, F, B, P	--	H, F, B, P	--	--
1997	B, P	B, P	--	--	B, P	--	B, P	--	--
1998	H, F, B, P	H, F, B, P	--	--	H, F, B, P	--	H, F, B, P	--	--
1999	B, P	B, P	--	--	B, P	--	B, P	--	--
2000	H, B, P	H, B, P	H, B, P	--	Dry	H, B, P	H, B, P	--	--
2001	H, F, B, P	H, F, B, P	H, F, B, P	--	Dry	H, F, B, P	H, F, B, P	--	--
2002	H, F, B, P	H, F, B, P	H, F, B, P	--	Dry	H, F, B, P	H, F, B, P	--	--
2003	H, F, B, P	H, F, B, P	H, F, B, P	--	Dry	H, F, B, P	H, F, B, P	--	--
2004	H, F, B, P	H, F, B, P	H, F, B, P	--	Dry	H, F, B, P	H, F, B, P	--	--
2005	H, F, B, P	H, F, B, P	H, F, B, P	--	Dry	H, F, B, P	H, F, B, P	--	--
2006	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	Dry	--	H, F, B, P	H, F, B, P	--
2007	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	Dry	--	H, F, B, P	H, F, B, P	--
2008	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	Dry	--	H, F, B, P	H, F, B, P	--
2009	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	--	H, F, B, P	H, F, B, P	--
2010	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P

Table A-2: Aquatic biological monitoring summary for the Golden Reward monitoring sites from 1986 through 2010. Parameters: H = habitat, F = fish populations, B = benthic macroinvertebrate populations, and P = periphyton populations.

	Upper Nevada Gulch	Lower Nevada Gulch	Fantail Creek	Stewart Gulch	Whitetail Creek
1986	--	--	H, F, B, P	H, F, B, P	--
1987	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
1989	H, B, P	H, B, P	H, B, P	H, B, P	H, B, P
1991	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
1992	B, P	B, P	B, P	B, P	B, P
1993	B, P	B, P	B, P	B, P	B, P
1994	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
1995	B, P	B, P	B, P	B, P	B, P
1996	B, P	B, P	B, P	B, P	B, P
1997	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
1998	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
1999	B, P	B, P	B, P	B, P	B, P
2000	B, P	B, P	B, P	B, P	B, P
2001	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
2002	B, P	B, P	B, P	B, P	B, P
2003	B, P	B, P	B, P	B, P	B, P
2004	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
2005	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
2006	--	B, P	B, P	B, P	B, P
2007	--	B, P	B, P	B, P	B, P
2008	--	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
2009	--	B, P	B, P	B, P	B, P
2010	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P

Appendix B

Flow Data

Table B-1: Flow recorded at sites on Annie Creek, Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, and Cleopatra Creek during sampling events, 2002 – 2010.

Stream/Site	Date	Flow (m^3/s)
Annie Creek		
AC-1-BIO	8/27/2002	0.00611
	8/26/2003	0.00863
	9/1/2004	0.00119
	8/26/2005	0.00297
	8/30/2006	0.00017
	8/28/2007	0.00106
	8/25/2008	0.00115
	8/26/2009	0.02830
	8/24/2010	0.00835
AC-2-BIO	8/27/2002	0.00136
	8/26/2003	0.00634
	9/1/2004	0.00116
	8/26/2005	0.00368
	8/30/2006	0.00047
	8/28/2007	0.00103
	8/26/2008	0.01968
	8/26/2009	0.02850
	8/24/2010	0.01063
AC-3-BIO	8/27/2002	0.00368
	8/26/2003	0.00849
	9/1/2004	0.00142
	8/26/2005	0.00538
	8/30/2006	0.00792
	8/29/2007	0.00792
	8/27/2008	0.01443
	8/26/2009	0.01358
	8/24/2010	0.01529
Ross Valley		
RV-2-BIO	8/30/2006	0.00005
	8/28/2007	0.00236
	8/26/2008	0.00555
	8/26/2009	0.00223
	8/24/2010	0.00068
Lost Camp Gulch		
LC-1-BIO	8/24/2010	0.00237
Deadwood Creek		
DC-1-BIO	8/28/2002	Dry
	8/28/2003	Dry
	9/3/2004	Dry
	8/25/2005	Dry
	8/31/2006	Dry
	8/30/2007	Dry
	8/27/2008	Dry
	8/27/2009	0.00053

Stream/Site	Date	Flow (m^3/s)
	8/26/2010	0.00009
DC-2-BIO	8/28/2002	0.00057
	8/28/2003	0.00860
	9/3/2004	0.00085
	8/25/2005	0.00093
	8/26/2010	0.00540
False Bottom Creek		
FB-1-BIO	8/28/2002	0.00125
	8/28/2003	0.00302
	8/31//2004	0.00057
	8/28/2005	0.00134
	8/31/2006	0.00043
	8/29/2007	0.00018
	8/28/2008	0.00193
	8/25/2009	0.00446
	8/25/2010	0.00176
Cleopatra Creek		
CC-1A-BIO	8/31/2006	0.00012
	8/27/2007	0.00015
	8/28/2008	0.00059
	8/25/2009	0.00085
	8/25/2010	0.00024

Table B-2: Flow recorded at sites on Nevada Gulch, Fantail Creek, Whitetail Creek, and Stewart Gulch during sampling events, 2002 – 2010.

Stream/Site	Date	Flow (m^3/s)
Fantail Creek	8/28/2002	0.00079
	8/27/2003	0.00201
	8/30/2004	0.00071
	8/26/2005	0.00142
	8/29/2006	0.00044
	8/30/2007	0.00060
	8/27/2008	0.00264
	8/26/2010	0.00209
Upper Nevada Gulch	8/28/2002	0.00035
	8/27/2003	0.00005
	9/2/2004	0.00076
	8/28/2005	0.00078
	8/26/2010	0.00087
Lower Nevada Gulch	8/28/2002	<0.0001
	8/27/2003	<0.00001
	9/2/2004	<0.00001
	8/28/2005	0.00011
	8/30/2006	0.00005
	8/30/2007	0.00006
	8/27/2008	0.00024
	8/26/2010	0.00030
Stewart Gulch	8/27/2002	0.02017
	8/25/2003	0.03027
	9/2/2004	0.01755
	8/27/2005	0.02581
	8/26/2006	0.02356
	8/30/2007	0.02970
	8/26/2008	0.02635
	8/25/2010	0.03364
Whitetail Creek	8/27/2002	0.00109
	8/25/2003	0.00815
	9/2/2004	0.00068
	8/27/2005	0.00983
	8/29/2006	0.00500
	8/30/2007	0.01107
	8/27/2008	0.01872
	8/25//2010	0.02207

Appendix C

Historical Fish Data

Table C-1: Historical data for mountain sucker populations at Site AC-2-BIO on Annie Creek, 1992 – 2010.

Site/Year	Number Collected	Mean Length (mm)	Mean Weight (g)	Density (#/ha)	Biomass (kg/ha)	Relative Weight (Wr)
1992	94	62	3.9	17,090	67	--
1995	3	89	5.7	102	0.6	--
1998	NF	--	--	--	--	--
2001	18	116	29	818	23.7	--
2002	19	92	12	1,056	12.8	--
2003	10	107	13	714	9.1	--
2004	9	122	20	750	15.3	--
2005	6	132	25	500	12.7	--
2006	8	135	29	533	15.5	--
2007	NF	--	--	--	--	--
2008	2	164	50	71	3.6	--
2009	NF	--	--	--	--	
2010	1	148	42	59	2.5	--

Table C-3: Historical data for brook trout and brown trout populations at Site AC-3-BIO on Annie Creek, 1992 – 2010.

Site/ Year	Species	Number Collected	Mean Length (mm)	Mean Weight (g)	Density (#/ha)	Biomass (kg/ha)	Relative Weight (Wr)
1992	Brook Trout	4	91	10.3	567	6	87.4
1995	Brook Trout	53	130	32.4	2,453	79.5	100.7
	Brown Trout	25	76	4.4	1,528	6.7	--
2001	Brook Trout	54	124	24	1,929	46.3	88.8
	Brown Trout	94	136	28	3,393	94.0	86.2
2002	Brook Trout	55	114	20	2,500	50.0	93.8
	Brown Trout	57	164	48	1,682	80.4	86.3
2003	Brook Trout	33	134	34	1,571	53.4	104.5
	Brown Trout	22	150	52	1,048	54.2	100.4
2004	Brook Trout	43	89	13	2,529	32.6	93.9
	Brown Trout	10	116	31	588	18.2	77.2
2005	Brook Trout	71	99	16	3,087	48.2	99.4
	Brown Trout	17	138	38	739	27.9	91.5
2006	Brook Trout	90	99	12	5,353	66.3	95.4
	Brown Trout	8	192	71	471	33.5	95.8
2007	Brook Trout	110	107	17	4,917	82.1	97.3
	Brown Trout	21	123	54	875	47.6	97.7
2008	Brook Trout	127	100	16	4,750	75.1	101.8
	Brown Trout	9	139	31	321	10.0	99.0
2009	Brook Trout	118	108	17	4,923	83.2	94.9
	Brown Trout	6	201	85	231	19.6	95.8
2010	Brook Trout	127	97	14	6500	89.1	101.2
	Brown Trout	10	118	39	500	19.7	104.1

Table C-2: Historical data for brook trout populations in Deadwood (2001 – 2010) and False Bottom Creek (1995 – 2010).

Site/Year	Number Collected	Mean Length (mm)	Mean Weight (g)	Density (#/ha)	Biomass (kg/ha)	Mean Condition W_r
Deadwood Creek, Site DC-2-BIO						
2001	82	103	11	4,824	54.0	83.2
2002	50	108	14	5,000	70.5	94.1
2003	31	101	15	2,583	38	97.7
2004	30	93	8	2,727	22.3	--
2005	15	115	18	1,250	21.9	96.0
2010	169	104	13	28,500	379	87.7
False Bottom Creek, Site FB-1-BIO						
1995	48	127	23	4,590	104.2	93.4
1996	119	89	12	13,778	159.8	94.7
1998	114	100	12.5	11,389	142.4	103.6
2001	105	87	7	9,636	68.4	75.2
2002	45	97	12	5,000	58.0	107.2
2003	22	108	18	3,143	56.9	104.9
2004	18	85	7	2,571	18.3	84.2
2005	7	130	24	875	21.4	114.6
2006	36	90	10	4,625	47.9	100.6
2007	28	97	9	2,545	23.2	--
2008	46	111	15	3,067	46.0	104.0
2009	156	77	7	16,100	119.1	101.8
2010	98	99	12	7,538	93.5	94.7

Table C-4: Historical data for brook trout populations Stewart Gulch and Whitetail Creek, 1986 – 2010. NS = not sampled, NR = Not Recorded.

Site/Year	Number Collected	Mean Length (mm)	Mean Weight (g)	Density (#/ha)	Biomass (kg/ha)	Mean Condition (W_r)
Stewart Gulch						
1986	80	128	33	5,467	180.4	110
1987	NS	--	--	--	--	--
1991	72	NR	NR	NR	NR	NR
1994	64	113	25	3,300	82.5	104
1997	21	162	53	820	43.5	102
1998	55	136	54	2,748	147.3	111
2001	75	131	34	3,080	105.3	99
2004	62	118	23	3,444	80.6	93
2005	127	109	18	6,550	114.6	101
2008	160	109	21	7,545	157.7	106
2010	104	113	25	6500	161.9	107
Whitetail Creek						
1986	NS	--	--	--	--	--
1987	6	159	54	476	25.7	112
1991	7	NR	NR	NR	NR	NR
1994	0	--	--	--	--	--
1997	20	165	50	1,163	58.2	100
1998	21	140	49	1,062	51.5	110
2001	73	86	8	4,056	31.2	109
2004	30	113	18	2,308	40.6	98
2005	22	111	19	1,692	31.8	104
2008	77	113	22	3,250	72.8	111
2010	62	105	15	3,263	52.6	115

Appendix D

Historical Benthic Macroinvertebrate Data – Wharf Sites

Table D-1: Benthic macroinvertebrate density (number of organisms/m^2) and selected population parameters for sites on Annie Creek, South Dakota, in late summer/fall of 1992 - 2010. NS = Not Sampled.

	Annie Creek																
Site AC-1-BIO	**1992[a]**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	3,932	4,508	8,696	10,397	4,909	1,841	819	4,775	39,612	38,461	7,641	1,977	2,026[e]	4,243[e]	3,118[e]	1,960[e]	3,216[e]
Number of Taxa	35	28	27	24	26	19	29	34	21	27	29	29	24	11	23	29	25
Shannon-Weaver Diversity (H')	3.71	3.20	3.16	3.11	3.17	3.09	3.84	3.18	2.49	3.18	3.03	2.93	2.52	1.75	2.88	4.08	3.36
Number of EPT Taxa	12	12	9	7	10	7	9	10	3	3	4	9	6	1	4	6	6
%Ephemeroptera Abundance	23	2	5	0	8	10	17	8	<1	<1	18	37	20	0	40	9	32
Site AC-2-BIO	**1992**	**1995[b]**	**1996[b]**	**1997[b]**	**1998[b]**	**1999[b]**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	10,838	1,333	4,586	3,597	992	5,215	2,119	10,097	4,607	2,046	1,025	2,708	950[e]	493[e]	839[e]	1,580[e]	896[e]
Number of Taxa	40	30	29	32	17	31	34	34	42	48	30	35	25	30	39	36	28
Shannon-Weaver Diversity (H')	2.82	3.80	2.11	3.13	2.32	3.20	3.89	2.65	3.94	4.31	3.74	3.67	3.54	3.84	3.85	4.05	3.84
Number of EPT Taxa	17	9	14	16	6	9	13	8	12	11	10	10	4	8	13	11	7
% Ephemeroptera Abundance	10	0	68	44	58	7	8	1	4	4	12	12	22	10	28	17	6
Site AC-3-BIO	**1992[c]**	**1995[d]**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	9,344	4,621	NS	NS	NS	NS	10,095	12,598	3,282	5,581	3,274	3,525	1,875[e]	3,505[e]	3,424[e]	2,697[e]	4,170[e]
Number of Taxa	49	29	NS	NS	NS	NS	37	41	40	47	40	34	33	37	39	38	39
Shannon-Weaver Diversity (H')	4.12	3.02	NS	NS	NS	NS	3.78	3.85	3.87	3.75	3.09	3.75	3.92	3.64	4.12	4.21	4.22
Number of EPT Taxa	20	13	NS	NS	NS	NS	16	14	14	17	14	14	14	14	17	14	15
% Ephemeroptera Abundance	17	1	NS	NS	NS	NS	2	2	2	2	2	5	10	10	13	15	16

[a] Data from Site 1-A of 1992 Aquatic Biological Assessment, just downstream of Site AC-1 (C&A 1993).

[b] Data from Site AC-2 of 1995-1999 Aquatic Biological Monitoring, downstream of Site AC-2-BIO (CEC 1996b, 1997a, 1998a, 1999a, 2000).

[c] Data from Site AC-6 of 1992 Aquatic Biological Assessment (C&A 1993).

[d] Data from Site AC-6 (CEC 1996a).

[e] Data were collected using SDDENR procedures, thus values represent abundance (number of organisms/sample).

Table D-2: Benthic macroinvertebrate population density (number of organisms/m^2) and selected parameters for Lost Camp Gulch, Ross Valley, and Cleopatra Creek, South Dakota, in late summer/fall, 2006-2010. NS = Not Sampled

	Lost Camp Gulch															
Site LC-1-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1,087[a]
Number of Taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	26
Shannon-Weaver Diversity (H')	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.87
Number of EPT Taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	11
% Ephemeroptera Abundance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	24
	Ross Valley															
Site RV-2-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	558[a]	695[a]	1,375[a]	944[a]	1,648[a]
Number of Taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	25	38	31	26	33
Shannon-Weaver Diversity (H')	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.48	4.10	3.51	3.75	3.97
Number of EPT Taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	6	10	7	8	10
% Ephemeroptera Abundance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	8	4	15	10	4
	Cleopatra Creek															
Site CC-1A-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1,515[a]	1,450[a]	4,576[a]	5,369[a]	2,126[a]
Number of Taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	11	19	22	18	19
Shannon-Weaver Diversity (H')	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.71	3.01	3.31	2.35	3.11
Number of EPT Taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1	4	7	6	3
% Ephemeroptera Abundance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	1	1	1	0

[a] Data were collected using SDDENR procedures, thus this value represent abundance (number of organisms/sample).

Table D-3. Benthic macroinvertebrate density (number of organisms/m^2) and selected population parameters for sites on Deadwood Creek, South Dakota, in late summer/fall, 1995 - 2010. NS = Not Sampled.

	Deadwood Creek															
Site DC-1-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	861	525	1,688	828	737	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	3,900[a]	631[a]
Number of Taxa	25	20	28	20	23	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	20	19
Shannon-Weaver Diversity (H')	3.51	3.41	3.46	3.29	2.99	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	1.91	3.11
Number of EPT Taxa	6	4	8	8	9	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	5	3
% Ephemeroptera Abundance	9	3	5	22	14	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	3	0
Site DC-2-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	NS	NS	NS	NS	NS	1,320	3,292	5,160	1,877	7,865	7,951	NS	NS	NS	NS	2,340[a]
Number of Taxa	NS	NS	NS	NS	NS	33	27	43	31	39	41	NS	NS	NS	NS	30
Shannon-Weaver Diversity (H')	NS	NS	NS	NS	NS	3.50	2.83	3.68	3.41	3.81	3.91	NS	NS	NS	NS	3.23
Number of EPT Taxa	NS	NS	NS	NS	NS	13	5	13	12	16	14	NS	NS	NS	NS	13
% Ephemeroptera Abundance	NS	NS	NS	NS	NS	8	<1	10	8	7	18	NS	NS	NS	NS	7
	False Bottom Creek															
Site FB-1-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	3,247	619	1,451	1,313	511	3,711	2,313	3,927	2,498	2,901	7,726	1,255[a]	459[a]	1,238[e]	797[a]	1,443
Number of Taxa	24	20	27	22	23	30	36	44	39	48	33	32	31	37	29	28
Shannon-Weaver Diversity (H')	2.81	3.26	3.57	3.10	3.57	3.48	3.35	3.80	3.7	4.02	3.34	3.66	4.18	4.16	3.87	3.38
Number of EPT Taxa	8	9	12	6	11	13	10	13	13	15	12	11	10	11	10	12
% Ephemeroptera Abundance	16	26	20	12	17	20	9	15	10	17	18	35	1	0.3	8	26

[a] Data were collected using SDDENR procedures, thus this value represent abundance (number of organisms/sample).

Appendix E

Historical Benthic Macroinvertebrate Data - Golden Reward Sites

Table E-1. Benthic macroinvertebrate density (number of organisms/m^2) and selected population parameters for sites on Fantail Creek and Nevada Gulch, South Dakota, in late summer/fall of 1995 - 2010. NS = Not Sampled.

Fantail Creek	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	2,061	4,714	1,738	1,088	7,897	24,540	25,085	506	14,518	9,349	1,900 [a]	1,600 [a]	669 [a]	1,254 [a]	3,600 [a]	2,772 [a]
Number of Taxa	38	35	27	30	40	49	40	41	57	41	34	33	32	51	28	28
Shannon-Weaver Diversity (H')	3.41	2.53	3.22	3.29	2.76	2.66	2.79	4.13	3.49	3.50	3.45	3.20	3.72	4.60	3.05	2.96
Number of EPT Taxa	11	12	7	11	13	14	10	12	14	9	11	13	12	14	8	10
% Ephemeroptera Abundance	7	3	1	23	11	1	8	2	19	>1	32	33	14	14	15	14
Upper Nevada Gulch	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	1,431	1,064	771	721	1,317	5,866	971	3,276	2,533	1,472	832 [a]	NS	NS	NS	NS	2,499 [a]
Number of Taxa	32	32	32	23	20	28	29	39	55	32	30	NS	NS	NS	NS	34
Shannon-Weaver Diversity (H')	2.60	2.80	3.66	2.46	1.73	2.64	3.02	3.58	2.69	3.28	3.99	NS	NS	NS	NS	3.26
Number of EPT Taxa	10	6	11	6	7	7	7	7	15	5	6	NS	NS	NS	NS	7
% Ephemeroptera Abundance	14	23	10	3	16	2	4	3	4	0	3	NS	NS	NS	NS	1
Lower Nevada Gulch	**1995[d]**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	1,317	8,007	3,726	1,429	4,245	6,100	1,736	9,759	2,940	4,334	1,860 [a]	1,800 [a]	1,773 [a]	2,340 [a]	1,410 [a]	2,913 [a]
Number of Taxa	30	41	35	35	46	24	30	28	47	39	27	31	38	33	35	25
Shannon-Weaver Diversity (H')	3.33	2.94	2.72	3.15	3.03	2.12	3.13	3.30	3.87	2.89	3.71	3.48	4.28	4.27	4.10	2.89
Number of EPT Taxa	10	15	10	11	15	6	9	4	10	10	6	8	13	8	9	9
% Ephemeroptera Abundance	3	1	1	15	4	0	5	2	4	4	21	22	5	3	7	1

[a] Data were collected using SDDENR procedures, thus this value represent abundance (number of organisms/sample).

Table E-2. Benthic macroinvertebrate density (number of organisms/m^2) and selected population parameters for sites on Stewart Gulch and Whitetail Creek, South Dakota, late summer/fall of 1995 - 2010.

Stewart Gulch	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	5,977	4,509	2,737	467	4,791	8,957	5,116	13,225	5,464	4,213	9,921 [a]	2,910 [a]	4,070 [a]	3,311 [a]	4,470 [a]	5,619 [a]
Number of Taxa	31	24	34	21	29	34	37	42	45	44	36	28	33	40	30	31
Shannon-Weaver Diversity (H')	2.69	3.24	2.52	2.37	2.64	3.04	3.18	3.07	3.41	3.83	3.79	3.83	3.91	3.99	3.62	3.94
Number of EPT Taxa	10	13	10	9	13	12	12	12	14	13	11	11	10	12	9	15
% Ephemeroptera Abundance	11	22	48	50	9	25	10	11	15	16	22	13	22	24	23	14
Whitetail Creek	**1995[d]**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Density	2,154	4,351	1,700	2,305	14,349	4,902	19,051	10,699	23,110	6,613	5,794 [a]	3,357 [a]	3,417 [a]	7,886 [a]	5,610 [a]	6,492 [a]
Number of Taxa	35	33	32	31	38	33	40	40	62	47	37	30	41	43	39	38
Shannon-Weaver Diversity (H')	3.57	3.80	3.62	3.41	3.73	3.48	3.38	3.93	3.78	4.07	4.11	3.89	4.47	4.39	4.03	4.10
Number of EPT Taxa	12	15	11	12	16	12	12	13	18	14	11	11	14	15	11	17
% Ephemeroptera Abundance	8	10	6	13	6	7	4	17	3	8	11	31	17	15	17	16

[a] Data were collected using SDDENR procedures, thus this value represent abundance (number of organisms/sample).

Table E-3: Proportional abundance (%) of benthic macroinvertebrates collected in qualitative kick samples in Fantail Creek, Upper Nevada Gulch, Lower Nevada Gulch, Stewart Gulch, and Whitetail Creek, South Dakota, late summer/fall of 1986 - 2004. NR = Not Reported. NS = Not Sampled.

Fantail Creek	**1986**	**1987**	**1989**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Total Number Collected	47	50	361	343	141	104	413	344	1,164	248	459	2,648	2,530	1,624	105	1,668	785
Number of Taxa	15	14	15	23	15	35	43	24	16	14	18	31	27	25	32	41	25
Shannon-Weaver Index (H')	NR	NR	NR	NR	NR	2.45	2.83	3.72	1.80	1.67	2.64	2.88	3.07	2.76	4.31	4.12	2.46
Upper Nevada Gulch	**1986**	**1987**	**1989**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Total Number Collected	NS	124	43	93	275	31	731	684	423	896	242	804	282	525	224	435	163
Number of Taxa	NS	20	15	15	22	19	43	19	20	23	15	10	16	11	22	37	15
Shannon-Weaver Index (H')	NS	NR	NR	NR	NR	2.61	2.83	3.03	1.82	2.95	1.78	1.89	3.01	2.05	3.60	3.94	1.86
Lower Nevada Gulch	**1986**	**1987**	**1989**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Total Number Collected	NS	83	17	128	41	34	31	366	896	378	157	678	538	295	1,444	1,332	165
Number of Taxa	NS	19	14	14	18	13	17	21	27	23	22	31	14	18	19	32	21
Shannon-Weaver Index (H')	NS	NR	NR	NR	NR	2.37	2.85	3.19	3.48	3.06	2.99	3.41	2.72	2.83	3.31	4.17	2.83
Stewart Gulch	**1986**	**1987**	**1989**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Total Number Collected	104	105	501	226	180	252	1,720	2,044	2,824	94	295	2,280	716	4,168	3,910	3,312	1,965
Number of Taxa	9	20	22	24	14	36	28	20	13	15	19	18	16	24	24	30	26
Shannon-Weaver Index (H')	NR	NR	NR	NR	NR	3.40	2.94	2.93	2.99	2.73	2.22	2.60	2.87	2.46	3.69	2.41	3.24
Whitetail Creek	**1986**	**1987**	**1989**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Total Number Collected		55	284	258	86	77	202	1,932	309	402	1,172	2,060	808	2,335	1,380	2,330	349
Number of Taxa		13	18	23	14	24	24	21	27	16	22	24	26	24	27	37	32
Shannon-Weaver Index (H')		NR	NR	NR	NR	2.74	2.57	3.20	3.72	3.90	3.12	3.52	3.59	2.53	3.83	4.29	4.37

Appendix F

Historical Periphyton Data - Wharf Sites

Table F-1. Relative abundance (%) and number of periphyton taxa collected from sites on Annie Creek, South Dakota, in late summer/fall of 1992 - 2010. NS = not sampled.

SITE AC-1-BIO	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta																			
Centric diatoms	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.1	--	--	--	--
Pennate diatoms	97.6	19.0	82.6	65.0	20.4	20.7	86.9	12.4	1.6	4.1	3.6	21.1	23.2	87.0	87.2	100	100	100	34.1
Chlorophyta	0.6	--	--	--	--	--	--	--	29.3	5.3	96.2	78.9	76.8	2.2	6.7	--	--	--	59.1
Chrysophyta	--	--	--	--	--	--	--	--	--	--	0.2	--	--	--	5.0	--	--	--	--
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--	--	10.8	--	--	--	--	6.8
Cyanophyta	1.7	81.0	17.4	35.0	79.6	79.3	13.1	87.6	66.1	90.6	--	--	--	--	--	--	--	--	--
Euglenophyta	0.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rhodophyta	--	--	--	--	--	--	--	--	3.0	--	--	--	--	--	--	--	--	--	--
Density (cells/mm^2)		21	2,059	6,115	673	750	8,628	339	182,718	1,082,059	2,401	4,577	18,940	2,885	179	19,324	1,169	438	44
Number Of Taxa	--	6	13	11	4	2	13	3	21	22	12	13	11	11	29	15	21	13	10
SITE AC-2-BIO	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta																			
Centric diatoms	--	5.3	--	--	--	--	--	--	0.1	2.8	--	--	--	--	--	--	--	--	--
Pennate diatoms	98.4	31.6	22.2	29.4	7.3	14.8	54.0	62.0	1.0	0.8	100	24.8	13.8	95.5	100	100	98.8	90.5	94.8
Chlorophyta	0.4	--	--	--	--	--	--	--	18.3	74.2	--	51.5	86.2	--	--	--	--	--	5.2
Chrysophyta	0.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyanophyta	1.1	63.1	77.8	70.6	92.7	85.2	46.0	38.0	80.6	21.8	--	23.4	--	--	--	--	--	9.5	--
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--	--	4.5	--	--	1.2	--	--
Euglenophyta	--	--	--	--	--	--	--	--	--	--	--	0.3	--	--	--	--	--	--	--
Rhodophyta	--	--	--	--	--	--	--	--	--	0.4	--	--	--	--	--	--	--	--	--
Density (cells/mm^2)		19	1,338	1,685	578	1,536	1,423	702	78,047	79,104	75	2,005	1,667	4,228	328	8,369	168	694	154
Number Of Taxa	--	10	14	8	3	3	13	11	19	30	12	21	11	12	16	19	20	15	15

Table F-1(cont.). Relative abundance (%) and number of periphyton taxa collected from sites on Annie Creek, South Dakota, in late summer/fall of 1992 - 2010. NS = not sampled.

SITE AC-3-BIO	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	200	2004	2005	2006	2007	2008	2009	2010
Bacillariophyta	NS	NS	NS	NS	NS	NS	NS	NS											
Centric diatoms	NS	NS	NS	NS	NS	NS	NS	NS	0.1	3.1	--	--	--	--	--	--	--	--	--
Pennate diatoms	NS	NS	NS	NS	NS	NS	NS	NS	4.2	5.5	66.1	67.7	76.5	93.5	99.1	100	100	100	96.3
Chlorophyta	NS	NS	NS	NS	NS	NS	NS	NS	0.7	35.4	33.9	32.3	23.5	--	--	--	--	--	3.7
Cryptophyta	NS	NS	NS	NS	NS	NS	NS	NS	--	--	--	--	--	6.5	--	--	--	--	--
Cyanophyta	NS	NS	NS	NS	NS	NS	NS	NS	95.0	55.8	--	--	--	--	0.9	--	--	--	--
Rhodophyta	NS	NS	NS	NS	NS	NS	NS	NS	--	0.1	--	--	--	--	--	--	--	--	--
Density (cells/mm^2)	NS	NS	NS	NS	NS	NS	NS	NS	54,113	15,247	1,652	154	3,118	83	176	12,765	11,840	5,170	216
Number Of Taxa	NS	NS	NS	NS	NS	NS	NS	NS	17	33	24	11	19	15	11	15	21	18	19

Table F-2. Relative abundance (%), total number of taxa, and density (cells/mm^2) of periphyton collected from sites on Cleopatra Creek and Deadwood Creek, South Dakota, in late summer/fall, 1995 - 2010. NS = not sampled.

SITE CC-1A-BIO	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Bacillariophyta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS					
Pennate diatoms	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	100	100	100	100	83.3
Cyanophyta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--	--	--	16.7
Density (cells/mm^2)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	5,664	30,019	15,395	838	233
Number Of Taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	10	10	17	13	15
SITE DC-1-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta						DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY		
Pennate diatoms	15.6	2.5	2.2	10.3	3.3	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	100	90.1
Chrysophyta	--	--	--	--	--	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	--	9.9
Cyanophyta	84.4	97.5	97.8	89.7	96.7	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	--	--
Density (cells/mm^2)	846	488	548	630	878	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	1,087	252
Number Of Taxa	6	2	2	5	4	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	8	16
SITE DC-2-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta	NS	NS	NS	NS	NS							NS	NS	NS	NS	
Centric diatoms	NS	NS	NS	NS	NS	1.6	--	1.6	1.3	1.0	--	NS	NS	NS	NS	--
Pennate diatoms	NS	NS	NS	NS	NS	7.9	23.5	98.4	76.0	95.1	96.2	NS	NS	NS	NS	82.6
Chlorophyta	NS	NS	NS	NS	NS	3.1	1.8	--	22.7	1.0	3.8	NS	NS	NS	NS	17.4
Chrysophyta	NS	NS	NS	NS	NS	0.1	--	--	--	--	--	NS	NS	NS	NS	--
Cyanophyta	NS	NS	NS	NS	NS	87.3	54.9	--	--	2.9	--	NS	NS	NS	NS	--
Rhodophyta	NS	NS	NS	NS	NS	--	19.8	--	--	--	--	NS	NS	NS	NS	--
Density (cells/mm^2)	NS	NS	NS	NS	NS	243,000	31,383	8,367	1,591	2,555	1,435	NS	NS	NS	NS	673
Number Of Taxa	NS	NS	NS	NS	NS	22	23	14	20	24	15	NS	NS	NS	NS	20

Table F-3: Relative abundance (%), total number of taxa, and density (cells/mm^2) of periphyton collected from sites on False Bottom Creek, Ross Valley, and Lost Camp Gulch, South Dakota, in late summer/fall, 1995 - 2010. NS = not sampled.

SITE FB-1-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta																
Pennate diatoms	32.1	3.6	4.3	23.9	55.5	17.2	5.7	100	100	97.2	100	99.2	98.2	85.2	100	92.2
Chlorophyta	--	--	--	--	--	0.2	0.3	--	--	2.8	--	0.8	1.8	14.8	--	--
Cyanophyta	67.9	96.4	95.7	76.1	44.5	82.6	54.2	--	--	--	--	--	--	--	--	7.8
Rhodophyta	--	--	--	--	--	--	39.7	--	--	--	--	--	--	--	--	--
Density (cells/mm^2)	876	494	560	704	667	87,862	20,886	561	86	4,355	1,865	498	3,598	445	153	116
Number Of Taxa	8	2	2	5	13	18	32	20	11	20	5	15	25	16	18	19
SITE RV-2-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS					
Pennate diatoms	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	98.7	91.2	91.1	69.1	56.8
Chlorophyta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.3	8.8		30.9	21.6
Cyanophyta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	--	--	8.9	--	21.6
Density (cells/mm^2)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	159	216	1,301	1621	578
Number Of Taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	19	14	18	18	24
SITE LC-1-BIO	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Pennate diatoms	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	97.5
Cryptophyta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.5
Density (cells/mm^2)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	80
Number Of Taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	18

Table F-4: Chlorophyll a and Ash Free Dry Weight (AFDW) Data for sites on Annie Creek, Lost Camp Gulch, Ross Valley, Deadwood Creek, False Bottom Creek, and Cleopatra Creek, South Dakota, 2006 – 2010. NS = not sampled.

Site	2006	2007	2008	2009	2010
Annie Creek, Site AC-1-BIO					
Chlorophyll *a* (mg/m^2)	10.5	64.1	3.0	6.5	9.4
AFDW (mg/m^2)	5,303	34,697	1,894	2,424	5,303
Annie Creek, Site AC-2-BIO					
Chlorophyll *a* (mg/m^2)	8.3	11.4	2.2	6.7	16.3
AFDW (mg/m^2)	6,364	26,061	2,576	2,879	13,485
Annie Creek, Site AC-3-BIO					
Chlorophyll *a* (mg/m^2)	12.3	22.8	41.1	16.5	18.1
AFDW (mg/m^2)	5,152	12,121	7,424	6,212	5,000
Lost Camp Gulch, Site LC-1-BIO					
Chlorophyll *a* (mg/m^2)	NS	NS	NS	NS	26.6
AFDW (mg/m^2)	NS	NS	NS	NS	6,061
Ross Valley, Site RV-2-BIO					
Chlorophyll *a* (mg/m^2)	7.4	13.0	4.2	7.1	32.8
AFDW (mg/m^2)	4,848	46,667	4,091	4,697	30,909
Deadwood Creek, Site DC-1-BIO					
Chlorophyll *a* (mg/m^2)	DRY	DRY	DRY	9.8	5.1
AFDW (mg/m^2)	DRY	DRY	DRY	3,030	14,848
Deadwood Creek, Site DC-2-BIO					
Chlorophyll *a* (mg/m^2)	NS	NS	NS	NS	17.2
AFDW (mg/m^2)	NS	NS	NS	NS	21,515
False Bottom Creek, Site FB-1-BIO					
Chlorophyll *a* (mg/m^2)	6.3	3.1	2.2	1.1	6.7
AFDW (mg/m^2)	23,636	6,818	5,455	1,970	4,394
Cleopatra Creek, Site CC-1-BIO					
Chlorophyll *a* (mg/m^2)	3.8	33.3	4.2	5.6	7.8
AFDW (mg/m^2)	14,687	7,424	3,030	2,424	5,909

Appendix G

Historical Periphyton Data - Golden Reward Sites

Table G-1: Relative abundance (%), total number of taxa, and density (cells/mm^2) of periphyton collected from Fantail Creek and Upper Nevada Gulch, South Dakota, in late summer/fall of 1993 - 2010. * = cells/sample. NS = not sampled.

Fantail Creek	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta																		
Centric diatoms	--	--	--	--	--	--	--	--	--	--	4.6	2.4	--	--	--	--	3.4	--
Pennate diatoms	19.5	78.1	41.8	16.6	44.1	19.3	64.7	18.4	12.8	100	95.4	97.6	100	100	100	100	96.6	100
Chlorophyta	--	--	--	--	--	--	--	8.2	21.4	--	--	--	--	--	--	--	--	--
Chrysophyta	--	0.2	--	--	--	--	--	<0.1	--	--	--	--	--	--	--	--	--	--
Cyanophyta	80.5	21.7	58.2	83.4	55.9	80.7	35.3	73.3	65.8	--	--	--	--	--	--	--	--	--
Density (cells/mm^2)	1,941*	6,160	1,023	643	1,065	958	675	47,550	171,137	747	1,426	6,004	1,189	23	456	640	116	21
Number Of Taxa	10	7	4	2	8	10	11	20	20	18	15	17	7	10	14	15	15	17
Upper Nevada Gulch	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta														NS	NS	NS	NS	
Centric diatoms	--	0.3	--	--	--	--	--	--	--	--	--	--	--	NS	NS	NS	NS	--
Pennate diatoms	20.3	35.2	33.0	100	59.2	9.2	100	11.7	3.2	37.5	8.4	96.6	78.8	NS	NS	NS	NS	98.7
Chlorophyta	--	--	--	--	--	--	--	12.2	2.9	62.5	91.6	3.4	18.2	NS	NS	NS	NS	--
Chrysophyta	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.3
Cryptophyta	--	--	--	--	--	--	--	--	--	--	--	--	3.0	NS	NS	NS	NS	--
Cyanophyta	79.7	64.5	67.0	--	40.8	90.8	--	76.2	51.1	--	--	--	--	NS	NS	NS	NS	--
Rhodophyta	--	--	--	--	--	--	--	--	42.8	--	--	--	--	NS	NS	NS	NS	--
Density (cells/mm^2)	9,313*	1,995	1,243	6	1,750	655	2	31,285	30,399	3,522	1,278	561	1,126	NS	NS	NS	NS	80
Number Of Taxa	8	11	8	2	11	3	2	15	14	21	13	21	13	NS	NS	NS	NS	17

Table G-2: Relative abundance (%), total number of taxa, and density (cells/mm^2) of periphyton collected from Lower Nevada Gulch, Stewart Gulch, and Whitetail Creek, South Dakota, in late summer/fall of 1993 - 2010. * = cells/sample.

Lower Nevada Gulch	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta																		
Centric diatoms	--	0.3	--	--	--	--	--	--	--	--	--	--	--	--	4.6	4.4	--	--
Pennate diatoms	31.6	36.5	27.2	82.5	74.8	15.8	54.7	28.2	14.2	100	88.8	100	100	100	95.4	95.6	84.1	100
Chlorophyta	--	--	--	--	--	--	--	13.6	11.8	--	--	--	--	--	--	--	15.9	--
Cyanophyta	68.4	63.2	72.8	17.5	25.2	84.2	45.3	58.2	74.0	--	11.2	--	--	--	--	--	--	--
Density (cells/mm^2)	13,368*	4,609	1,308	3,410	2,356	565	525	62,062	62,047	10,629	2,552	15,151	9,556	882	12,094	16,871	2,678	242
Number Of Taxa	6	11	7	3	9	2	6	29	11	11	28	11	13	17	20	21	21	25
Stewart Gulch	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta																		
Centric diatoms	<0.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pennate diatoms	24.1	26.5	59.8	30.8	72.2	5.3	73.5	14.4	23.0	100	89.9	100	97.3	100	100	100	95.2	100
Chlorophyta	--	--	--	--	--	--	--	17.5	2.6	--	--	--	--	--	--	--	4.8	--
Cyanophyta	75.8	73.5	40.2	69.2	27.8	94.7	26.5	63.7	74.4	--	10.1	--	2.7	--	--	--	--	--
Rhodophyta	--	--	--	--	--	--	--	--	4.4	--	--	--	--	--	--	--	--	--
Density (cells/mm^2)	29,395*	2,477	2,071	775	2,141	566	1,008	58,065	16,466	4,457	2,749	2,429	13,544	1,791	1,912	1,385	5,977	1,678
Number Of Taxa	13	7	6	4	11	2	9	26	19	10	10	7	11	11	16	12	14	17
Whitetail Creek	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Bacillariophyta)																		
Centric diatoms	1.1	--	--	--	--	--	--	0.1	--	--	--	0.9	--	--	9.0	5.3	--	2.6
Pennate diatoms	31.5	48.0	50.4	65.5	88.0	71.3	92.0	16.5	13.2	78.4	81.2	98.2	100	100	91.0	94.7	100	97.4
Chlorophyta	--	--	--	--	--	--	--	0.8	3.9	--	--	--	--	--	--	--	--	--
Cyanophyta	67.4	52.0	49.6	34.5	12.0	28.7	8.0	82.6	82.9	21.6	18.8	0.9	--	--	--	--	--	--
Density (cells/mm^2)	12,204*	1,050	1,679	2,414	4,949	3,530	3,708	46,901	15,158	1,827	8,152	10,166	44,668	1,725	5,901	5,487	8,787	970
Number Of Taxa	11	6	5	6	12	10	9	28	30	21	17	28	23	23	20	21	18	23

Table G-3: Chlorophyll a and Ash Free Dry Weight (AFDW) Data for sites on Fantail Creek, Nevada Gulch, Stewart Gulch, and Whitetail Creek, South Dakota, 2005 – 2010.

Site	2005	2006	2007	2008	2009	2010
Fantail Creek						
Chlorophyll *a* (mg/m^2)	813.8[a]	4.9	2.0	0.4	2.9	3.4
AFDW (mg/m^2)	23.1[b]	3,939	4,091	3,939	1,515	3,939
Upper Nevada Gulch						
Chlorophyll *a* (mg/m^2)	1,474.2[a]	NS	NS	NS	NS	10.3
AFDW (mg/m^2)	42.7[b]	NS	NS	NS	NS	5,000
Lower Nevada Gulch						
Chlorophyll *a* (mg/m^2)	371.5[a]	13.0	22.1	15.6	7.1	10.7
AFDW (mg/m^2)	40.4[b]	6,970	11,970	7,121	3,182	5,303
Stewart Gulch						
Chlorophyll *a* (mg/m^2)	866.8[a]	13.0	6.9	3.4	56.3	45.8
AFDW (mg/m^2)	17.6[b]	11,061	4,242	4,091	8,939	8,333
Whitetail Creek						
Chlorophyll *a* (mg/m^2)	135.6[a]	28.1	10.3	24.1	55.4	49.8
AFDW (mg/m^2)	13.4[b]	12,121	10,909	6,818	7,121	10,758

[a] Reported as mg/m^3.
[b] Reported as mg per 25 mL sample.