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APPENDIX K
AQUATIC RESOURCES

GEI Consultants

Consulting Engineers and Scientists

2020 Aquatic Biological Monitoring of Streams in the Vicinity of the Wharf Mine

Lawrence County, South Dakota

April 2021

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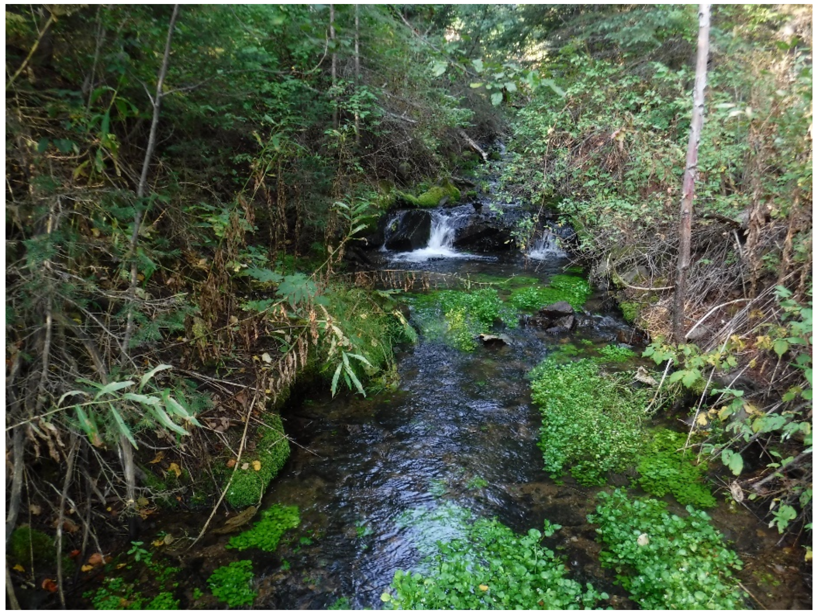

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1. Introduction

The purpose of this study is to monitor aquatic habitat, fish, benthic macroinvertebrates, and periphyton in streams near the Wharf Mine in the northern Black Hills of South Dakota (Figure 1-1). The Wharf Mine study area includes sites in Annie Creek, Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, McKinley Gulch, and Cleopatra Creek. The Golden Reward mine area includes sites in Fantail Creek, Nevada Gulch, and Stewart Gulch. This sampling is part of an annual monitoring of biological populations in these streams as they relate to current mining activities at Coeur Wharf, which includes the Golden Reward Mine, the Expansion Areas, and the Processing Facilities, as required in their National Pollutant Discharge Elimination System (NPDES) discharge permit. Current data are compared to corresponding reference sites, which are not affected by mining activities but may be influenced by historical and current human activities. Current data are also compared to data from previous years to evaluate possible relationships between the aquatic populations and mining activities.

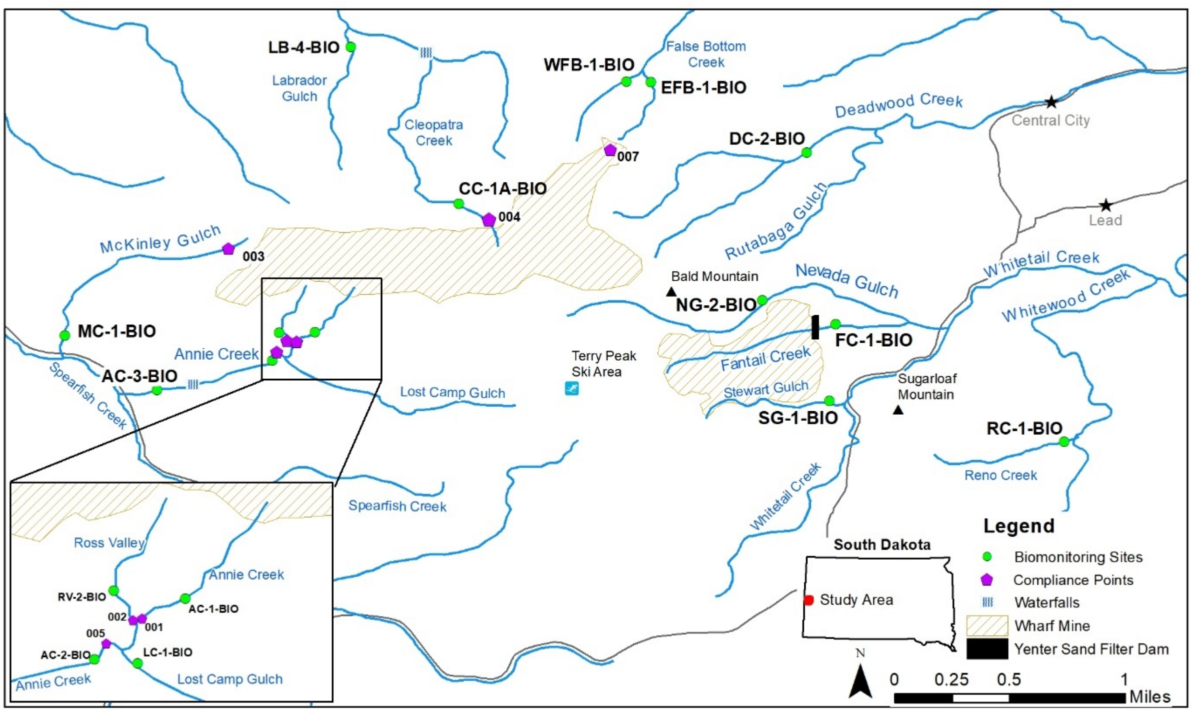

Figure 1-1: Aquatic biological monitoring sites on streams near the Wharf mine, Lead, South Dakota in August 2020.

This report presents results from the annual aquatic biological monitoring conducted in August 2020 by GEI Consultants, Inc. (GEI, formerly Chadwick Ecological Consultants, Inc. [CEC]), in Annie Creek, Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, McKinley Gulch, Cleopatra Creek, Fantail Creek, Nevada Gulch, Stewart Gulch, Reno Creek, and Labrador Gulch. Sites on Labrador Gulch and Reno Creek serve as reference sites for comparison to sites downgradient of mining activities. Biological parameters evaluated in these streams in August 2020 included fish, benthic macroinvertebrates, and periphyton populations. Aquatic habitat parameters were also measured and summarized.

1.1 Monitoring History

1.1.1 Labrador Gulch

Labrador Gulch was added to the Wharf Sampling and Analysis Plan (SAP) in 2018 and has been part of the Richmond Hill Mine's monitoring program since 1993. Labrador Gulch does not receive any mine discharge and has served as a reference site (with fish) for the Richmond Hill Mine. This stream has a cascading waterfall immediately upstream of the confluence with Cleopatra Creek that isolates the brook trout population from downstream populations. The fish habitat is relatively complex with a variety of small scour pools, low and high gradient riffles, runs, and cascading habitats that support the self-sustaining brook trout population. From 1995 to 2003, habitat and macroinvertebrate sampling occurred on an annual basis, including fish sampling in most years (Table 1-1). Since 2005, habitat, benthic macroinvertebrate, and periphyton monitoring occurred in all years, while fish populations were only monitored on a 3-year cycle until 2017 when sampling became annual.

1.1.2 Reno Creek

In 2017, a site on Reno Creek was added as a reference site for the project. Personnel from GEI, South Dakota Game, Fish, and Parks (SDGFP), and South Dakota Department of Environment and Natural Resources (SDDENR) collaborated on site selection and location. This site has no known influence from past historical mining activities or past human impacts within its drainage, although the Mickelson Trail and a water supply pipe for the town of Lead cross Reno Creek at two locations. The upper part of the watershed contains the Powder House Pass subdivision which is a large lot residential district with a permitted (SD0028615) onsite wastewater treatment system. A review of available discharge monitoring reports indicates limited numeric violations (2018 and 2019) of the total ammonia nitrogen permit limit, although each exceedance was resolved by post event compliance. There is evidence of past forest management activities (i.e., slash piles) by the United States Forest Service (USFS) in the area, and in July 2020, extensive treefall damage occurred during a storm event. As a result, the site was moved 21 meters (m) upstream from the original downstream boundary to avoid a deadfall tree. Wharf will continue to sample Site RC-1-BIO on a yearly basis (Table 1-1).

Table 1-1: Aquatic biological monitoring summary for sites on Labrador Gulch, Reno Creek, Annie Creek, Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, Cleopatra Creek, Fantail Creek, Nevada Gulch, Stewart Gulch, and Whitetail Creek from 1986 through 2020. Parameters: H = habitat, F = fish populations, B = benthic macroinvertebrate populations, and P = periphyton populations.

Date	Labrador Gulch Reference Site	Reno Creek Reference Site	Annie Creek			Ross Valley	Lost Camp Gulch	Deadwood Creek		False Bottom Creek		Cleopatra Creek	Fantail Creek	Upper Nevada Gulch	Nevada Gulch	Stewart Gulch	Whitetail Creek
	LB-4-BIO-BIO	RC-1-BIO	AC-1-BIO	AC-2-BIO	AC-3-BIO	RV-2-BIO	LC-1-BIO	DC-1-BIO	DC-2-BIO	EFB-1-BIO	WFB-1-BIO	CC-1A-BIO	FC-1-BIO	NG-1-BIO	NG-2-BIO	SG-1-BIO	--
1986	--	--	--	--	--	--	--	--	--	--	--	--	H, F, B, P	--	--	H, F, B, P	--
1987	--	--	--	--	--	--	--	--	--	--	--	--	B, P	H, F, B, P	H, F, B, P	B, P	H, F, B, P
1988	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1989	--	--	--	--	--	--	--	--	--	--	--	--	H, B, P	H, B, P	H, B, P	H, B, P	H, B, P
1990	--	--	H, B	H, F, B	--	--	--	--	--	--	--	--	--	--	--	--	--
1991	--	--	--	B, P	--	--	--	--	--	--	--	--	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
1992	--	--	F, B, P	F, B, P	H, F, B	--	--	--	--	--	--	--	B, P	B, P	B, P	B, P	B, P
1993	F	--	H, B, P	H, B, P	--	--	--	--	--	--	--	--	B, P	B, P	B, P	B, P	B, P
1994	F	--	B, P	B, P	--	--	--	--	--	--	--	--	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
1995	H, F, B	--	H, F, B, P	H, F, B, P	F, B	--	--	H, F, B, P	--	H, F, B, P	--	--	B, P	B, P	B, P	B, P	B, P
1996	H, F, B	--	B, P	B, P	--	--	--	H, F, B, P	--	H, F, B, P	--	--	B, P	B, P	B, P	B, P	B, P
1997	H, F, B	--	B, P	B, P	--	--	--	B, P	--	B, P	--	--	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
1998	H, F, B	--	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
1999	H, B	--	B, P	B, P	--	--	--	B, P	--	B, P	--	--	B, P	B, P	B, P	B, P	B, P
2000	H, F, B	--	H, B, P	H, B, P	H, B, P	--	--	Dry	H, B, P	H, B, P	--	--	B, P	B, P	B, P	B, P	B, P
2001	H, B	--	H, F, B, P	H, F, B, P	H, F, B, P	--	--	Dry	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
2002	H, F, B	--	H, F, B, P	H, F, B, P	H, F, B, P	--	--	Dry	H, F, B, P	H, F, B, P	--	--	B, P	B, P	B, P	B, P	B, P

Date	Labrador Gulch Reference Site	Reno Creek Reference Site	Annie Creek			Ross Valley	Lost Camp Gulch	Deadwood Creek		False Bottom Creek		Cleopatra Creek	Fantail Creek	Upper Nevada Gulch	Nevada Gulch	Stewart Gulch	Whitetail Creek
	LB-4-BIO-BIO	RC-1-BIO	AC-1-BIO	AC-2-BIO	AC-3-BIO	RV-2-BIO	LC-1-BIO	DC-1-BIO	DC-2-BIO	EFB-1-BIO	WFB-1-BIO	CC-1A-BIO	FC-1-BIO	NG-1-BIO	NG-2-BIO	SG-1-BIO	--
2003	H, B	--	H, F, B, P	H, F, B, P	H, F, B, P	--	--	Dry	H, F, B, P	H, F, B, P	--	--	B, P	B, P	B, P	B, P	B, P
2004	--	--	H, F, B, P	H, F, B, P	H, F, B, P	--	--	Dry	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
2005	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	--	--	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
2006	H, B, P	--	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	B, P	--	B, P	B, P	B, P
2007	H, B, P	--	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	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	H, F, B, P	--	Dry	--	--	H, F, B, P	H, F, B, P	H, F, B, P	--	H, F, B, P	H, F, B, P	H, F, B, P
2009	H, 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	B, P	--	B, P	B, P	B, P
2010	H, 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	--	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P	H, F, B, P
2011	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	H, F, B, P	--	H, F, B, P	H, F, B, P	H, F, B, P
2012	H, 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	H, F, B, P	--	H, F, B, P	H, F, B, P	H, F, B, P
2013	H, 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	H, F, B, P	--	H, F, B, P	H, F, B, P	H, F, B, P
2014	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	H, F, B, P	--	H, F, B, P	H, F, B, P	H, F, B, P
2015	H, 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	H, F, B, P	--	H, F, B, P	H, F, B, P	H, F, B, P
2016	H, 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	DRY	H, F, B, P	--	H, F, B, P	H, F, B, P	H, F, B, P
2017	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	DRY	H, F, B, P	--	H, F, B, P	H, F, B, P	H, F, B, P
2018	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	H, F, B, P	H, F, B, P	H, F, B, P	--	H, F, B, P	H, F, B, P	--
2019	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	H, F, B, P	DRY	H, F, B, P	--	H, F, B, P	H, F, B, P	--
2020	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	H, F, B, P	DRY	H, F, B, P	--	H, F, B, P	H, F, B, P	--

1.1.3 Annie Creek, Ross Valley, McKinley Gulch, and Lost Camp Gulch

Limited sampling began on Annie Creek in 1990 (Table 1-1). In 1992, habitat was measured, and fish and benthic macroinvertebrates were extensively sampled for the Annie Creek/Reliance Tailings Project (Chadwick & Associates, Inc. [C&A] 1993). This sampling provided data on the existing fish populations at six sites in Annie Creek. Brook Trout (*Salvelinus fontinalis*) and Brown Trout (*Salmo trutta*) were limited to the lower portion of Annie Creek, just upstream of the confluence with Spearfish Creek and downstream of the falls on Annie Creek (Figure 1-1). The continued absence of trout in the upper portion is due to the falls, which act as a barrier to upstream fish movement.

Historically, a population of Mountain Suckers (*Catostomus platyrhynchus*) was found in Annie Creek at monitoring Site AC-2-BIO. In 1990 and 1992, Mountain Suckers were abundant at Site AC-2-BIO, with multiple age classes inhabiting the stream. In 1990 and 1992, 380 and 127 Mountain Suckers were collected, respectively (C&A 1993). Density estimates during these years were over 15,000 fish per hectare (C&A 1993). A few individuals were also found in Annie Creek above the confluence with Lost Camp Gulch and in the vicinity of the confluence with Ross Valley, but none were found further upstream at Site AC-1-BIO or within Lost Camp Gulch (C&A 1993). Electrofishing at two locations on Annie Creek further downstream of Site AC-2-BIO also found abundant Mountain Suckers, with high numbers collected in the pool immediately below the culvert that passes under Annie Creek Road as well as the pool below Annie Creek Falls (C&A 1993, CEC 2001). In 1995, habitat measurements indicated that a 100-year flood event had altered Annie Creek by increasing channel widths and causing erosion of the banks (CEC 1996b).

In 1995, an ammonia and cyanide release occurred via Ross Valley into Annie Creek, and Mountain Sucker and macroinvertebrate numbers were reduced (CEC 1996a; 1996b). Only 3 live Mountain Suckers (density estimate: 102 Mountain Suckers per ha) were collected in Site AC-2-BIO, and 68 dead Mountain Suckers were observed (CEC 1996a; 1996b). Complete details of the effects of this event and sampling for recovery patterns were presented previously (CEC 1996c). Macroinvertebrate monitoring from 1996 through 2001 indicated that the benthic community had recovered from the 1995 release (CEC 1997a, 1998a, 1999a, 2000a, 2001a, and 2002a). However, no Mountain Suckers were found during the 1998 and 1999 surveys, indicating that populations had still not recovered from the ammonia and cyanide release in 1995 (CEC 2001). Elevated ammonia levels were also recorded in February 2002 and April 2004. From 2001 to 2006, density estimates at Site AC-2-BIO ranged from 818 Mountain Suckers per hectare to 500 Mountain Suckers per hectare, with a small population persisting within the site (CEC 2002, 2003, 2004, 2005, 2006, 2007). During these years, annual electrofishing surveys found from 8 to 18 Mountain Suckers within Site AC-2-BIO.

High biological oxygen demand (BOD) water that exceeded standards was inadvertently released into upper Annie Creek in 2007 by Wharf Resources, Inc. In addition, ammonia and cyanide standards were exceeded downstream of mining activities in Annie Creek in 2007 (GEI 2008b). Biomass accumulations were observed during annual monitoring on Annie Creek in August 2007 by GEI personnel (GEI 2008a). Biomass accumulations on the stream bottom were also observed by SDDENR personnel during a site inspection on November 27, 2007. Benthic invertebrate communities in middle and upper Annie Creek appeared stressed in August 2007, typical of communities tolerant of low dissolved oxygen (GEI 2008a). Furthermore, no Mountain Suckers were collected from Site AC-2-BIO, where a population had existed in past years (GEI 2008a). On April 8, 2008 Wharf Resources, Inc received a violation of their mining permit from SDDENR.

As a result of the absence of Mountain Suckers in August 2007 and the failure to meet water quality permit limits, Wharf Resources, Inc. was ordered to clean up the biomass accumulations by August 1, 2008 in an amended order for the violations of the surface water discharge and mining permit (GEI 2008b). The clean-up effort was conducted on July 15 and 16, 2008 and supervised by GEI personnel. The clean-up process included the use of a vacuum truck to collect the biomass and affected sediments from the surface of the riparian areas and the streambed in Annie Creek.

Sampling of aquatic biological populations in 2008 was conducted in June, prior to clean-up activities, and in August, after clean-up activities. Overall, annual monitoring data collected in August 2008 indicated that Site AC-1-BIO was not fully recovered from the release of high BOD water into Annie Creek, while Site AC-2-BIO appeared largely recovered when compared to data from August 2007. Four Mountain Suckers were collected during June 2008, and two were collected in August 2008, with a density estimates of 182 and 71 Mountain Suckers per hectare at Site AC-2-BIO during these two surveys, respectively. During the August 2009 survey, no Mountain Suckers were collected (GEI 2010). One Mountain Sucker was collected during the 2010 survey (GEI 2011), and since 2011, no Mountain Suckers have been observed in the upper portion of Annie Creek or its tributaries (GEI 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, and 2020). During the water quality upset in upper Annie Creek, Site AC-3-BIO appeared healthy in 2008, similar to 2007 conditions. Continued monitoring has shown improvement in the aquatic habitat and benthic macroinvertebrate conditions at sites AC-1-BIO and AC-2-BIO since 2007.

Data were collected on Annie Creek by C&A in 1993 and 1994, by CEC in 1995 through 2005, and by GEI in 2006 through 2020. Sampling has usually been conducted in late August or early September. Benthic macroinvertebrate and periphyton data have been collected nearly every year and habitat and fish population data were collected every two to three years from 1990 through 2000 based on SDGFP wildlife monitoring guidelines. Habitat measurements and fish, benthic macroinvertebrate, and periphyton populations were sampled at Annie Creek sites from 2001 to 2020. At Site AC-1-BIO, data have been collected in every year since 1990 except for 1991 (Mariah Associates, Inc. 1990, 1992a, 1992b; C&A 1993, 1994a, 1995a; CEC 1996b, 1997a, 1998a, 1999a, 2000a, 2001a, 2002a, 2003a, 2004a, 2005a

2006a; GEI 2007a, 2008a, 2009a, 2010a, 2011a, 2012, 2013, 2014, 2015, 2016, 2017a, 2018a, 2019, 2020). In terms of data continuity, Site AC-2-BIO and Site AC-2, established in 1990 and sampled through 1999, are considered the same site due to their proximity. When data are combined for these two sites, this reach of Annie Creek has been sampled every year since 1990. Site AC-3-BIO was not sampled as part of the monitoring study prior to 2000. However, at this site (formerly Site AC-6), habitat measurements, and fish and benthic invertebrates were sampled as part of another study in June and October 1992 (C&A 1993) and data are used for comparison with Site AC-3-BIO. Additionally, fish and benthic macroinvertebrates were sampled in 1995 at this site as part of the investigation to determine the effects of an accidental ammonia and cyanide release into Annie Creek in that year and are used as long-term comparison data. In 2020, Site AC-3-BIO was not accessible for routine sampling due to the extensive tree falls caused by the July 8, 2020 tornado activity.

Both Ross Valley and McKinley Gulch were included in the Wharf monitoring program in 2006 to address the monitoring needs downstream of their existing compliance points (006B and 003, respectively) in the headwater portion of each sub-basin. Ross Valley has maintained perennial flowing waters since 2006, although no routine discharge occurs from the lined storage basin upstream of Compliance Point 006B. Historically, two sampling locations were established in this drainage in April 2004 in response to the release of ammonia (CEC 2005a). Site RV-1-BIO is in the headwaters and upstream of the current monitoring site and is no longer monitored while Site RV-2-BIO is currently monitored. Site RV-2-BIO has been sampled for fish, benthic invertebrates, periphyton, and habitat every year since 2006 (Table 1-1).

Lost Camp Gulch was included in the Wharf monitoring program in 2010 (Table 1-1), as part of the supplementary sampling necessary for the potential mine expansion. Specifically, this site was used to establish baseline aquatic resource conditions in a basin before mine expansion occurred, per the requirements of the SDDENR. The headwaters are located near Terry Peak, and there is a residential sub-division located in a sub-basin that drains into Lost Camp Gulch. In the past, the Lost Camp Gulch sub-basin receives heavy recreational ATV traffic, and the trail adjacent to the stream influences sediment conditions in both Lost Camp Gulch and Annie Creek, although recent forest management efforts by the USFS have limited access to the Annie Creek Basin. Habitat measurements and fish, benthic macroinvertebrate, and periphyton populations have been sampled at the Lost Camp Gulch site from 2010 to 2020.

The McKinley Gulch site has never been formally established but the channel is visited each year at the culvert crossing on Highway 14 to determine the presence of flowing water. Similarly, the compliance point in McKinley Gulch is located immediately downgradient of a lined storage pond which has no direct discharge to the channel. However, in extremely wet years both storage ponds receive surface water runoff that may exceed the holding capacity of the pond, allowing surface water and contaminants to flow downgradient in the channel.

1.1.4 Deadwood Creek and False Bottom Creek

In 1995, Wharf Resources initiated a baseline aquatic biological monitoring study for upper Deadwood Creek and False Bottom Creek in anticipation of a possible mine expansion (CEC 1996a). This study evaluated the existing status of aquatic habitat, fish, benthic macroinvertebrate, and periphyton populations in these streams. The Wharf Resources expansion was approved in June 1998. The Expansion Area is located on the east side of Foley Ridge and is west and southwest of the Deadwood and False Bottom drainages (Figure 1-1). Development of the Portland pit began in March 1999, and development of the Trojan pit began in 2000.

Data collected in 1995 (Site DC-1-BIO) indicated that aquatic habitat in upper Deadwood Creek was very limited due to low, interrupted flows (Table 1-1; CEC 1996a). No fish were found in this upper section of the stream, but benthic macroinvertebrate communities appeared healthy and included species considered sensitive to pollutants. Periphyton communities were similar to those found in other streams in the area. Results from additional baseline sampling from 1996 through 2001 also indicated limited aquatic habitat and no fish, but healthy benthic macroinvertebrate and periphyton populations. The original site on upper Deadwood Creek was dry most years since 2000, but a small amount of water was present in August 2009 and 2010. An additional site (Site DC-2-BIO) further downstream was added in 2000 to provide a site with perennial flow and fish populations (CEC 1997b, 1998c, 1999c, 2000a, 2001a, 2002a, 2003a, 2004a, 2005a, and 2006a). This additional site was sampled from 2000 through 2005 but was discontinued from the monitoring plan from 2006 to 2009 because sampling of the benthic macroinvertebrate and periphyton populations still occurred further upstream on Deadwood Creek when practicable. Monitoring habitat, and fish, benthic macroinvertebrates, and periphyton populations began again at Site DC-2-BIO in 2010 as part of the Wharf expansion permit. Monitoring at this site has continued on a yearly basis given the perennial flow which supports a resident Brook Trout population.

In 1995, two sites were sampled on False Bottom Creek. One was located upstream of the confluence on East Fork False Bottom Creek (formerly FB-1; currently EFB-1-BIO), and one was located immediately downstream of the confluence with West Fork False Bottom Creek (historical Site FB-2). Aquatic habitat in 1995 at two sites on False Bottom Creek was suitable to support fish, and healthy populations of Brook Trout were found at both study sites. Benthic macroinvertebrate and periphyton populations were also healthy in False Bottom Creek in 1995 (CEC 1996a). Additional sampling from 1996 through 2000 provided similar conclusions (CEC 1997b, 1998c, 1999c, 2000a, and 2001a). Sampling was reduced to one site on the East Fork False Bottom Creek (FB-1-BIO) in 2000 because of the similarity between the two sites (CEC 2002a, 2003a).

In August 2017, during a site visit to False Bottom Creek, SDGFP raised the issue that the current biological monitoring location was not in the original location as established in 1995. In 2017 a new rebar sign was posted on the West Fork identifying the water quality monitoring location as Site FB-2, which caused further confusion. In recent years, the biological monitoring occurred on the West Fork which is not consistent with past Site FB-1-BIO conditions.

These observations precipitated a Root Cause Analysis (RCA) to identify the root causes of the event or decision-making process that resulted in this error and to develop corrective actions. Wharf and GEI personnel concluded that Site FB-1-BIO was relocated to the West Fork rather than the East Fork and developed corrective actions. The factors contributing to the changes in site location in each year are discussed in detail in a memo written by GEI (2018a). In summary, East Fork False Bottom Creek (EFB) was sampled in 2000 through 2006, 2009, and 2010, while West Fork False Bottom Creek (WFB) was sampled in 2007, 2008, and 2011 through 2017. Both sites have been sampled since 2018.

1.1.5 Cleopatra Creek

Sampling on Cleopatra Creek began in 1985. In 1991, as per an agreement between LAC Minerals, Wharf Resources, and SDGFP, LAC Minerals and Wharf Resources shared an aquatic sampling location, designated Site CC-1. Previous designations for this site have been SQ-1 (Knudson 2003) and SQ-1-BIO (CEC 2000c). Sampling on this stream had previously been conducted by OEA Research, Inc. and KNK Aquatic Ecology (Knudson 2003). In 2006, the Wharf monitoring site on Cleopatra Creek was moved upstream of its former location to the headwaters of Cleopatra Creek (Figure 1-1) between Monitoring Well 41 and Compliance Point 004 and designated as Site CC-1A-BIO (GEI 2007a). When sufficient surface water present, the 2006 through 2015 and 2018 monitoring results are used to evaluate the status of the aquatic biological populations in Cleopatra Creek in relation to ongoing mine operations (Table 1-1; GEI 2007a, 2008a, 2009a, 2010a, 2011a, 2012, 2013, 2014, 2015, 2016, 2017a, 2018a, 2019, 2020). However, Cleopatra Creek was dry in four out of the last five years which has limited the suitability of Site CC-1A-BIO as a biomonitoring site (GEI 2017a, 2018a, 2020).

1.1.6 Fantail Creek, Nevada Gulch, and Stewart Gulch

Sampling of these streams is a continuation of a long-term aquatic biological monitoring program that was initiated in 1986 to collect baseline data on the aquatic resources of Fantail Creek and Stewart Gulch prior to establishment of the Golden Reward gold mine, in compliance with South Dakota Mined Land Reclamation Regulations (Golden Reward Mining Company [GRMC] 1987). Nevada Gulch was added to the scope of the monitoring program in 1987. 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 final reclamation and reclaimed approximately 189 acres from April through November 2002. All but 5.23 acres of the total area of disturbed land (approximately 403 acres) has been reclaimed since 2002. 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.

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. Streams were then surveyed semiregularly from 1989 to 2010 and annually through 2020 (Table 1-1; GRMC 1990, 1992, 1993; Chadwick & Associates, Inc. 1994b, 1995b; Chadwick Ecological Consultants, Inc. 1996d, 1997c, 1998b, 1999b, 2000b, 2001b, 2002b, 2003b, 2004b, 2005b, and 2006b; GEI 2007b, 2008c, 2009b, 2010b, 2011b, 2012, 2013, 2014, 2015, 2016, 2017a, 2018a, 2019, 2020). This schedule was revised in 1998 to synchronize sampling with the schedule for the Wharf Mine. Sampling followed the activities and methods outlined in the most recent Sampling and Analysis Plan (GEI 2018b).

The historical study site on Fantail Creek was near the confluence with Nevada Gulch, approximately 1.0 km downstream of the Yenter Sand Filter Dam. Construction of the filter dam began in 2002 due to sedimentation concerns from the reclaimed mine site, GRMC installed a sand filter dam in Fantail Creek. Rock was added to the face of the dam in August 2003 to increase the area of sediment filtration (Kim Schultz, personal communication). 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 filter dam outfall. In 2008, the Gilded Mountain Road was constructed over Fantail Creek in the study reach, approximately 70 m downstream from the top of the site. The site was moved downstream of the road crossing with the top of the site just downstream of the road culvert.

The study site on Nevada Gulch (Lower Nevada Gulch) replaced a site further upstream (Upper Nevada Gulch) and served as the background control site from 2006 through 2016 (CEC 2006d). The site runs directly alongside the paved Nevada Gulch Road. From 2017 to 2020, the Lower Nevada Gulch site (Site NG-2-BIO) was sampled but is no longer considered a background control site due to mining activities occurring upstream in the watershed.

The Stewart Gulch site is located near the confluence with Whitetail Creek downstream of Reno Creek, Nevada Gulch, and Fantail Creek. The site is near Highway 14 and contains historic flow control structures and a modern stream gage. A large portion of the flow in Stewart Gulch comes from an adit located in abandoned mine workings in Whitetail Creek.

2. Study Area

Currently, there are fifteen monitoring sites in the Wharf study area (Table 2-1). Other monitoring sites have existed but were either moved or are no longer included in the monitoring program. All sites in the Wharf Mine area are located in Black Hills Core Highlands of the Middle Rockies Ecoregion (Omernik 1987; Omernik and Gallant 1987).

Table 2-1: GPS coordinates for Wharf sites.

Stream/Site	Latitude and longitude	Elevation (m)
Reference Sites		
Labrador Gulch, LB-4-BIO	44°22.523’ -103°51.893’	1,683
Reno Creek, RC-1-BIO	44°19.267’ -103°46.264’	1,647
Mining Activity Sites		
Annie Creek, Site AC-1-BIO	44°20.245' -103°52.058'	1,762
Annie Creek, Site AC-2-BIO	44°19.951' -103°52.420'	1,691
Annie Creek, Site AC-3-BIO	44°19.642' -103°53.628'	1,576
Ross Valley, Site RV-2-BIO	44°20.088' -103°52.380'	1,730
Lost Camp Gulch, Site LC-1-BIO	44°19.921' -103°52.381'	1,698
Deadwood Creek, Site DC-2-BIO	44º21.587' -103º48.258'	1,623
East Fork False Bottom Creek, Site EFB-1-BIO	44°22.207' -103°49.558'	1,673
West Fork False Bottom Creek, Site WFB-1-BIO	44°22.205' -103°49.574'	1,677
McKinley Gulch, MG-1-BIO	Not established, approx. 44°20.073' -103°54.162	1,593
Cleopatra Creek, Site CC-1A-BIO	44°21.161' -103°51.106'	1,808
Fantail Creek, FC-1-BIO	44°20.205' -103°48.028'	1,684
Nevada Gulch, NG-2-BIO	44°20.432' -103°48.564'	1,726
Stewart Gulch, SG-1-BIO	44°19.576' -103°47.984'	1,695

2.1 Reference Sites

The Wharf Mine is located in the headwaters of many drainages, therefore, all monitoring sites for this project are located downgradient of mining activities. As a result, it is not possible to establish upstream reference or control sites to evaluate possible impacts from mining activities. In 2017, the sites on Whitetail Creek and Nevada Gulch were discontinued as background control sites for aquatic life use assessment and two new reference site locations were established on Labrador Gulch and Reno Creek with the assistance from SDGFP and SDDENR. These sites are located in adjacent drainage basins and are intended to be used as a tool to evaluate whether patterns in the data downstream of the mining areas reveal similar patterns to the reference sites. These reference sites should also help tease out the effects of regional climatic conditions from other patterns in the data downgradient of the Wharf's influence.

2.1.1 Labrador Gulch

The headwaters of Labrador Gulch are located approximately 8.7 kilometers (km) west of Lead, South Dakota, and flow northeast into Cleopatra Creek downstream of Site CC-1A-BIO. Labrador Gulch contains a resident trout population for comparison to larger streams that contain fish populations (lower Annie Creek, Deadwood Creek, False Bottom Creek, and Stewart Gulch). Labrador Gulch is not currently classified in the administrative rules, although the reach of Cleopatra Creek that it enters is classified with the standard beneficial uses and coldwater permanent fish life propagation water, immersion recreation water, and limited contact recreation waters (SDDENR 2015, Administrative Rules, Chapter 74:51:03:10).

Site LB-4-BIO: This site corresponds to Richmond Hill Mine designation LB-4, although the acronym BIO has been added for consistency with naming conventions used for the Wharf Mine. The bottom of the site is located approximately 25 m upstream from the confluence with Cleopatra Creek, above a small cascade that is a barrier to upstream movement by fish, at an elevation of 1,683 m above sea level.

2.1.2 Reno Creek

Reno Creek is located 3.3 km south of Lead, South Dakota and is used for comparison with the smaller (narrower) streams that do not typically support fish populations (upper Annie Creek, Ross Valley, Lost Camp Gulch, McKinley Gulch, Cleopatra Creek, and Fantail Creek sites). This site serves as a baseline representation of relatively non-impacted conditions for a small, headwater stream in the Black Hills. Reno Creek is a tributary to Whitewood Creek and is classified with the standard beneficial uses and coldwater permanent fish life propagation water, immersion recreation water, and limited contact recreation waters (SDDENR 2015, Administrative Rules, Chapter 74:51:03:10).

Site RC-1-BIO: This site is located approximately 170 m upstream of the confluence with Whitewood Creek, at an elevation of 1,647 m above sea level.

2.2 Mining Activity Sites

2.2.1 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. As part of the annual biological monitoring activities in 2020, three study sites on Annie Creek were sampled (Figure 1-1,

Table 1-1). The study sites were renamed in 2000 with site names corresponding to the Aquatic Biological Monitoring Plan (CEC 2000c), as was required by the renewal of the Wharf Resources Surface Water Discharge Permit in 1999. The study sites and corresponding site names from previous monitoring efforts are described below.

Site AC-1-BIO: This site is located near the headwaters of Annie Creek, at an elevation of 1,762 m above sea level, approximately 0.5 km upstream of Ross Valley and 0.7 km upstream from Lost Camp Gulch. Site AC-1-BIO is downstream of Outfall 006A and upstream of Compliance Points 001 and 005.

Site AC-2-BIO: This site corresponds to Site AC-4, historically, and is located approximately 0.4 km downstream of Ross Valley, at an elevation of 1,691 m above sea level, just downstream of the confluence with Lost Camp Gulch and upstream of the falls. Site AC-2-BIO is approximately 0.5 km downstream of the original monitoring Site AC-2. This site is downstream of Outfall 006A, Outfall 006B, and Compliance Point 001. This site is upstream of Compliance Point 005.

Site AC-3-BIO: This site corresponds to the historical Site AC-6 and is located approximately 0.2 km upstream of the confluence with Spearfish Creek at an elevation of 1,576 m above sea level. This site is downstream of the falls and provides information on the lower reach of Annie Creek. This site is downstream of Outfalls 006A and 006B and Compliance Points 001 and 005.

The upper portion of Annie Creek, including the reaches where sites AC-1-BIO and AC-2-BIO are located, is classified with the standard beneficial uses that are applied to all streams by the SDDENR. These uses are irrigation, fish and wildlife propagation, recreation, and stock watering (SDDENR 2015, Administrative Rules, Chapter 74:51:03:01). Lower Annie Creek from the confluence with Spearfish Creek upstream to Township 4N, Range 2E, Section 3 (T4N, R2E, S3), which includes Site AC-3-BIO, has two additional beneficial uses: coldwater marginal fish life propagation waters and limited-contact recreation waters (SDDENR 2015, Administrative Rules, Chapter 74:51:03:10).

2.2.2 Ross Valley

The headwaters of Ross Valley are located approximately 7.7 km west of Lead, South Dakota (Figure 1-1), at an elevation of 1,805 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 between sites AC-1-BIO and AC-2-BIO. Ross Valley Creek is classified with the standard beneficial uses that are applied to all streams by the SDDENR. These uses are irrigation, fish and wildlife propagation, recreation, and stock watering (SDDENR 2015, Administrative Rules, Chapter 74:51:03:01).

Site RV-2-BIO: This site is downstream of Site RV-1-BIO and near the mouth of Ross Valley, approximately 200 m upstream of the confluence with Annie Creek. It is located downstream of Outfall 006B and just upstream of Compliance Point 002 at an elevation of 1,740 m.

2.2.3 Lost Camp Gulch

The headwaters of Lost Camp Gulch are located approximately 7 km west of Lead, South Dakota (Figure 1-1), 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 just downstream of the Ross Valley confluence. Lost Camp Gulch is classified with the standard beneficial uses that are applied to all streams by the SDDENR. These uses are irrigation, fish and wildlife propagation, recreation, and stock watering (SDDENR 2015, Administrative Rules, Chapter 74:51:03:01).

Site LC-1-BIO: This site is located about 200 m upstream of the confluence with Annie Creek at an elevation of 1,694 m.

2.2.4 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 1-1). Near its headwaters, Deadwood Creek has a dense canopy cover with extensive woody debris and abundant riparian vegetation. Downstream of this area, the stream channel and vegetative canopy widen slightly, making the stream more accessible. Deadwood Creek in this upper section has the standard beneficial uses as designated by SDDENR for irrigation, fish and wildlife propagation, recreation, and stock watering. Lower Deadwood Creek from the confluence with Whitewood Creek up to Township 5N, Range 3E, Section 30 (T5N, R3E, S30) is additionally classified as coldwater marginal fish life propagation waters, immersion recreation waters, and limited-contact recreation waters (SDDENR 2015, Administrative Rules, Chapter 74:51:03:10).

Site DC-2-BIO: This site is approximately 300 m downstream of the confluence of the North and South forks of Deadwood Creek and downstream of Site DC-1-BIO at an elevation of 1,624 m.

2.2.5 False Bottom Creek

The headwaters of False Bottom Creek are located 5.3 km northwest of Lead (Figure 1-1), at an elevation of 1,673 m above sea level. False Bottom Creek flows north, joining 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. False Bottom Creek is classified with the standard beneficial uses and additionally as coldwater marginal fish life propagation water and limited-contact recreation waters in the study area (SDDENR 2015, Administrative Rules, Chapter 74:51:03:10).

Site EFB-1-BIO: This site is located just upstream of the confluence with West Fork False Bottom Creek at an elevation of 1,672 m, approximately 1 km downstream from its headwaters. Site EFB-1-BIO corresponds to water quality monitoring Site FB-1.

Site WFB-1-BIO: This site is also located just upstream of the confluence with the East Fork False Bottom Creek at an elevation of 1,669 m, approximately 1 km downstream from its headwaters. Site WFB-1-BIO corresponds to water quality monitoring Site FB-2.

2.2.6 McKinley Gulch

The headwaters of McKinley Gulch are located approximately 8.5 km west of Lead, South Dakota at an elevation of approximately 1,558 m. McKinley Gulch is a small, ephemeral stream that flows into Spearfish Creek approximately 0.8 km downstream of the inflow from Annie Creek (Figure 1-1). McKinley Gulch was dry in 2020, as it has been historically, and the exact location of Site MG-1-BIO has not been established. McKinley Gulch is not currently classified in the administrative rules, although the reach of Spearfish Creek that it enters is classified with the standard beneficial uses and coldwater permanent fish life propagation water, immersion recreation water, and limited contact recreation water (SDDENR 2015, Administrative Rules, Chapter 74:51:03:10).

2.2.7 Cleopatra Creek

Cleopatra Creek is a tributary to Spearfish Creek, with headwaters located approximately 8.0 km west of Lead, South Dakota. Cleopatra Creek is a tributary to Spearfish Creek with its confluence at the community of Maurice (Figure 1-1). The headwaters of Cleopatra Creek are located in the vicinity of mining operations by Wharf and flows near the LAC Minerals Richmond Hill Mine. Cleopatra Creek is classified with the standard beneficial uses and with coldwater permanent fish life propagation water, immersion recreation water, and limited contact recreation waters (SDDENR 2015, Administrative Rules, Chapter 74:51:03:10).

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. It is located at an elevation of 1,808 m above sea level. The previous location of Site CC-1-BIO was downstream of Compliance Point 004 between the East Fork and Labrador Gulch.

2.2.8 Fantail Creek

The headwaters of Fantail Creek are located approximately 4.9 km from Lead, South Dakota (Figure 1-1). 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. 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 Golden Reward Mine 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). Fantail Creek is classified with the standard beneficial uses and with coldwater permanent fish life propagation water, immersion recreation water, and limited contact recreation waters (SDDENR 2015, Administrative Rules, Chapter 74:51:03:10).

Site FC-1-BIO: The Fantail Creek site is located immediately downstream of the intersection between Fantail Creek Road and Gilded Mountain Road, at an elevation of 1,684 m above sea level.

2.2.9 Nevada Gulch

The headwaters of Nevada Gulch are approximately 5.3 km from Lead, South Dakota (Figure 1-1). Nevada Gulch flows east from its headwaters on the northeast slopes of Terry Peak to its confluence with Whitetail Creek. The drainage is in a narrow valley that contains a paved state road and several private residences. Nevada Gulch is classified with the standard beneficial uses and coldwater marginal fish life propagation water and limited contact recreation waters (SDDENR 2015, Administrative Rules, Chapter 74:51:03:10).

Site NG-2-BIO: This site is located 2.0 km west of the intersection between Highway 85 and Nevada Gulch Road, at an elevation of 1,726 m above sea level. This site served as a background control until 2017.

2.2.10 Stewart Gulch

The headwaters of Stewart Gulch are located approximately 4.7 km from Lead, South Dakota. Stewart Gulch is located south of the mine and flows due east for approximately 1.5 km before joining Whitetail Creek (Figure 1-1). 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. Stewart Gulch is classified with the standard beneficial uses and coldwater permanent fish life propagation water and limited contact recreation waters (SDDENR 2015, Administration Rules, Chapter 74:51:03:10).

Site SG-1-BIO: This is located approximately 9 m upstream of the confluence with Whitetail Creek near monitoring well PW02 and extends upstream approximately 100 m, just downstream of the groundwater seep. The site is located at an elevation of 1,695 m above sea level.

3. Methods

3.1 Habitat Assessment

Physical habitat data were collected in August 2020 at the biological monitoring sites using a standard method that has been consistently used by GEI Consultants, Inc. (GEI) for this region and includes a subset of metrics from the U.S. Forest Service, as described by Platts et al. (1983) and Overton et al. (1997).

Once the downstream site boundary was identified (transect one), transects were established every 10 m to achieve the 11 total transacts for each study site. The section of stream sampled was chosen to be representative of the habitat present in that stream reach in terms of pool to riffle ratio, shading, streamside vegetation, bank stability, etc. The upstream and downstream boundaries were often located at physical habitat features that restricted fish movement. In-stream habitat units (e.g., riffle, run, pool, etc.) were identified, working from the downstream end to the upstream end of each monitoring site. Measurements for the following metrics were made within each habitat unit over the entire site length of approximately 100 meters:

1. **Channel Width** – measurement of surface water width plus width of left and right banks collected at each transect.
2. **Water Width** – measurement of the surface water width collected at each transect within the habitat unit.
3. **Water Depth** – measurement of water depth collected at 25, 50, and 75% of the water width along each transect.
4. **Maximum Water Depth** – measurement collected at the deepest point in each habitat unit.
5. **Water Velocity** – measurements collected 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, and the mean value is reported.
7. **Eroding Streambank** – length of eroding streambank along each bank for entire length of habitat unit.
8. **Streambank Vegetation** – describes dominant streambank vegetation at the transect.
9. **Streambank Cover** – visual estimate of percentage of streambank covered by different vegetation types, along entire length of habitat unit.

10. **Streambank Stability** – rating of whether streambank is stable or exhibits erosional or depositional characteristics at the transect; where a rating of 1 represents stable bank, 2 represents cut/sloughing bank, or 3 represents a depositional bank.
11. **Streambank Angle** – rating of whether streambank is sloping, vertical, or undercut at the transect, where a rating of 1 represents an undercut bank, 2 represents a sloping bank, or 3 represents a vertical bank.
12. **Streambank Undercut** – depth of undercut bank for each bank at the transect. Values expressed in this report represent the mean undercut streambank for the entire reach.
13. **Vegetation Overhang** – measurement of vegetation overhanging water column providing fish cover at each transect. Values expressed in this report represent the mean overhanging vegetation for the entire site length.
14. **Substrate Composition** – estimate of the percentage of the stream bottom covered by bedrock and boulder (> 304 millimeter [mm]), rubble (76 - 304 mm), gravel (4.8 - 75 mm), coarse sediment (0.8 - 4.8 mm), or fine sediment (≤ 0.8 mm) within each habitat unit.

Additionally, water depths and velocities were measured at one transect at each study site using an OTT MF Pro flow meter to allow calculation of discharge. Lastly, precipitation data from GHCND:USC00394834 in nearby Lead, SD (NOAA 2020) was downloaded to evaluate wet-dry year type conditions since the Annie Creek stream gage was decommissioned in 2018.

Select habitat metrics are reported in the Results section. Total length and percent eroding bank are calculated as the sums of all units within the respective habitat types, average water width and depth are calculated as the averages of all units within the respective habitat types, and average maximum depth is calculated as the average of the maximum depths within each unit of a habitat type.

3.2 Fish Populations

Fish populations were quantitatively sampled (consistent with SDGFP guidelines) by electrofishing at all monitoring sites that contained flowing water in August 2020 to determine presence/absence, species composition, density, biomass, size structure, and condition (i.e., body "plumpness," as an indicator of overall health) of the fish assemblage. Sampling consisted of making at least three passes through the representative stream section (approximately 100 m reaches) using a Smith-Root LSR4 electrofishing backpack set to approximately 150 volts and 18 percent duty cycle. If an adequate proportion of the total number of fish sampled were collected on the first and second passes, three passes were typically adequate. If not, a fourth pass was performed to provide a more accurate estimate of the total fish population within the site. If no fish were collected during the first pass, no more passes were conducted, and fish were considered absent from the reach. When physical habitat features did not limit fish movement, the upper and lower boundaries at each site were blocked with nets to reduce fish immigration or emigration during sampling.

Fish captured during each pass were retained separately to allow for estimates of population density. All fish were identified by species, counted, measured for total length (mm), weighed (gram, g), and released. Any obvious injuries, deformities, or signs of disease were noted in the comments section of the data sheet. Population density was estimated by using a maximum likelihood estimator and the MicroFish program developed for the U.S. Forest Service (Van Deventer and Platts 1983, 1986). These sampling procedures provided species lists and estimates of density (number per hectare, #/ha) and biomass (kilogram per hectare, kg/ha). In addition, length-frequency data were used to analyze the size structure of the fish populations to determine whether recruitment likely occurred from natural reproduction within or near the reach, or by immigration from populations outside of the reach (Everhart and Youngs 1981; Anderson and Neumann 1996).

The fish population at Site AC-3-BIO was not sampled in 2020 due to extensive deadfall covering the stream caused by the July 2020 tornado activity. As a result, no fish could be collected for whole-body tissue selenium analysis which routinely occurs at this site.

3.2.1 Metric Calculations

The condition of trout was evaluated using the relative weight index (W_r) (Anderson and Neumann 1996; Neuman et al. 2012) as well as Fulton's condition factor (K) (Anderson and Neumann 1996, Neumann et al. 2012). Values for these indices were compared among sites to evaluate the health of the fish and to identify potential environmental stressors that may be affecting the populations. To determine relative weight, measured fish weights were compared to length-specific standard weights constructed to represent the species. Relative weight values were only calculated for Brook Trout greater than 120 mm and Brown Trout greater than 140 mm. Expected values of the relative weight index have the same general range across species. Relative weight values generally fall between 70 and 130 (Murphy and Willis 1991). Relative weight values between 95 and 105 are the optimal management target range for most species. Relative weights below 95 represent fish below the optimum weight (i.e., underweight) and relative weights above 105 represent those above the optimum weight (i.e., overweight; Anderson 1980; Anderson and Neumann 1996). Low relative weights can indicate a lack of suitable prey or other stressors that may have a negative influence on fish health, while high relative weights may indicate an overabundance of prey in proportion to predators.

Additionally, Fulton's condition factor was calculated to further evaluate fish health among sites. This metric does not have a minimum size requirement for individuals to be included in the calculation. In fish populations dominated by smaller, first year age class fish, as is often the case at the Wharf sites, a much greater proportion of the population can be included in the calculation of Fulton's condition factor than can be in the calculation of the relative weight index. Thus, Fulton's condition factor may better evaluate the overall health of some fish populations, despite the associated limitations. Fulton's condition factor is not standardized to allow comparisons among different species of fish, or between populations with greatly different size structures. The condition factor of many trout populations in the western United States (US) averages approximately 1.00 (Carlander 1969), so a condition value at or near 1.00 is considered desirable and indicative of a healthy population.

Further analysis of fish populations across all sites was conducted using quartile analysis that examines 2020 density and biomass at each site compared to the 1990-2019 density and biomass values categorized by quartiles: Q1 = minimum value to 25^{th} centile, Q2 = $25\text{-}50^{th}$ centile, Q3 = $50\text{-}75^{th}$ centile, and Q4 = 75^{th} centile to maximum value. Fish population quartiles were split into fish less than 150 mm and fish greater than or equal to 150 mm, which roughly corresponds to a lower threshold for the second year age class or greater (zero-year age class are fish in the first year of life, aka Young-of-Year; YOY; and first year age class includes juveniles and fish in their second year of life).

3.3 Benthic Macroinvertebrate Populations

Benthic macroinvertebrate population sampling was conducted at all monitoring sites with flowing water present in August 2020. Consistent with the SDDENR protocol (SDDENR2017), a 0.1 m^2 area was sampled using a kick net (20 × 50 centimeter [cm] opening and 500 micrometer [µm] mesh size) beginning with Transect 1 and proceeding upstream to each of the 11 transects delineated during the habitat assessment. At Transect 1, a randomly selected location (25, 50, or 75% of the water width) was identified for macroinvertebrate collection with collection location systematically rotating at subsequent transects. In erosional habitat, loose rocks and large substrates were kicked vigorously for 30 seconds to dislodge organisms into the net. In depositional habitats, similar techniques were used, except that the net was dragged through the standing water within the 0.1 m^2 area to capture suspended benthic organisms. In habitats with dense vegetation (i.e., aquatic plants or filamentous algae), the net was swept through the vegetation or strands of filaments were removed and placed in the sample. The collected organisms were combined into a single, "reach-wide" composition sample for each site. All samples were transferred to appropriately labeled sample containers, preserved with 95% ethyl alcohol, and returned with a Chain of Custody form to the GEI laboratory for processing.

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, an experienced technician or taxonomist checked all sorted samples, and the results were documented for 10% of the samples. These procedures indicated over 99% thoroughness for sorting from sample debris.

The sorted specimens were then identified to the lowest practical taxonomic level using available keys (dependent upon the age and condition of each specimen) and counted by taxon (Carter and Resh 2001). Quality assurance for identifications and counts (Whittaker 1975; Stribling et al. 2003) were randomly conducted on 10% of the samples and indicated 98% or higher agreement for taxonomic and count accuracy of identified taxa.

Oligochaetes were mounted on glass slides prior to identification, and chironomids were identified under a dissecting microscope. 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.

These procedures provided species lists and estimates of abundance. Further analyses were conducted to calculate additional population metrics including measures of species richness, community composition, tolerance, trophic habit, and life history.

3.3.1 Metric Calculations

Many metrics are available for evaluating benthic macroinvertebrate populations with most belonging to one of five categories: richness, composition, tolerance, trophic habit, and life history. The large number of available metrics necessitates a focus on those that are most useful in the region or state of interest (Barbour et al. 1999). The most useful metrics are those that best distinguish impacted and unimpacted sites and include “reference” conditions established using 20 to 50 unimpacted sites (Bowman and Somers 2005; Grafe 2002). These references have not been determined for the Wharf study, due to the challenges of identifying “reference” conditions in the Black Hills mining region. As agreed to by Wharf, SDGFP, and SDDENR, several metrics used on other Black Hills monitoring projects and/or previously used in biomonitoring projects were used in this study to analyze benthic macroinvertebrate data and to compare study sites with reference sites (Table 3-1).

The metrics listed below were calculated for Wharf study sites to allow comparisons between the current data and previous years and between study sites and their respective reference sites. Some metrics have established ranges or values that can indicate the occurrence of a disturbance that affects benthic macroinvertebrate communities while other metrics are evaluated within the context of historical ranges.

Table 3-1: Summary of benthic macroinvertebrate metrics calculated for the Wharf biomonitoring sites.

Metric	Type of Metric	Definition	Change Expected Following Environmental Disturbance
Density	Richness	Total abundance of invertebrates (#/sample).	Decrease
Number of Taxa	Richness	Number of distinct taxa	Usually Decrease
Number of EPT Taxa	Richness	Number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT).	Decrease
Shannon-Weaver Diversity Index	Composition	The extent that density is spread among a wide number of species.	Decrease
Percent Sensitive EPT Taxa	Composition	Percent of total taxa comprised of EPT taxa with tolerance values between 0 and 4.	Decrease
EPT Index	Composition	Percent of total taxa comprised of EPTs.	Decrease
Percent *Baetis sp.*	Composition	Percent of Ephemeroptera abundance comprised of individuals representing *Baetis sp.*	Increase
Number of non-*Baetis* Ephemeroptera	Composition	Number of Ephemeroptera individuals not in the genus *Baetis*.	Decrease
Percent Chironomidae	Composition	Percent of midge larvae	Increase
Number of Plecoptera Taxa	Composition	Number of taxa within the order Plecoptera.	Decrease
Percent Abundance of Oligochaetes & Hirudinea	Composition	Percentage of total abundance comprised of oligochaetes (segmented worms) and Hirudinea (leeches).	Variable
Dominant Taxon	Composition	Species name of most abundant taxon.	--
Percent Dominant Taxon	Composition	Measures the dominance of the single most abundant taxon.	Increase
Number of Common Taxa	Composition	Number of taxa common to both reference and non- reference sites.	Decrease
Community Loss Index	Composition	Percent of species at the reference site not present at the non-reference site.	Increase
Hilsenhoff Biotic Index (HBI)	Tolerance	Abundance-weighted mean of the tolerance values.	Increase
Percent Tolerant Taxa	Tolerance	Percent of total taxa comprised of taxa with tolerance values ranging from 7 to 10.	Increase
Percent Intolerant Taxa	Tolerance	Percent of total taxa comprised of taxa with tolerance values ranging from 0 to 4.	Decrease
Number of Intolerant Taxa	Tolerance	Count of the total taxa with tolerance values ranging from 0 to 4.	Decrease
Number of Predator Taxa	Trophic Habit	Number of taxa belonging to this functional feeding group.	Decrease
Percent Collector-Gatherers	Trophic Habit	Relative abundance belonging to this functional feeding group.	Variable
Number of Shredder Taxa	Trophic Habit	Number of taxa belonging to this functional feeding group.	Decrease
Number of Univoltine Taxa	Life History	Number of taxa classified as having a life history of 1 year.	Increase
Number of Semivoltine Taxa	Life History	Number of taxa classified as having a life history of greater than 1 year.	Decrease
Percent Semivoltine taxa	Life History	Percentage of total taxa comprised of taxa classified as having a life history of greater than 1 year.	Decrease
Number of Merovoltine Taxa	Life History	Number of taxa classified as having a merovoltine (three or more years) life history.	Decrease

3.3.1.1 Richness Metrics

Three metrics were calculated for richness: Density, Number of Taxa, and the Number of EPT Taxa. The Number of Taxa is commonly used to represent invertebrate species richness at a site, and higher richness usually indicates better water quality. 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) are generally an indicator of good water quality because most of these taxa are sensitive to a wide range of pollutants (Hynes 1970; Wiederholm 1984; Klemm et al. 1990; Merritt et al. 2008, Barbour et al. 1999). The Number of Taxa and the Number of EPT Taxa would be expected to be higher in unimpacted sites than in impacted sites. However, in some cases, the Number of Taxa can increase due to increases in the number of non-insect taxa or to tolerant insect taxa which indicate poor water quality. Therefore, changes in the Number of Taxa were also evaluated with respect to species composition. The Number of Taxa and the Number of EPT Taxa were determined for each study site and compared to the reference sites to determine whether any sites were negatively impacted.

3.3.1.2 Composition Metrics

Composition analyses included the calculation of twelve metrics: the Shannon-Weaver Diversity Index (Diversity), Percent Sensitive EPT Taxa, EPT Index, Percent *Baetis sp.*, number of non-*Baetis* Ephemeroptera, Percent Chironomidae, Number of Plecoptera Taxa, Percent Abundance of Oligochaetes & Hirudinea, the Dominant Taxon and Percent Dominant Taxon, Number of Common Taxa between the reference and non-reference sites, and the Community Loss Index.

The US Environmental Protection Agency (EPA) recommends Diversity for measuring the stress level of invertebrate communities (Klemm et al. 1990). This index ranges from 0 to greater than 4. Values greater than 2.5 are indicative of a healthy invertebrate community (Wilhm 1970; Klemm et al. 1990).

In addition to the Number of EPT Taxa (a richness Metric discussed above), two other EPT metrics were calculated. The Percent Sensitive EPT Taxa metric characterizes the EPT taxa that have low tolerance to perturbation (organic, inorganic, nutrient, and metal pollution and physical disturbance) out of all taxa present. Tolerance values for each taxon are obtained from the Northwest (Idaho) Regional Tolerance Value database (see additional explanation below), with sensitive taxa ranging from 0 to 4 on a scale of 0 to 10. The percent of sensitive EPT taxa would be expected to be higher in unimpacted sites (Wiederholm 1984; Klemm et al. 1990; Barbour et al. 1999). The EPT Index was also calculated as the percent of the total taxa that is comprised of EPT taxa. The EPT Index is expected to decrease with increasing environmental perturbation. The other mayfly composition metrics include Percent *Baetis sp.* which is calculated as the abundance of *Baetis* mayflies divided by the abundance of all mayflies. *Baetis* mayflies are relatively tolerant of environmental stressors, and high abundances of these groups can indicate conditions less suitable for more sensitive taxa. Number of non-*Baetis* mayfly individuals was also calculated, to indicate the abundance of other mayfly species.

The composition-based metric of Percent Chironomidae describes relatively high abundances of one family of dipterans (true flies) that are typically tolerant of less suitable environmental conditions. In addition, the Percent Dominant Taxon metric is expected to increase with environmental perturbation, as a high relative abundance of a single taxon is correlated with low diversity within the macroinvertebrate community and can indicate stressors are present. The Dominant Taxon was also identified, and its tolerance value noted. The Number of Plecoptera (stonefly) taxa was also included, as stoneflies can be sensitive to certain environmental stressors. Percent Abundance of Oligochaetes & Hirudinea was also calculated.

The Community Loss Index uses the Number of Common Taxa metric to measure the changes in benthic invertebrate communities between reference sites and potentially impaired sites. This metric is calculated by taking the Number of Taxa at the reference site, subtracting the Number of Common Taxa between the two sites, and then dividing the remaining number by the total taxa present at the potentially impaired site. The calculated values are dimensionless, and values increase with increasing dissimilarity with the reference site (Plafkin et al. 1989). Because this metric is only evaluating dissimilarity, the reason for dissimilarity should be determined in cases where large differences were identified between reference sites and potentially impaired sites.

3.3.1.3 Tolerance Metrics

Four metrics were also calculated for perturbation tolerance: The Hilsenhoff Biotic Index (HBI, Hilsenhoff 1987), Percent Tolerant Taxa, Percent Intolerant (or sensitive) Taxa, and Number of Intolerant Taxa. The HBI was originally designed to gauge the effects of organic pollution. The Idaho Department of Environmental Quality compiled a set of updated values in the Northwest Regional Tolerance Value database (Appendix B of Barbour et al. 1999) which measure sensitivity to general environmental stress (Grafe 2002). Although multiple tolerance databases are available (Barbour et al. 1999), benthic invertebrate communities in the Black Hills Core Highlands have the most taxa in common with the communities used to develop the Northwest Regional Tolerance Value database. The updated tolerance values range from 0 (sensitive, intolerant organisms) to 10 (highly tolerant organisms) and were assigned to each identified taxon. If an identified taxon was not listed in Appendix B of Barbour et al. (1999) or a tolerance value was not given for that taxon, best available literature was used to determine a tolerance value. The final HBI value is an abundance-weighted mean of the tolerance values. The HBI is expected to be higher at impacted sites because the community is expected to be comprised of more tolerant (higher scoring) organisms.

Hilsenhoff Biotic Index scores are also used to categorize benthic macroinvertebrate communities with scores of 0.00 - 3.50 considered as "Excellent," 3.51 - 4.50 are considered "Very Good," 4.51 - 5.50 are considered "Good," 5.51 - 6.50 are considered "Fair," 6.51 - 7.50 are considered "Fairly Poor," 7.51 - 8.50 are considered "Poor," and 8.51 - 10.00 are considered "Very Poor" (Hilsenhoff 1987). HBI values and ratings were compared between reference sites and the mining activity sites to determine if there are indications of environmental stress present downstream of the mining area.

The proportion of the community composed of tolerant or intolerant taxa was also used to evaluate community sensitivity to environmental stress. Tolerant taxa are defined as those that have been assigned tolerance values of 7, 8, 9, or 10. Intolerant taxa are those that have been assigned values of 0, 1, 2, 3, or 4. Stressed sites tend to support communities dominated by tolerant taxa (Barbour et al. 1999; Grafe 2002), so the percentage of tolerant taxa tends to increase, and the percentage of intolerant taxa tends to decrease with increasing environmental stress. The proportions of tolerant and intolerant taxa were compared between sites to evaluate whether individual sites showed signs of environmental stress.

3.3.1.4 Trophic Habit Metrics

Trophic functional feeding metrics – Number of Predator Taxa, Percent Collector-Gatherers, and Number of Shredder Taxa were also determined for each community based on Merritt et al. (2008). Predators rely upon a persistent prey base for survival, so patterns in populations often correspond to water quality and environmental disturbances that affect the prey base (Merritt et al. 2008). Specialized feeders, such as predators, are often considered sensitive organisms and are usually well represented in healthy streams (Barbour et al. 1999). Predator metrics are expected to decrease with increased disturbance.

Fine particulate organic matter is the primary food source of collector-gatherers, and their relative abundance can indicate disturbances associated with sedimentation and/or nutrient enrichment (Hargett 2011). These species are generalist feeders and can adjust to a broader range of food materials than specialist feeders and tolerate a broader range of conditions. Disturbances that increase organic matter in the stream, such as nutrient enrichment, may result in a community shift favoring the dominance of collector-gatherers (Hargett 2011). However, physical disturbances, such as increased sedimentation, can reduce these species. High percentages or large changes in the Percent Collector-Gatherers metric over time are often indicative of increased nutrient enrichment or sedimentation. Conversely, shredders often feed upon leaf litter and other unstable substrates; therefore, their low abundance or absence can be indicative of recent disturbance or lack of leaf litter or other suitable forage within a given site.

3.3.1.5 Life History Metric

Life history metrics listed include the Number of Univoltine Taxa, the Number of Semivoltine Taxa, the Percent Semivoltine taxa, and the Number of Merovoltine Taxa. Univoltine, semivoltine, and merovoltine are terms used to describe benthic macroinvertebrates that take one year, more than one year, and three or more years to complete a life cycle (generation), respectively. Short-term disruptions in suitable aquatic conditions, either chemical or physical, can reduce the Number of Taxa with longer life history traits (semivoltine and merovoltine organisms), and increase the relative abundance of more short-lived (univoltine) taxa. Therefore, as anthropogenic stressors increase, a community often shifts towards taxa with a shorter life history strategy, because longer-lived organisms are unable to persist long enough to reproduce.

3.4 Periphyton Populations

Periphyton population sampling was conducted at monitoring sites with flowing water present in August 2020 following SDDENR (2017) methods. Using this protocol, one piece of substrate was sampled at each of the 11 transects delineated during the habitat assessment. Within Transect 1, a randomly selected location (25, 50, or 75% of the water width) was identified for periphyton collection which systematically rotated at 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) sample bottle. In depositional habitats, the top 1 cm of sediment from a 12 cm^2 area was collected using a 60 mL syringe and added to the 500 mL sample bottle.

The 11 periphyton samples were combined to create a single “reach-wide” composition sample for the site, and this composition sample was brought up to a total of 500 ml. After thorough mixing, a 50 mL aliquot was removed for taxonomic identification and enumeration and preserved with Lugol’s solution. A second aliquot of 25 mL was filtered onto a Whatman GF/F filter for chlorophyll-a determination and stored wrapped in foil in the dark on ice in the field and then placed in a freezer. A third aliquot of 25 mL for biomass determination was filtered onto a pre-combusted Whatman GF/F filter for ash-free dry mass (AFDM) 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 (SM 10200 C.2, D.2, E.4, F.2.c) were sent to Aquatic Analysts, Friday Harbor, WA for processing. Samples for chlorophyll-a (SM 10200 H) and AFDM (SM 10300 C.5 (modified)) determination were processed by GEI (APHA 2005).

3.4.1 Metric Calculations

As with the benthic macroinvertebrate data, additional metrics were calculated from the periphyton data including richness, composition, tolerance, and trophic habit categories (Table 3-2). Candidate metrics were selected, based upon input from SDGFP, from Barbour et al. (1999), and elimination of redundant and unresponsive metrics also followed Barbour et al. (1999).

Table 3-2: Summary of periphyton metrics calculated for the Wharf biomonitoring sites.

Metric	Type of Metric	Definition	Change Expected Following Environmental Disturbance
Density	Richness	Number of periphyton cells/cm	Variable
Relative Diatom Density	Richness	Ratio of diatom taxa to the total number of taxa	Variable
Number of Taxa (species)	Richness	Number of distinct periphyton taxa	Decrease
Number of Diatom Taxa	Richness	Number of distinct diatom taxa	Decrease
Number of Periphyton Divisions	Richness	Number of periphyton divisions represented in the sample	Variable
Number of Periphyton Genera	Richness	Number of Periphyton genera represented in the sample	Variable
Shannon-Weaver Diversity Index for Diatoms	Composition	The extent that density is spread among a wide number of species.	Decrease
Bahls Similarity Index	Composition	Proportion of periphyton taxa and density that is shared between study and reference sites.	Variable
Autotrophic Index	Composition	Ratio of AFDM to chl-a	Increase
Percent Tolerant Diatoms	Tolerance	Percent relative abundance of diatom taxa with tolerance value of 1.	Increase
Lange-Bertalot Pollution Index	Tolerance	Cumulative index of pollution tolerance values of all taxa sampled; separated into class 1 (tolerant), class 2, and class 3 (sensitive).	Decrease
Percent Eutrophic Diatoms	Trophic Habit	Percentage of taxa comprised of eutrophic diatoms	Variable
Percent Acidiphilic Diatoms	Trophic Habit	Percentage of taxa comprised of acidiphilic diatoms	Variable
Percent Alkaliphilic Diatoms	Trophic Habit	Percentage of taxa comprised of alkaliphilic diatoms	Variable
Percent Nitrogen Heterotrophs	Trophic Habit	Percentage of taxa comprised of Nitrogen heterotrophs	Variable
Percent High Oxygen Diatoms	Trophic Habit	Percentage of taxa comprised of high oxygen diatoms	Variable
Percent Motile Diatoms	Trophic Habit	Percentage of taxa comprised of motile diatoms	Increase
Percent Saprobic Diatoms	Trophic Habit	Percentage of taxa comprised of saprobic diatoms	Variable

3.4.1.1 Richness Metrics

Six metrics were calculated to describe richness – Density, Relative Diatom Density, Number of Taxa, Number of Diatom Taxa, Number of Periphyton Divisions, and Number of

Periphyton Genera. Density is a measure of the number of algae cells per unit area of substrate sampled, and relatively high values of density often indicate nutrient enrichment. However, other stressors such as extended periods of low flow can increase the density of periphyton, whereas high flow events that scour the substrate can reduce the density of periphyton. Therefore, this metric is often evaluated in the context of other supporting data. The Number of Taxa represents the biological diversity at a given site. This measure includes taxa from all algal Divisions present, although it should be recognized that several taxa within some Divisions are often too small to be identified during routine examinations (e.g., several Cyanophyta). Diatoms (Bacillariophyta) are generally larger, have more resilient physical architecture, and have a more stable taxonomy (Patrick and Reimer 1966, 1975; Wehr and Sheath 2003). Both the Number of Taxa and the Number of Diatom Taxa would be expected to decrease with increased perturbation.

3.4.1.2 Composition Metric

The Diversity, Bahls Similarity Index, and Autotrophic Index metrics were calculated to describe composition. Diversity is a function of both the Number of Taxa and the abundance of each taxon and often ranges from 0 to greater than 4. Because diatom species richness and composition often vary independently depending on environmental conditions, the changes in this metric over time is a useful tool to identify the presence of stressors. The diatoms are considered to be the most sensitive taxa to changes in water quality (Barbour et al. 1999). Stressed sites often are dominated by a few taxa with lower diversity.

The similarities between periphyton community at the reference site and those at other sites were evaluated using the Bahls Similarity Index (1993). This index compares the appropriate reference site to its respective site downstream of mining activities by calculating the relative abundances of each taxon common to both sites. The smaller relative abundance value for each common taxon is summed for an index that evaluates percent similarity of the periphyton community between sites. This index varies from 0 (different communities) to 100 (identical communities). Ratings for this index are Very Similar (>60), Somewhat Similar (60 - 40), Somewhat Dissimilar (40 - 20), and Very Dissimilar (<20) (Bahls 1993). Dissimilarity between sites can be expected due to habitat differences even if neither is affected by water quality issues or excessive environmental disturbance. If diatom communities are dissimilar, other metrics are carefully considered to determine whether the dissimilarity is due to perturbation or other differences between sites.

The Autotrophic Index was also calculated using the laboratory derived biomass estimates(SM 10300 C.6). This metric is calculated by dividing the AFDM value by the chlorophyll-a value and is used to indicate proportions of the assemblage composed of either heterotrophic (outside sources of organic matter, such as leaf litter) or autotrophic (in-stream sources such as periphyton) material. Communities less disturbed by organic pollution and dominated by algae usually contain Autotrophic Index values ranging from 50-100. Values greater than 400 often indicate communities affected by organic pollution. Values of approximately 250 are more typical for streams enriched with nitrogen or phosphorus and show a potential for increased algal growth (Watson and Gestring 1996; Biggs 1996). However, the Autotrophic Index should be cautiously interpreted because dead organic matter may artificially inflate the ratio. This phenomenon is commonly observed in streams with low flow conditions that allow for the accumulation of dead organic matter over time due to the infrequent high flow scouring events.

3.4.1.3 Tolerance Metrics

Two tolerance metrics were calculated – Percent Tolerant Diatoms and the Lange-Bertalot Pollution Index (Pollution Index). The Percent Tolerant Diatoms metric is the sum of the relative abundances of all pollution-tolerant species. Tolerance values are based on values in Bahls (1993), which incorporated previously published tolerance values that range from 1 to 3 (Lowe 1974; Lange-Bertalot 1979). Tolerant diatoms are defined as those diatoms with a tolerance value of 1, whereas sensitive diatoms receive a tolerance value of 3 (Bahls 1993). This metric is often insightful when evaluating water quality of low-order streams where primary productivity may be naturally low (Barbour et al. 1999), such as for the streams near Wharf.

The Pollution Index was also calculated. The Pollution Index is calculated by multiplying the relative abundance of each taxon by its pollution tolerance value. The sum for all taxa is the Pollution Index, which ranges from 1.0 (all tolerant taxa) to 3.0 (all sensitive taxa). The scores are rated according to Bahls (1993) as No Organic Enrichment (>2.50), Minor Organic Enrichment (2.01 to 2.50), Moderate Organic Enrichment (1.50 to 2.00), and Severe Organic Enrichment (<1.50).

3.4.1.4 Trophic Habit Metric

Percent motile, eutrophic, acidiphilic, alkaliphilic, nitrogen heterotrophs, high oxygen diatoms, and saprobic diatoms were also identified. Eutrophic diatoms are adapted to waters with nutrient enrichment, while acidiphilic and alkaliphilic diatoms are adapted to acidic and alkaline waters, respectively. nitrogen heterotrophs are able to utilize other sources of nitrogen in low-light environments as a source of nutrients, and high-oxygen diatoms require habitats with high levels of dissolved oxygen. Saprobic diatoms are able to utilize decaying organic matter and may increase in abundance following a disturbance that kills other, more sensitive genera. The diatom genera *Navicula*, *Nitzschia*, and *Surirella* are relatively mobile organisms that work their way to the benthic surface when covered by silt (Wehr and Sheath 2003). Because of their mobility, the combined relative abundance of these three genera and others is thought to reflect the amount and frequency of siltation at a site (Barbour et al. 1999; Bahls 1993). Therefore, the Percent Motile Diatoms metric is a surrogate siltation index and was calculated as the sum of the relative abundances of all motile genera. The Percent Motile Diatoms metric is expected to be greater at sites with more silt.

In 2020, GEI completed an extensive update of the periphyton taxa database used to calculate metrics. The original database contained tolerance, composition, and trophic habit (autecological metrics) gleaned from Bahls (1993), Van Dam et al. (1994), Barbour et al. (1999), Hill et al. (2000), and Fore and Grafe (2002) for over 1900 species. The update incorporated an extensive U.S. Geological Survey database (Porter 2008) and database from the Southern California Coastal Water Research Project (TR#0730), including online sources (e.g., www.diatoms.org) that supplemented many pieces of missing information. The Wharf periphyton taxonomic list includes 155 taxa and the updated database greatly increased (e.g., 17 to 325%) the ecological information for the Wharf taxa. As a result, all periphyton metrics were recalculated for the Wharf biomonitoring sites (active or abandoned sites) from 2006 to the present and were used to evaluate the long-term trends and site comparisons provided herein.

3.5 Water Quality

Water quality samples were collected by Wharf mine personnel from all active biomonitoring locations, including the reference sites, within 30 days of the biological sampling event. Water quality analyses included a suite of physicochemical and metals parameters analyzed by Midcontinent Testing Laboratories, Inc. in Rapid City, SD. The suite of analyses includes:

Physicochemical Analyses
- Discharge, field current meter
- pH, field SM 4500-H^+ B
- Temperature, field SM 2550 B
- Hardness, SM 2300 B
- Total dissolved solids, SM 2540 C
- Total suspended solids, SM 2540 D

Inorganic Analyses
- Calcium, SM 3111 B
- Cyanide (weak acid dissociable), Kelada 01
- Magnesium, SM 3111 B
- Nitrate as nitrogen, SM 4500-NO3 F
- Phosphorus (dissolved), SM 4500-P E

Metals Analyses
- Arsenic (Trec), EPA 200.8
- Cadmium (Trec), EPA 200.8
- Chromium (Trec), EPA 200.8
- Copper (Trec), EPA 200.8
- Iron (Trec), EPA 200.8
- Lead (Trec), EPA 200.8
- Mercury (Tot), EPA 200.8
- Nickel (Trec), EPA 200.8
- Selenium (Trec), EPA 200.8
- Selenate (Se^{6+}), IF Trec Se > 12 µg/L
- Selenite (Se^{4+}), IF Trec Se > 12 µg/L
- Silver (Trec), EPA 200.8
- Zinc (Trec), EPA 200.8

3.6 Data Analysis

Aquatic biological monitoring data were summarized and analyzed in relation to mining activities and natural occurrences, such as unusual flows and weather events. When appropriate, fish, benthic macroinvertebrate, and periphyton data were qualitatively correlated with stream habitat and flow data to explain temporal and spatial variation in the aquatic community. The data collected in August 2020 from sites downgradient of mining activities were also compared to data from the reference sites (GEI 2018b).

Long term analyses were limited to data beginning in 2006 as the SDDENR methods and laboratories used have been consistent since this time (GEI 2018b). The fish population density and biomass estimates were compared qualitatively between years and sites. Species composition and size structure were examined within sites to determine if fish are naturally reproducing at the site or are being recruited from other sources.

Least-squares regression analysis was performed on fish K and Wr and all benthic macroinvertebrate and periphyton metric data to evaluate any increasing or decreasing trends at each site. This parametric test is robust to deviations in the assumptions for parametric tests when used to evaluate whether the metric of interest is trending. The Mann Whitney U test, a nonparametric test, was used to evaluate the differences in the long-term median values for a subset of macroinvertebrate metrics (Abundance, Number of Taxa, Number of EPT Taxa, Diversity, EPT Index, Hilsenhoff Biotic Index) and periphyton metrics (Density, Number of Taxa, Number of Diatom Taxa, Diversity, Autotrophic Index, Percent Tolerant Diatoms, Pollution Index, trophic habit, and Percent Motile Diatoms) for a mining activity site and its comparative reference site. The Mann Whitney U test was performed using the fish metrics (K and Wr) for mining activity sites and compared to the Labrador Gulch reference site. Long-term statistical comparisons (Mann Whitney U test) were also performed for sites that use Reno Creek as their reference site. However, the results were cautiously interpreted due to the small sample size for the reference site (i.e., $n = 4$ for RC-1-BIO). The Kruskal-Wallis multiple comparison test was used to evaluate the differences in the long-term metrics among the three sites on Annie Creek which allows for comparisons among data sets that do not follow a normal distribution. This test is a modification of the Mann Whitney U test which allows for multiple comparisons (Hintze 2004). A 95% confidence level ($\alpha = 0.05$) was used to determine significant differences among sites for all statistical comparisons, including trend analyses.

4. Results and Discussion

4.1 Habitat Assessment

4.1.1 Labrador Gulch and Reno Creek

In 2020, Site RC-1-BIO was moved 21 m upstream to avoid a blown down tree that covered the bottom of the site. This change had little effect on the overall assessment of the stream. No changes to the site location on Labrador Gulch were necessary. Sites LB-4-BIO and RC-1-BIO on Labrador Gulch and Reno Creek, contained 11 and 13 habitat units, respectively, during 2020 surveys (Table 4-1). A large portion of both sites were comprised of fast water habitat, although each site also contained ample slow-water pool habitat. Overall, Site LB-4-BIO typically has a greater flow than at Site RC-1-BIO (Table 4-2). Average widths ranged from 1.6 to 2.9 m at Site LB-4-BIO and from 0.7 to 1.6 m at Site RC-1-BIO. Average water depths ranged from 11 to 20 cm and average maximum depths ranged from 16 to 35 cm at Site LB-4-BIO. At Site RC-1-BIO, average water depths ranged from 5 to 25 cm and average maximum depths ranged from 10 to 38 cm. Eroding banks were absent from both sites. Overall, Site LB-4-BIO was wider and deeper on average than Site RC-1-BIO.

Table 4-1: Habitat characteristics for Labrador Gulch and Reno Creek, August 2020. HGR = high gradient riffle; LGR = low gradient riffle; DMB, SLB, SLM, SMB, SMW, SPB, and STR = types of pools; STP = step pool complex.

Site/ Habitat Type	No. of Units	Total Length (m)	Average Water Width (m)	Average Water Depth (cm)	Average Maximum Depth (cm)	Eroding Bank (%)
LB-4-BIO						
HGR	3	44.8	1.7	11	21	0
LGR	3	24.4	1.6	11	16	0
DMB	1	3.0	2.6	19	31	0
SLB	1	3.0	1.8	20	25	0
SMB	2	9.5	1.9	18	29	0
STP	1	15.3	2.9	15	35	0
RC-1-BIO						
HGR	1	11.1	1.0	5	15	0
LGR	4	53.7	1.1	5	11	0
SLM	1	5.5	0.7	8	10	0
SMB	2	6.9	1.5	12	30	0
SMW	2	9.2	1.4	20	28	0
SPB	2	6.6	1.2	25	38	0
STR	1	9.0	1.6	6	14	0

Table 4-2: Average substrate characteristics for all habitat types at sites LB-4-BIO and RC-1-BIO, August 2020.

Site/ Habitat Type	Flow (cfs)	Average % Surface Fines	Substrate Composition (%)				
			Fine Sediment (≤ 0.8 mm)	Coarse Sediment (0.8 - 4.8 mm)	Gravel (4.8 - 75 mm)	Rubble (76 - 304 mm)	Boulder and Bedrock (> 304 mm)
LB-4-BIO	0.54	2	0	0	20	39	41
RC-1-BIO	0.08	18	11	15	30	26	17

Substrate compositions varied at both sites, with Site LB-4-BIO dominated by boulder/ bedrock and rubble, while Site RC-1-BIO was mainly comprised of gravel and rubble substrate (Table 4-2). Differences in substrate composition are likely due to the differing geologies and geomorphologies at these two sites. The Labrador Gulch site is a high-gradient stream that flows through a steep, bedrock canyon (Photo 4-1). Sources of fine sediment are generally absent within the reach. Any fine sediments would likely flow into Site LB-4-BIO from above and would only accumulate in slower, deeper sections of pools. In contrast, Site RC-1-BIO on Reno Creek is a lower gradient stream, in a more vegetated and forested valley, with ample sources of fine sediments (Photo 4-2). In fact, increased sedimentation, schist deposits, undercut banks, and scoured areas were observed in some locations on Reno Creek, indicative of recent high flows. Well vegetated banks at the site prevented bank erosion. Overall, measured fine sediments and surface fines were slightly higher at the Reno Creek site than at the Labrador Gulch site but were low at both sites.

Photo 4-1: High gradient and canyon walls in Labrador Gulch.

Photo 4-2: Low gradient, vegetated stream banks along Reno Creek.

4.1.2 Annie Creek, Ross Valley, Lost Camp Gulch

The Annie Creek Basin contains five of the fifteen monitoring sites, and each site was influenced to some degree by the tornado activity in July 2020. Lower Annie Creek (Site AC-3-BIO) received the most storm disturbance, and it was not practicable to perform the 2020 biomonitoring event due to the extensive deadfalls covering the stream (Photo 4-3). Eventually, a 20.4 m section, roughly 50 m upstream from the bottom of reach, was accessed which consisted of a gravel bar, pools, and a run. No habitat measurements were collected, and only a qualitative fish survey was conducted. Similarly, on Lost Camp Gulch, a massive pile of deadfalls covered 13.4 m of stream in the middle of Site LC-1-BIO (Photo 4-4). The tree covered section was excluded from the habitat assessment at Lost Camp Gulch.

Photo 4-3: Fallen trees from tornado activity at AC-3-BIO. Annie Creek is below trees in left picture. Right picture is of the short stream section that was accessible.

Photo 4-4: Deadfall at Site LC-1-BIO.

In August 2020, the numbers of habitat units observed at sites AC-1-BIO and AC-2-BIO were 16 and 13, respectively, while the numbers of habitat units at sites RV-2-BIO and LC-1-BIO were much lower at 3 and 6, respectively (Table 4-3). Fast water habitat types (riffles and/ runs) comprised most of all sites and no pools were found at sites RV-2-BIO and LC-1-BIO. Multiple pools were found at both of the Annie Creek sites with pool forming features including both large woody debris and boulders in the stream. Water widths and depths varied among all sites and in different habitat units (Table 4-3).

Table 4-3: Habitat characteristics for sites on Annie Creek, Ross Valley, and Lost Camp Gulch, August 2020. Habitat types: CAS = Cascade; HGR = high gradient riffle; LGR = low gradient riffle; Run = run; DMB, DMW, SLB, SMB, and SMW = types of pools; STP = step pool complex.

Site/ Habitat Type	No. of Units	Total Length (m)	Average Water Width (m)	Average Water Depth (cm)	Average Maximum Depth (cm)	Eroding Bank (%)
AC-1-BIO						
CAS	1	2.0	1.6	5	6	0
HGR	4	20.5	0.7	6	14	0
LGR	5	53.2	1.4	6	15	0
RUN	1	2.9	1.0	14	25	0
DMW	1	4.3	2.1	12	15	0
SMB	2	5.9	1.6	16	29	0
SLB	1	6.8	2.2	17	36	0
SMW	1	3.6	1.5	8	16	0
AC-2-BIO						
HGR	1	4.3	2.3	6	18	0
LGR	5	45.5	1.5	9	20	0
RUN	2	12.0	2.4	20	25	0
DMB	1	6.0	1.2	16	35	0
DMW	1	5.7	2.8	11	26	0
SMB	2	11.9	2.3	21	39	0
STP	1	15.6	2.5	24	37	0
RV-2-BIO						
HGR	1	8.5	0.8	8	10	0
LGR	2	92.5	0.8	5	14	0
LC-1-BIO						
LGR	3	76.5	1.4	6	15	0
RUN	2	9.9	1.5	11	20	0
DMB	1	2.7	2.0	19	31	0

Sites RV-2-BIO and LC-1-BIO sites are both located in the headwaters of comparatively small creeks and are characterized by relatively narrow water widths and shallow depths (Table 4-3). Site RV-2-BIO was narrower and shallower than other sites where widths were similar. Average water depths were similar and shallower at sites AC-1-BIO and LC-1-BIO on average, with many habitat types below 10 cm deep, than at Site AC-2-BIO, where multiple habitat types were greater than 20 cm deep. Maximum depths ranged from 6 cm in a cascade flowing over steep bedrock at Site AC-1-BIO, to 36 cm in a pool formed by boulders at Site AC-2-BIO.

Substrate composition at all sites included a range of substrate sizes. Boulders and bedrock were the dominant substrate size classes at Site AC-1-BIO, fine sediment at sites AC-2-BIO and RV-2-BIO, and rubble at Site LC-1-BIO (Table 4-4). Percent surface fines were slightly higher at sites AC-2-BIO and RV-2-BIO than the other sites, but percentages at all sites were moderate. Recreational usage of the dirt road adjacent to sites AC-2-BIO and LC-1-BIO likely contribute to the surface fines at these sites. Four-wheel drive vehicles have been observed using the road adjacent to Lost Camp Gulch during past sampling events. Road maintenance (i.e., filling in potholes) may also contribute to fine sediment inputs into Annie Creek. The higher percentages of fine substrates at the Ross Valley site are likely due to the low discharge typically found at this site and the accumulation of organic matter from the surrounding forest. All sites included abundant gravel, rubble, and boulders/bedrock, which are considered desirable substrate size classes, as all three substrate sizes provide habitat for benthic macroinvertebrates, and gravel serves as favorable spawning habitat for salmonids (Waters 1995). In some years, such as 2016, 2017, and 2020, prolonged low flows due to drought conditions reduced the flushing flow capacity to remove fine sediments.

Water widths and depths at Site RV-2-BIO were similar or lower than those measured at the reference site, Site RC-1-BIO (Table 4-1). Site RC-1-BIO also contained a much greater variety of habitat unit types, including pools and runs, than Site RV-2-BIO. Site RV-2-BIO contained no slow water habitat and was comprised mostly of low gradient riffles. However, it did contain more fines than Site RC-1-BIO. Habitat conditions at sites LC-1-BIO and RV-2-BIO were generally comparable to the reference site, with a variety of habitat units at both sites, including riffles, pools, and runs, and similar average widths, depths, and abundance of fines.

Table 4-4: Average substrate characteristics for all habitat types at each site on Annie Creek, Ross Valley, and Lost Camp Gulch, August 2020.

Site/ Habitat Type	Flow (cfs)	Average % Surface Fines	Substrate Composition (%)				
			Fine Sediment (≤ 0.8 mm)	Coarse Sediment (0.8 - 4.8 mm)	Gravel (4.8 - 75 mm)	Rubble (76 - 304 mm)	Boulder/ Bedrock (> 304 mm)
AC-1-BIO	0.11	21	14	13	18	19	37
AC-2-BIO	0.21	35	25	20	18	20	17
RV-2-BIO	0.02	31	29	27	19	16	9
LC-1-BIO	0.04	16	12	11	19	37	22

4.1.2.1 Summary of Habitat Conditions

Overall, fish habitat was favorable at the two accessible Annie Creek sites in 2020. Both sites contained a variety of habitat types, and surface fines and fine sediments did not account for large proportions of the substrate despite being greater than in 2019. No trends in fines or surface fines were observed at either Annie Creek site in recent years. Fine sediments are likely due to runoff from Annie Creek Road or the road adjacent to Lost Camp Gulch and not mining activities. No eroding banks were observed at any Annie Creek site during 2020. Eroding banks are strongly influenced by high flow events and areas of unvegetated or vulnerable streambanks and are unrelated to small discharges of water into the Annie Creek drainage via the Wharf outfalls. While some differences have occurred from year to year at the three Annie Creek sites, generally, the available habitat at these sites has been diverse, with a range of habitat types observed each year throughout the study period.

Habitat features at Site AC-1-BIO, Site AC-2-BIO, and the Reno Creek reference site, Site RC-1-BIO were similar. All sites were comprised mainly of low gradient riffles but contained a variety of small pools as well. Average and maximum depths were comparable at these three sites and eroding banks were absent. Overall, comparisons reveal no differences between the upper two Annie Creek sites and the reference site indicating that stream habitat in Annie Creek is not being affected by mining activities when compared to habitat at the reference site. Both sites on Annie Creek contain a mixture of habitat types, including deep water pool habitat suitable for fish. Substrate conditions are also favorable and indicate that interstitial spaces (habitat) are sufficient for macroinvertebrates.

4.1.2.2 Precipitation

Precipitation has varied in the Black Hills since 1995. During the years 2007, 2013, 2018 and 2019, peak precipitation data was large and/or frequent (Figure 4-1). The resulting high discharge in these years caused some minor changes to the habitat structure of Annie Creek, with some evidence of debris movement, scouring of fine sediments, or increased percentages of exposed banks observed in the habitat surveys. However, large and/or frequent precipitation in other years (i.e., 2010) did not result in habitat changes. Spring precipitation in 2016, 2017, and 2020 were not high and did not significantly alter habitat at any Annie Creek sites, while peak precipitation in 2018 and 2019 were high and are likely partially responsible for the general decrease in surface and fine sediments observed at all Annie Creek sites in those years. Precipitation in 2020 was similar to that in 2016 and 2017 and was accompanied by slight sedimentation in Annie Creek.

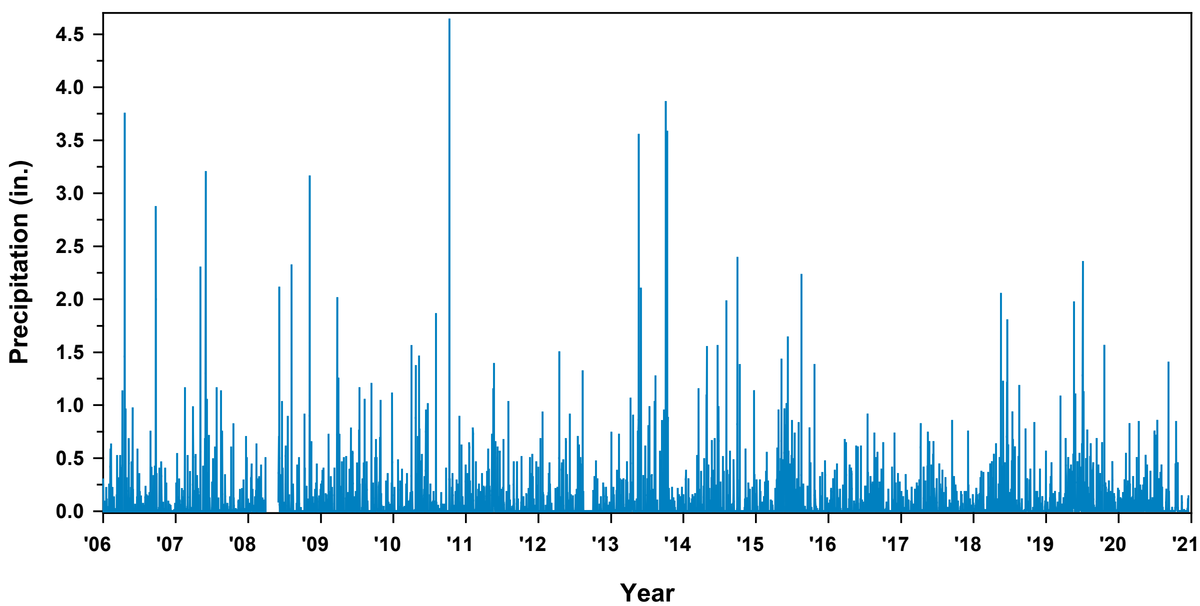

Figure 4-1: Cumulative daily precipitation in Lead, SD (GHCND:USC00394834) from 2006 to 2020 (NOAA 2020).

4.1.3 Deadwood Creek, False Bottom Creek, and Cleopatra Creek

Habitat measurements were collected at Site DC-2-BIO on Deadwood Creek, and sites EFB-1-BIO and WFB-1-BIO on the East Fork and West Fork of False Bottom Creek, respectively (Table 4-5). Small residual pockets of water were present at Site CC-1A-BIO, but no flow was present, and the riffles were dry (Photo 4-5). Therefore, the decision was made to not sample Cleopatra Creek in 2020, as was the case in 2016, 2017, and 2019.

Photo 4-5: Residual pockets of water with no flowing water in Cleopatra Creek.

Photo 4-6: Iron oxide deposits at Site WFB-1-BIO.

These biomonitoring sites are all located in the headwaters of comparatively small creeks and are characterized by relatively narrow water widths and shallow depths (Table 4-5). The number of habitat units at each of the sampling sites ranged from 13 to 16 units. All sites contained a mixture of fast water and slow water habitat types. Site DC-2-BIO was the only site dominated in terms of length by pool habitat, and sites DC-2-BIO and WFB-1-BIO were the only sites that contained eroding banks. Substrate compositions included a combination of sizes from fine sediment to boulders at all study sites in 2020 (Table 4-6). Surface fines and fine sediment were less abundant at Site EFB-1-BIO than at other sites. Rubble and boulder were the most abundant substrate at Site DC-2-BIO, gravel at Site EFB-1-BIO, and fine sediment at Site WFB-1-BIO. Iron oxide deposits were observed at Site WFB-1-BIO, similar to previous years of sampling on this fork, and these deposits impact the benthic invertebrates, fish, and periphyton at this site by limiting interstitial spaces (Photo 4-6).

Table 4-5: Habitat characteristics for sites on Deadwood Creek, East Fork False Bottom Creek, West Fork False Bottom Creek, August 2020. HGR = high gradient riffle; LGR = low gradient riffle; SRN = step run complex; Run = run; DMB, DMW, SLW, SMB, and SMW = types of pools.

Site/ Habitat Type	No. of Units	Total Length (m)	Average Water Width (m)	Average Water Depth (cm)	Average Maximum Depth (cm)	Eroding Bank (%)
DC-2-BIO						
LGR	7	38.6	1.4	8	12	0
RUN	3	15.8	1.6	12	19	0
SLW	1	3.2	1.7	20	25	0
SMW	1	4.4	2.4	33	35	0
SRN	4	49.1	1.4	10	20	6
EFB-1-BIO						
HGR	1	3.1	1.1	6	13	0
LGR	7	61.8	0.9	5	15	0
RUN	4	27.1	0.9	9	15	0
SMB	3	7.9	1.2	10	22	0
SMW	1	2.1	1.2	8	20	0
WFB-1-BIO						
LGR	6	72.4	1.0	4	10	7
DMW	2	17.3	1.2	14	18	0
SMB	2	5.7	1.5	12	23	25
SMW	3	7.6	1.6	8	22	0

Table 4-6: Substrate characteristics for sites at Deadwood Creek, West Fork False Bottom Creek, August 2020.

Site/ Habitat Type	Flow (cfs)	Average % Surface Fines	Substrate Composition (%)				
			Fine Sediment (≤ 0.8 mm)	Coarse Sediment (0.8 - 4.8 mm)	Gravel (4.8 - 75 mm)	Rubble (76 - 304 mm)	Boulder/ Bedrock (> 304 mm)
DC-2-BIO	0.09	22	21	9	17	28	25
EFB-1-BIO	0.12	8	7	24	33	25	11
WFB-1-BIO	0.03	20	27	22	24	21	6

4.1.3.1 Summary of Habitat Conditions

Habitat characteristics have been relatively stable at sites DC-2-BIO, EFB-1-BIO and WFB-1-BIO in recent years. The location of these sites in the headwaters of small streams makes high flow events that might lead to significant habitat changes or streambank erosion unlikely. Variability in streamflow from year to year can lead to changes in average depths and in fine sediment deposition within these small streams. In fact, length of pool habitat was greater than riffle habitat in Site DC-2-BIO in 2019 and 2020 which has not been the case in many recent years.

Aquatic habitat at sites DC-2-BIO, EFB-1-BIO, and WFB-1-BIO were comparable to the Labrador Gulch reference site, LB-4-BIO, in 2020. Average widths and depths were similar between these sites and Site LB-4-BIO, although average and maximum depths were slightly greater in the pools at the Deadwood Creek and Labrador Gulch sites. All sites contained a variety of substrate sizes with no one type being dominant. Fine sediment was dominant only at Site WFB-1-BIO. The iron oxides historically observed on the substrate at WFB-1-BIO continue to be present and are due to impacts of groundwater contributions upstream of Site WFB-1-BIO.

4.1.4 Fantail Creek, Nevada Gulch, and Stewart Gulch

The study sites at Fantail Creek, Nevada Gulch, and Stewart Gulch contained from 8 to 14 total habitat units, with low gradient riffles being the most prevalent habitat type within each site (Table 4-7). Average stream widths were narrower at Site FC-1-BIO than at sites NG-2-BIO and SG-1-BIO. Average water depths at the Stewart Gulch site ranged from 11 to 24 cm and maximum depths in pools ranged up to 38 cm while average water depths in Fantail Creek and Nevada Gulch ranged from 2 to 13 cm, with maximum depths up to 32 cm. A range of habitat units, including riffles and pools formed by various elements, such as logs or boulders, were also present in each site. Eroding banks were present at the sites in Fantail Creek and Nevada Gulch.

Table 4-7: Habitat characteristics for sites on Fantail Creek, Nevada Gulch, and Stewart Gulch, August 2020. HGR = high gradient riffle; LGR = low gradient riffle; Run = run; SRN = step run complex; SLB, SMB, SPB, SPO, SMO and SPW = types of pools; and STP = step pool complex.

Site/ Habitat Type	No. of Units	Total Length (m)	Average Water Width (m)	Average Water Depth (cm)	Average Maximum Depth (cm)	Eroding Bank (%)
FC-1-BIO						
LGR	4	76.6	0.9	3	10	0
SMB	2	2.9	1.2	8	14	5
STP	2	20.3	0.9	10	29	0
NG-2-BIO						
HGR	1	5.4	2.7	2	12	10
LGR	6	89.1	1.1	3	11	0
RUN	1	4.0	1.0	2	6	0
SLB	1	3.4	1.3	6	18	25
SPB	1	1.5	1.5	13	16	0
SPW	1	2.2	1.7	8	32	0
SG-1-BIO						
HGR	2	13.6	1.8	13	20	0
LGR	5	45.7	2.1	9	20	0
RUN	2	15.7	1.7	15	20	0

Site/ Habitat Type	No. of Units	Total Length (m)	Average Water Width (m)	Average Water Depth (cm)	Average Maximum Depth (cm)	Eroding Bank (%)
SMB	1	3.9	2.0	15	25	0
SPB	1	3.3	2.7	24	38	0
SPO	1	5.7	1.7	7	32	0
SMO	1	3.6	2.0	11	25	0
SRN	1	10.6	2.0	8	25	0

Substrate composition at these three sites included assorted sizes of substrate, with gravel being the most abundant substrate size class at all sites (Table 4-8). Surface fines ranged from 13 to 36 percent at all sites, and percentages of fine sediments were greatest at Site FC-1-BIO. Monitoring surveys have documented a fluctuation in the proportion of fine substrate in Fantail Creek during many recent events. Again, surface fines were dominant in 2020 (Photo 4-7), particularly in pool habitat, indicating that sedimentation may be occurring from Gilded Mountain Road (Photo 4-8). The location of this site in the headwaters of Fantail Creek limits the occurrence of high flow events, which would help flush large amounts of fine sediments downstream. The percentage of fine sediments in 2020 was roughly that same as it was in 2019 for all sites. Eroding banks were not observed except for small areas of Nevada Gulch and Fantail Creek, indicating good bank stability and a lack of current fine sediment inputs into the site from unstable banks (Table 4-7). Differences in aquatic habitat among sites in 2020 were mainly due to the surrounding geology (substrate size) and proximity to roads, and not associated with Wharf mining activities (Table 4-8).

Table 4-8: Substrate characteristics for sites on Fantail Creek, Nevada Gulch and Stewart Gulch, August 2020.

Site/ Habitat Type	Flow (cfs)	Average % Surface Fines	Substrate Composition (%)				
			Fine Sediment (≤ 0.8 mm)	Coarse Sediment (0.8 - 4.8 mm)	Gravel (4.8 - 75 mm)	Rubble (76 - 304 mm)	Boulder/ Bedrock (> 304 mm)
FC-1-BIO	0.03	36	17	12	59	9	3
NG-2-BIO	0.02	13	6	11	54	20	10
SG-1-BIO	0.77	17	10	18	34	22	16

Photo 4-7: Fine sediment accumulation in Fantail Creek channel, August 2020.

Photo 4-8: Road intersection immediately upstream of Site FC-1-BIO likely acting as a source of sediment to the stream, August 2020.

In recent years, Stewart Gulch has contained an abundant growth of watercress (*Nasturtium officinale*, Photo 4-9), which provides good habitat for first year age class trout and those less than one year old, referred to as young-of-the-year (YOY). However, in 2020, the areal extent of the watercress was substantially less than compared to previous years. The spring upstream of the site continues to provide nitrogen-rich groundwater to the stream which can facilitate the growth of watercress, even though discharge was substantially less in 2020. The reduced watercress coverage may be the natural cycle of the plant growth, because 2020 was more of a dry-year type with no apparent scouring precipitation events that could reduce the watercress coverage.

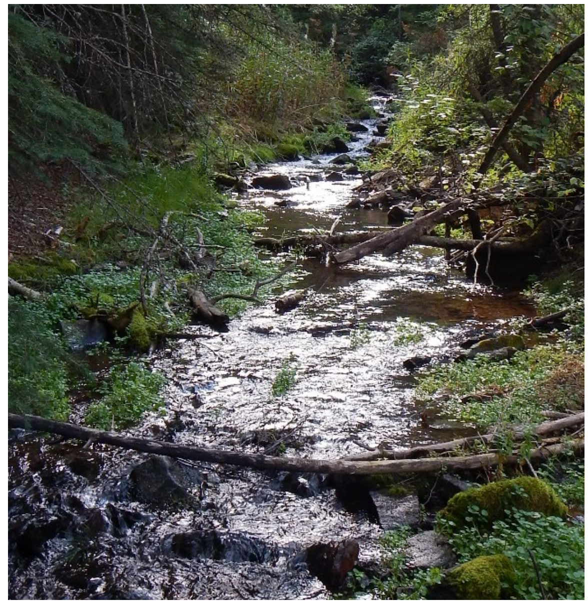

Photo 4-9: Abundance of watercress along margins of Stewart Gulch, August 2017 (left) and less coverage in August 2020 (right).

4.1.4.1 Summary of Habitat Conditions

Overall, habitat characteristics at sites on Fantail Creek, Nevada Gulch, and Stewart Gulch are favorable for benthic macroinvertebrates. Nevada and Stewart gulches contained a relatively low percentage of fines, while Fantail Creek contained a larger amount. Each site also contained ample amounts of riffle habitat which is preferred by many benthic macroinvertebrates. Similarly, substrate characteristics indicated sufficient amounts of gravel for mayflies, stoneflies, and caddisflies to inhabit interstitial spaces. Stream width and depth and abundance of pool habitat at Site SG-1-BIO is also sufficient to support fish. Fluctuations in habitat characteristics at these sites are, for the most part, minimal or related to natural variations in climatic conditions. The presence of surface fines decreased at many of these sites in 2018 and 2019 due to the frequent rainfall and increased flows events in the region (Figure 4-1).

Habitat conditions at Fantail Creek and Nevada Gulch were similar to those on Reno Creek at the refence site, Site RC-1-BIO. All streams are small streams with low discharge, narrow widths, shallow water depths, and minimal erosion which are conditions typical of their headwater locations. These sites are all dominated by low gradient riffles but contain multiple pools as well. The percentage of surface fines was greater at Fantail Creek but low overall. All three sites contained abundant gravel and rubble substrates, which provide suitable spawning areas for trout and favorable interstitial spaces for benthic macroinvertebrates to inhabit.

Stewart Gulch and the reference site on Labrador Gulch, Site LG-4-BIO, have comparable habitats. Both sites contain a relatively wide variety of habitat types with ample riffle and pool habitat, lack eroding banks, and have a good mixture of habitat types to support healthy populations of Brook Trout (See Fish Populations).

4.2 Fish Populations

4.2.1 Labrador Gulch

Seventeen Brook Trout, ranging from 73 to 186 mm, were collected from Site LB-4-BIO (Table 4-9, Figure 4-2). Age-classes sampled included YOY (<100 mm) and second year-plus age class (>140 mm, Figure 4-2). The YOY and second year-plus age class fish abundance in 2020 were similar to recent years with fewer fish less than 150 mm collected in 2020 than previous years (less than Q1) and fish greater than 150 mm being within Q1 of fish abundance since 1993 when sampling began at this site (Figure 4-3, Table 4-10). YOY collected in 2020 and in previous years indicate this segment of the stream supports all life stages of Brook Trout.

Density and biomass values have fluctuated since 1995 (Figure 4-4, Figure 4-5). Density in 2020 was within the ranges previously sampled (within Q2) while biomass was slightly lower than in other years (within Q2; Figure 4-6; Figure 4-7).

Table 4-9: Fish population metrics for Labrador Gulch and Reno Creek, August 2020.

Site/Species	Number Collected	Mean Length (mm)	Mean Weight (g)	Density #/ha ± 95% C.I.	Biomass (kg/ha)	Relative Weight (W_r)	Condition (K)
LB-4-BIO							
Brook Trout	17	144.5	36.2	947 ± 263	34.3	87.6	0.93
RC 1 BIO							
Brook Trout	37	90.6	7.5	3,083 ± 83	23.1	83.1	0.90

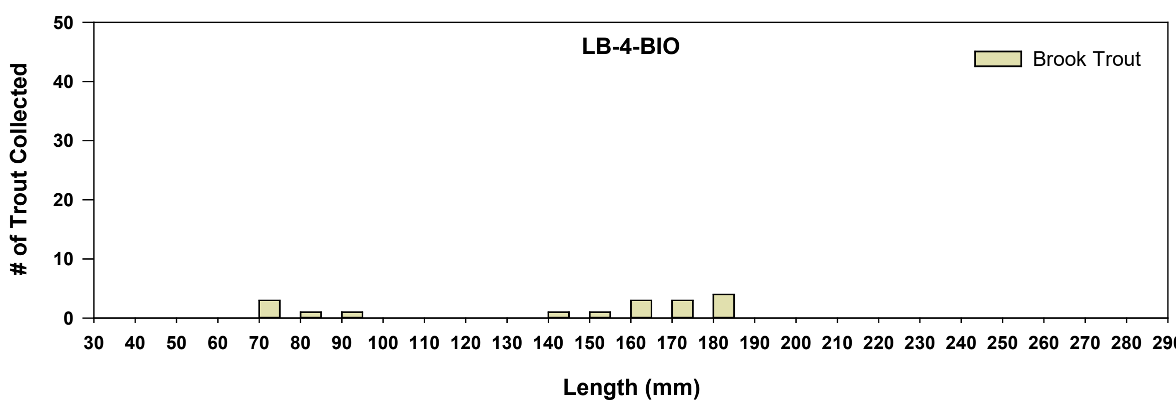

Figure 4-2: Length-frequency distribution for Brook Trout collected in Labrador Gulch at Site LB-4-BIO, August 2020.

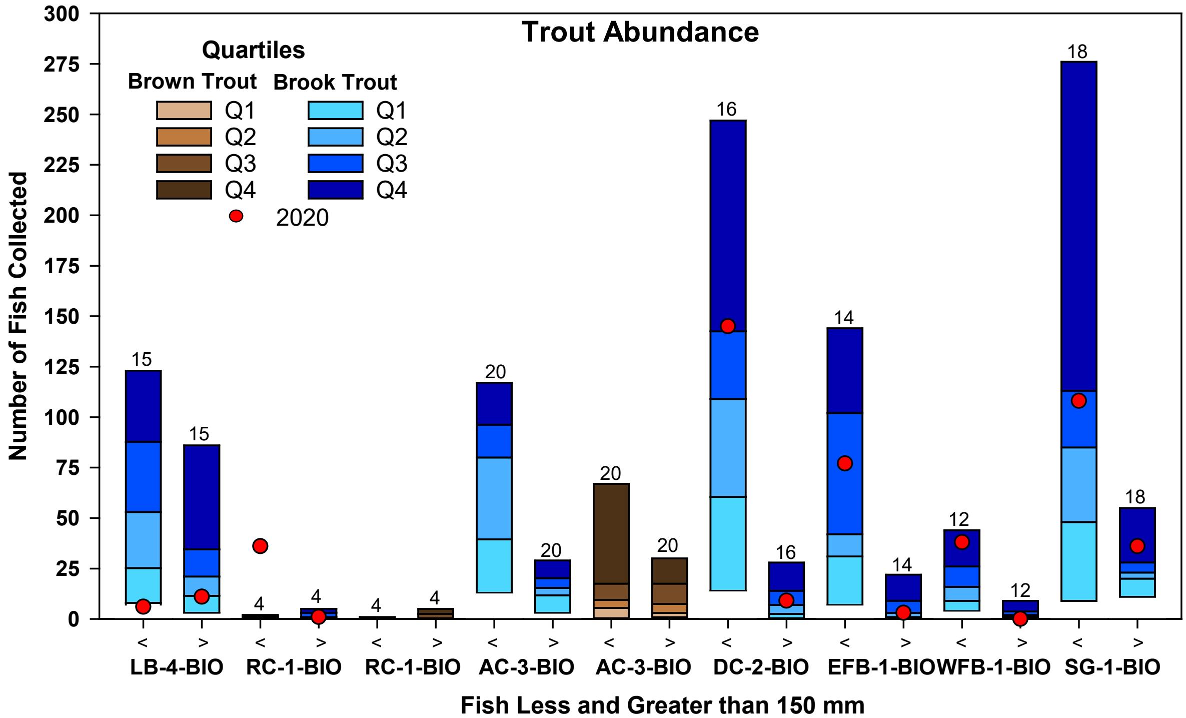

Figure 4-3: Quartile plots by length of Brook Trout and Brown Trout collected at Wharf sites from 1990 through 2020. Brown Trout collected in 2019 at EFB-1-BIO (n = 1) and in 2012 and 2017 at SG-1-BIO (n = 2 and n = 1, respectively) are not displayed. Sample size (e.g., number of years sampled) is displayed above each quartile and includes 2020. Note: AC-3-BIO was not sampled in 2020 and no Brown Trout were collected from RC-1-BIO in 2020.

Table 4-10: Quartile data (minimums, percentiles, and maximums) for Brook Trout and Brown Trout less than or greater than 150 mm in length at Wharf sites from 1990 through 2020. NS = Not sampled.

Site/Species	Abundance (<150 mm)						Abundance (≥150 mm)					
	Min	25th	50th	75th	Max	2020	Min	25th	50th	75th	Max	2020
LB-4-BIO												
Brook Trout	7	25.3	53.5	87.8	123	6	3	12.3	21.0	34.5	86	11
RC-1-BIO												
Brook Trout	0	0.5	1.0	2.0	3	36	0	0.5	1.0	3.0	5	1
Brown Trout	0	0.0	0.0	0.5	1	0	0	0.0	0.0	2.5	5	0
AC--BIO3												
Brook Trout	13	39.5	80.0	96.3	117	NS	3	11.8	15.0	20.3	29	NS
Brown Trout	0	5.5	9.5	17.5	67	NS	1	3.0	7.5	17.5	30	NS
DC-2-BIO												
Brook Trout	14	60.5	109.0	142.5	247	145	0	2.5	7.0	14.0	27	9
EFB-1-BIO												
Brook Trout	7	31.0	42.0	102.0	144	77	0	1.0	3.0	9.0	22	3
Brown Trout	0	0.0	0.0	0.0	1	0	0	0.0	0.0	0.0	0	0
WFB-1-BIO												
Brook Trout	4	9.0	16.0	26.0	44	38	0	1.0	2.0	3.5	9	0
SG-1-BIO												
Brook Trout	9	48.0	85.0	113.0	276	108	11	20.0	23.0	27.0	55	36
Brown Trout	0	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0	2	0

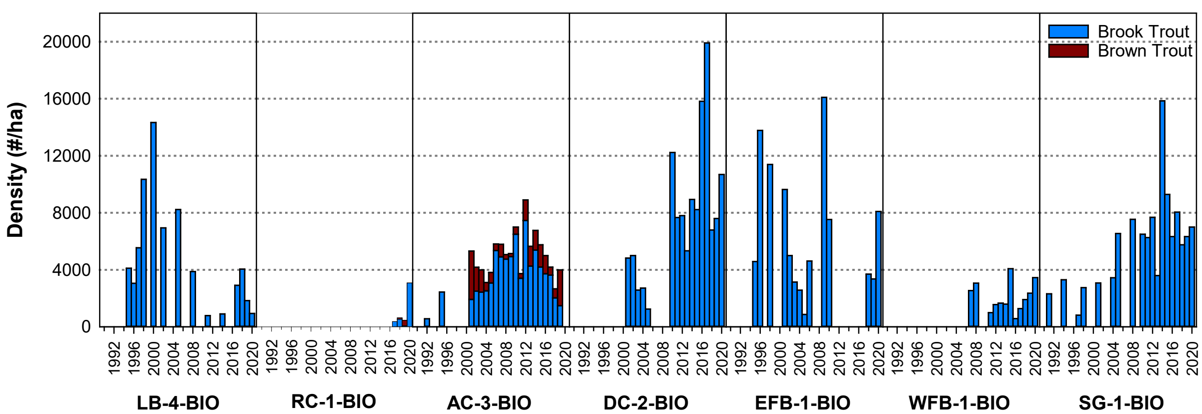

Figure 4-4: Trout population density values at the Wharf sites from 1990-2020. Data for AC-3-BIO is stacked. Brown trout collected in 2019 at EFB-1-BIO (n = 1) and in 2012 and 2017 at SG-1-BIO (n = 2 and n = 1, respectively) are not displayed.

Mean condition factor and relative weight values at Site LB-4-BIO were less than the optimal ranges and similar to other sites sampled in 2020, indicating that Brook Trout at all sites may be ecologically stressed. This site is not located downstream of mining activities, and lower condition factor and relative weight values indicate variations in fish condition due to natural factors such as low precipitation (i.e., lower flows) and warmer water temperatures in recent years (Figure 4-1). No increasing or decreasing trends since 2006 were observed for abundance, density, biomass, or condition factor, although, relative weight (Wr) has significantly decreased since 2006 (p = 0.02, slope = -1.72 Wr/year). The frequency of fish sampling at Site LB-4-BIO has been variable since 2006, as a result, some interannual variability may not be evident in the data.

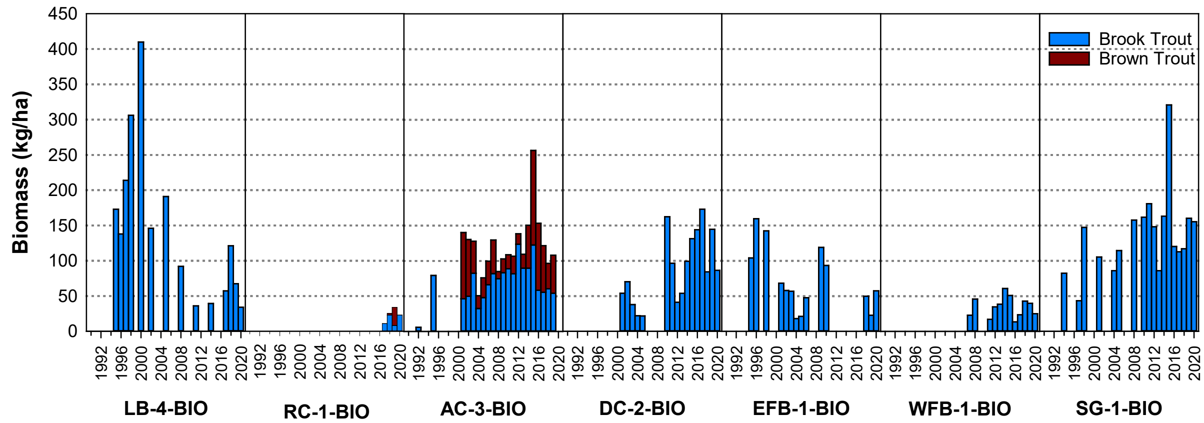

Figure 4-5: Trout population biomass values at the Wharf sites from 1990 to 2020. Data for AC-3-BIO is stacked. Brown trout collected in 2019 at EFB-1-BIO (n = 1) and in 2012 and 2017 at SG-1-BIO (n = 2 and n = 1, respectively) are not displayed.

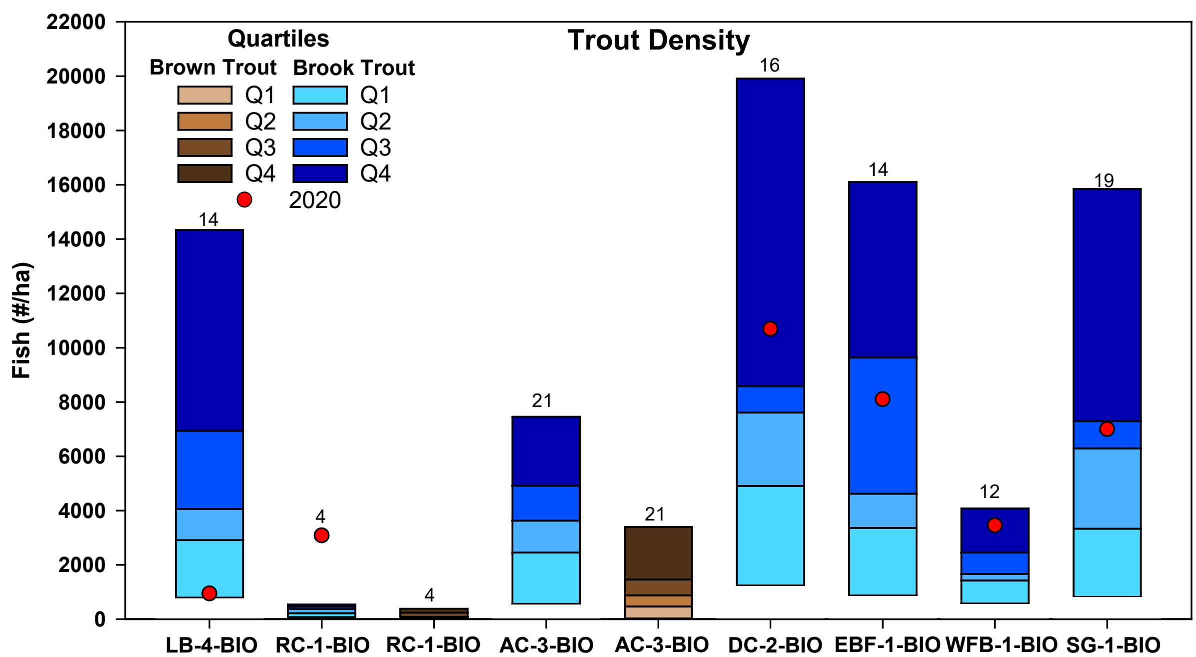

Figure 4-6: Quartile plots of Brook Trout and Brown Trout population density values at Wharf sites from 1990 through 2020. Brown trout collected in 2019 at EFB-1-BIO (n = 1) and in 2012 and 2017 at SG-1-BIO (n = 2 and n = 1, respectively) are not displayed. Sample size is displayed above each quartile and includes 2020. In 2020, AC-3-BIO was not sampled, and no Brown Trout were collected from RC-1-BIO.

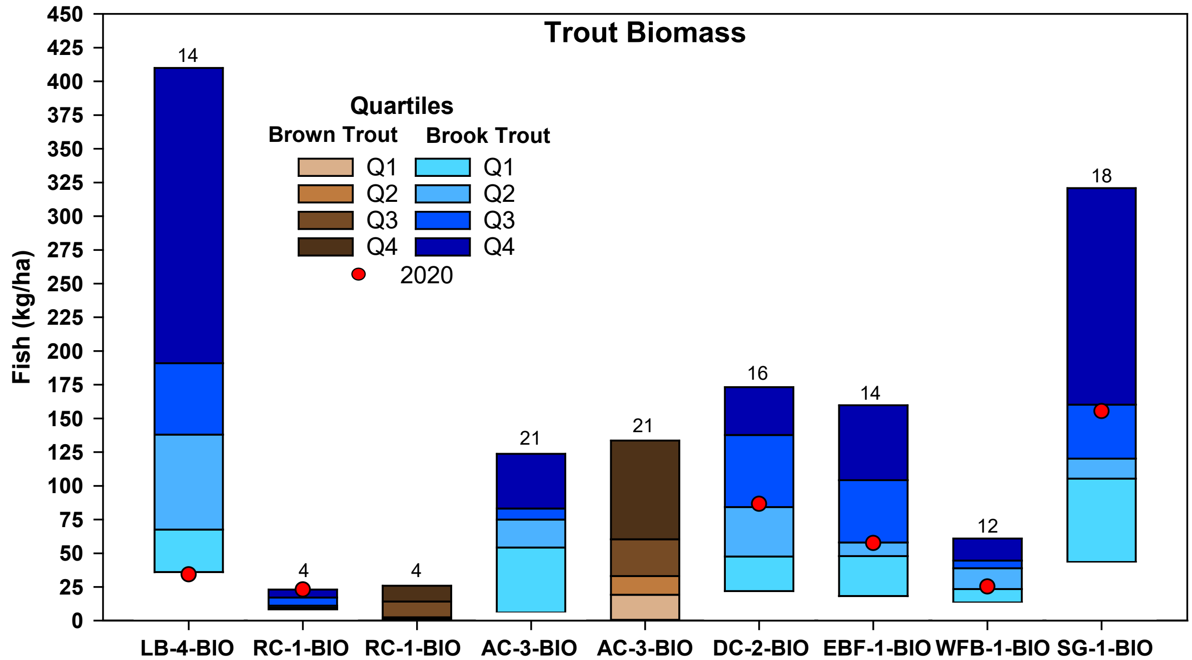

Figure 4-7: Quartile plots of Brook Trout and Brown Trout population biomass values at Wharf sites from 1990 through 2020. Brown trout collected in 2019 at EFB-1-BIO (n = 1) and in 2012 and 2017 at SG-1-BIO (n = 2 and n = 1, respectively) are not displayed. Sample size is displayed above each quartile and includes 2020. In 2020, AC-3-BIO was not sampled, and no Brown Trout were collected from RC- 1-BIO.

4.2.2 Reno Creek

Thirty seven Brook Trout were collected at Site RC-1-BIO in 2020 (Table 4-9; Appendix A) which is more than twice as many trout collected in previous years. However, no Brown Trout were collected in 2020 compared to five in 2019 and one in 2018. Most fish lengths ranged from 75 to 100 mm, with one fish at 179 mm, indicating that fish were all YOY except for one second year fish (Figure 4-8). Last year, all fish were second year age class and no YOY were observed. The abundance of fish less than 150 mm in 2020 was much greater than previous years (greater than Q4) and the abundance of fish greater than 150 mm were similar to that sampled since 2017 (within Q2; Figure 4-3, Table 4-10).

Density and biomass values have fluctuated since 2017 (Figure 4-4; Figure 4-5) and both were greater in 2020 than in previous years (both greater than Q4; Figure 4-6; Figure 4-7). During greater flows in fall of 2019, 2nd year fish likely moved into small streams, such as Reno Creek, to spawn and then moved downstream. A high number of YOY was then observed in 2020.

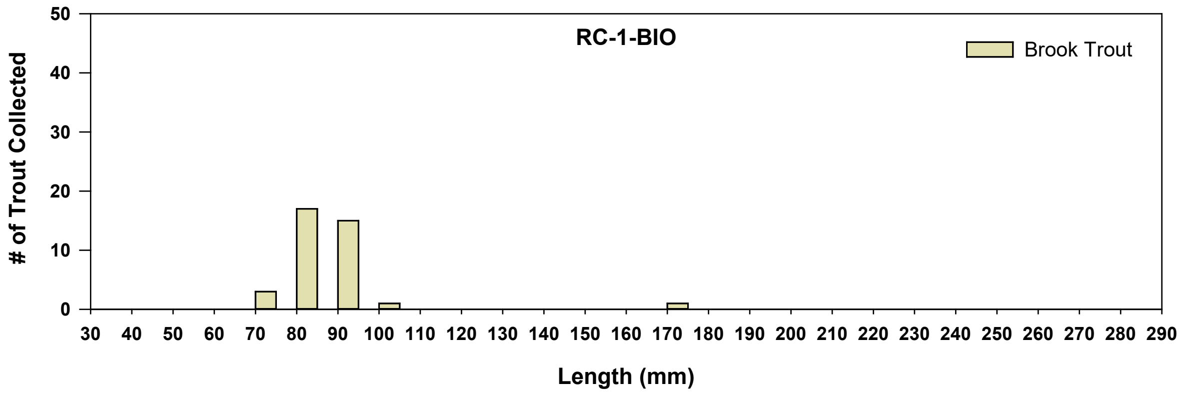

Figure 4-8: Length-frequency distribution for fish collected at Site RC-1-BIO in Reno Creek, August 2020.

As with Labrador Gulch, mean condition factor and relative weight values at Site RC-1-BIO were less than the optimal but similar to other sites sampled in 2020. Considering the reference type conditions found in Reno Creek basin, the lower condition factor and relative weight values at this site indicate variations in fish condition due to natural factors despite some development in the upper watershed.

No qualitative trends for abundance, density, or biomass or significant trends for relative weight or condition factor were observed for this site. However, trends are difficult to identify with only four years of data and should be interpreted with caution.

4.2.3 Annie Creek

4.2.3.1 Site AC-1-BIO

No fish were collected during sampling at Site AC-1-BIO in August 2020 (Appendix A). Fish have not been collected at this site in any year over the course of the study (GEI 2007a, 2008a, 2008c, 2009a, 2010a, 2011a, 2012, 2013, 2014, 2015, 2016, 2017a, 2018a, 2019, 2020). The absence of fish at this site reflects its headwater location upstream of perennial fish habitat (C&A 1993). Also, small waterfalls that either impede or prevent upstream fish migration are common in this section of Annie Creek.

4.2.3.2 Site AC-2-BIO

No fish were collected during sampling at Site AC-2-BIO in August 2020 (Appendix A). Mountain Sucker were collected in large numbers in the early 1990s, but populations declined after the 1995 ammonia and cyanide release, high BOD in 2007, and 2008 clean up (GEI 2008a, c). No fish have been collected at this site since 2010.

4.2.3.3 Site AC-3-BIO

The majority of lower Annie Creek, including most of Site AC-3-BIO was not accessible for fish collection in 2020 due to extensive deadfall from the tornado activity on July 8, 2020. Only a 20.4 m section, roughly 50 m upstream from bottom of reach, was accessible and qualitatively sampled with electrofishing equipment but no fish were collected.

Sampling began at this site in 1992, with annual sampling beginning in 2001, and Brook and Brown Trout have been collected in most years. YOY and first year age class Brook Trout were more numerous than second year class fish in all years but 2019 (Figure 4-3; Table 4-10). This change is part of an overall decreasing trend in YOY and first year class Brook Trout abundance since 2012 which was likely due to competition with Brown Trout which has increased in density since 2009. Even with this trend, the quartile data indicate that resident populations of Brook Trout utilize the lower portion of Annie Creek and that high numbers of YOY trout are sampled during some years and natural reproduction occurs in or near this reach.

YOY and first- and second-year age class Brown Trout have been collected from Site AC-3-BIO in most years since sampling began, although second year-plus age class Brown Trout are generally present in lower numbers (Figure 4-3; Table 4-10;). However, a large proportion of the Brown Trout sampled in 2016 to 2019 were second-age year class fish, and YOY were absent in 2016 to 2018. This indicates that in some years Site AC-3-BIO may act as a spawning and rearing stream for Brown Trout from Spearfish Creek, which is approximately 200 m downstream of the site.

The highest Brook Trout density and biomass values were observed in 2012 and values have trended downwards since (Figure 4-4; Figure 4-5). Brown Trout density at Site AC-3-BIO was greatest in 2019 while biomass was greatest in 2015. The dominant species as measured by biomass has been Brook Trout in most years, except for in 2015 through 2017, when Brown Trout comprised more of the total biomass at the site. Prior to 2016, Brown Trout had been collected in a more limited size range than Brook Trout in most years, indicating that this stream served as spawning and rearing habitat for Brown Trout. However, the population included a wider size range of Brown Trout in 2016 through 2019, indicating that this species may now inhabit Site AC-3 year-round.

Condition factors and relative weights for both species have been within or approaching optimal ranges in most years since 2006. Brook Trout condition factor significantly improved from 2006 to 2019 ($p = 0.02$, slope = 0.012 K/year) while relative weight did not trend, and no trend was observed for Brown Trout for either metric. Increased precipitation in 2018 following the 2017 drought in the Black Hills (NOAA 2020) appears to have positively affected relative weights and condition factors, indicating that low flows and generally associated higher water temperatures during the previous summer may have been causing stress to fish inhabiting Site AC-3-BIO. The long-term median relative weight and condition factor for Brook Trout were not significantly different than the reference site, Site LB-4-BIO.

4.2.4 Ross Valley

No fish were collected in this stream during sampling at Site RV-2-BIO from 2006 when sampling began at this site through 2020 (Table 4-11). The small stream size and habitat in Ross Valley remain inaccessible and unlikely to unsuitable to support fish.

Table 4-11: Fish population metrics for sites on Ross Valley, Lost Camp Gulch, Deadwood Creek, West Fork False Bottom Creek, and Cleopatra Creek, August 2020.

Site/Species	Number Collected	Mean Length (mm)	Mean Weight (g)	Density (#/ha) ± 95% C.I.	Biomass (kg/ha)	Relative Weight (W_r)	Condition (K)
RV-2-BIO	No Fish	--	--	--	--	--	--
LC-1-BIO	No Fish	--	--	--	--	--	--
DC-2-BIO							
Brook Trout	154	85.7	8.1	10,688 ± 1,000	86.57	82.9	0.91
EFB-1-BIO							
Brook Trout	80	81.7	7.1	8,100 ± 300	57.51	84.9	0.88
WFB-1-BIO							
Brook Trout	38	86.3	7.3	3,455 ± 82	25.22	86.2	0.91
CC-1A-BIO	No Fish	--	--	--	--	--	--

4.2.5 Lost Camp Gulch

No fish have been collected from Site LC-1-BIO from 2010 when sampling began at this site through 2020 (Table 4-11). Very low flows were observed in this site during 2016 and 2017 sampling, indicating that aquatic habitat at this site may be limited during drier years. Similar to sites AC-1-BIO, AC-2-BIO, and RV-2-BIO, the physical locations of Lost Camp Gulch, upstream of fish barriers, likely precludes any establishment of fish population.

4.2.6 Deadwood Creek

In August 2020, 154 Brook Trout were collected from Site DC-2-BIO (Table 4-11). Fish ranged in length from 50 mm to 182 mm (Appendix A), indicating that multiple age classes of fish were present (Figure 4-9). Fish less than 150 mm were especially abundant in 2020 and more numerous than larger Brook Trout (Figure 4-3; Table 4-10). In addition, the abundance of fish less than 150 mm and greater than 150 mm were similar to the annual abundances since 2001 when fish sampling began at this site (within Q4 and Q3, respectively). Multiple size classes of Brook Trout have been present in all years in which Site DC-2-BIO was sampled (GEI 2011a, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020), indicating consistent natural reproduction of Brook Trout in this reach of Deadwood Creek. Over the years, fewer second year-plus age class sized fish have been observed compared to YOY and first year age class fish at this site, indicating this section of stream may serve primarily as a spawning and rearing area. Deep water habitat is also minimal at this site, limiting suitable habitat for larger, second year-plus age class trout.

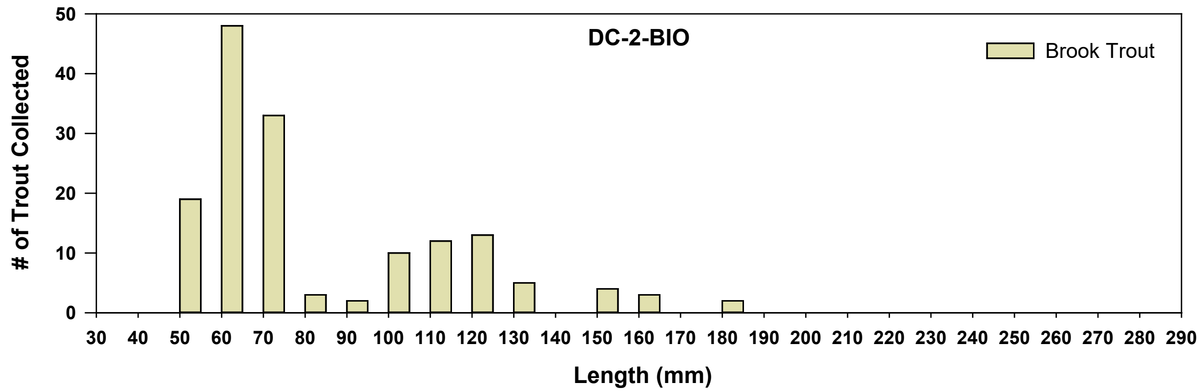

Figure 4-9: Length-frequency distribution for fish collected at Site DC-2-BIO in Deadwood Creek, August 2020.

Trout population density and biomass values have fluctuated since 2001 (Figure 4-4; Figure 4-5), and the 2020 values were within the range previously sampled (within Q4 and Q3, respectively; Figure 4-6; Figure 4-7). The highest Brook Trout density and biomass values were observed in 2017.

The relative weight and condition factor values of Brook Trout at this site were both less than the optimal ranges and have been decreasing since 2010, although not significantly. These trends may be due to the high density of fish sampled at this site in previous years. The historic high densities may have led to competition for limited food and habitat resources and could increase stress, reducing the overall condition of the Brook Trout population at this site. No other trends were observed for Brook Trout abundance, density, or biomass metrics.

When compared to the reference site, LB-4-BIO, the number of total fish, density, and biomass were greater at Site DC-2-BIO, but fish were larger (mean length and weight) and relative weight and condition factor were slightly higher at Site LB-4-BIO (Table 4-9; Table 4-11), although not significantly different between the sites. This indicates that the high numbers of fish may cause competition for food and habitat resources at Site DC-2-BIO.

4.2.7 False Bottom Creek

The site location on False Bottom Creek was inadvertently changed between the East Fork to the West Fork in some years; these locations are now designated as Site EFB-1-BIO and Site WFB-1-BIO, respectively. In 2006 and 2009-2010, Site EFB-1-BIO was sampled, and in 2007-2008 and 2011-2017, Site WFB-1-BIO was sampled. Both sites have been sampled since 2018. Fish populations from these two locations are discussed separately below.

4.2.7.1 Site EFB-1-BIO

Eighty Brook Trout were sampled at Site EFB-1-BIO in August 2020 (Table 4-11), and sizes ranged from 55 to 194 mm. All but three fish were YOY and first year age class fish, indicating natural reproduction in or near this site (Figure 4-10, Appendix A). In addition, the abundance of fish less than and greater than 150 mm in 2020 were similar to that sampled since 1995 when sampling began at this site (within Q3 and the median value for the site, respectively; Figure 4-3; Table 4-10). Over the years, fewer second year-plus age class fish have been observed compared to YOY and first year age class fish at this site, indicating this section of stream may serve primarily as a spawning and rearing area.

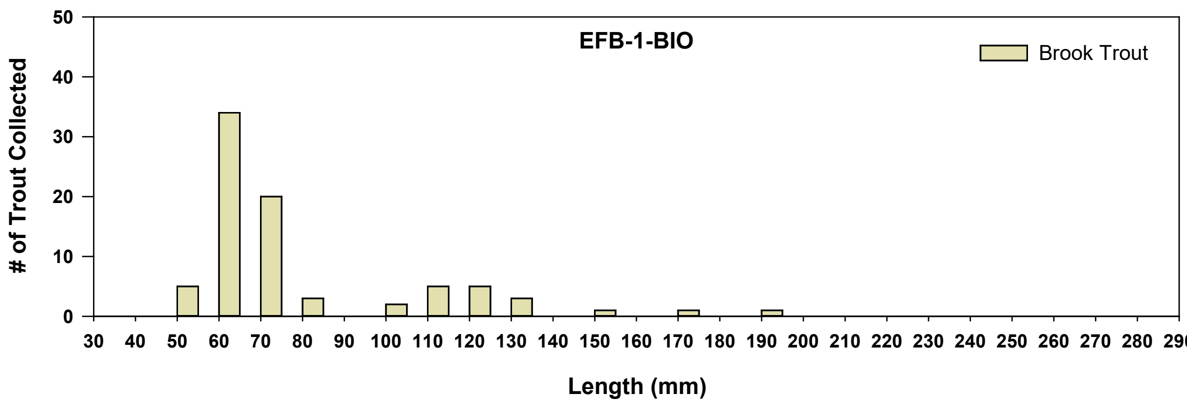

Figure 4-10: Length-frequency distribution for fish collected at Site EFB-1-BIO in False Bottom Creek, 2020.

Brook Trout population density and biomass at Site EFB-1-BIO have fluctuated from year to year since 1995 (Figure 4-4; Figure 4-5) and 2020 values within the ranges previously sampled (within Q3 and Q2, respectively; Figure 4-6; Figure 4-7). Density and biomass at Site EFB-1-BIO have typically been greater than at Site WFB-1-BIO, with median values comparable to the maximum density and biomass values at Site WFB-1-BIO.

The relative weight and condition factor values of Brook Trout at Site EFB-1-BIO were both less than the optimal ranges. Determining trends in the data at Site EFB-1-BIO is less than ideal given the variable sampling years, but no increasing or decreasing trends since 2006 were observed for abundance, density, and biomass. In addition, significant trends were not present for relative weight or condition factor.

When compared to the reference site on Labrador Gulch, Brook Trout density and biomass were greater at Site EFB-1-BIO while condition factor and relative weight were greater at Site LB-4-BIO (Table 4-9; Table 4-11), although not significantly.

4.2.7.2 Site WFB-1-BIO

Thirty-eight Brook Trout were collected at Site WFB-1-BIO in August 2020 (Table 4-11). Fish ranged from 62 to 145 mm and were comprised YOY and first year age class fish

(Figure 4-11; Appendix A). All fish were less than 150 mm in 2020 and fish less than 150 mm have been more numerous than larger Brook Trout in most years since 2007 when sampling began (Figure 4-3; Table 4-10). In addition, the number of YOY and first year age class Brook Trout collected in 2020 were similar to that sampled in previous years (within Q4) while the absence of second year-plus age class has occurred in other years since 2007 when sampling began at this site (within Q1).

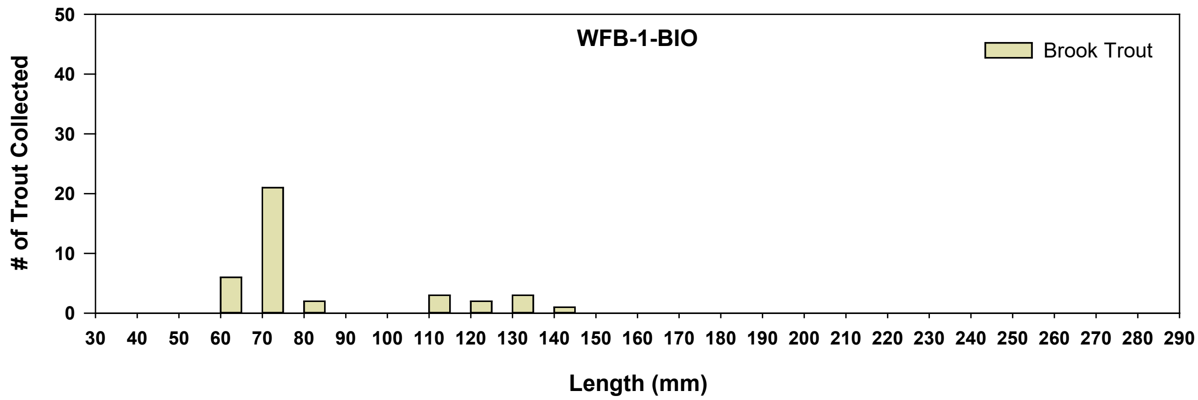

Figure 4-11: Length-frequency distribution for fish collected at Site WFB-1-BIO in False Bottom Creek, August 2020.

In 2007 and 2011, YOY were present, but second year-plus age class fish were absent (GEI 2008a, 2009a, 2012). In 2015, YOY Brook Trout were the most numerous age class, even though first year age class and second year-plus age class fish were also present in small numbers. In 2016 and 2017, few fish of any size class were observed, and YOY were either rare or absent. The total number of Brook Trout sampled in 2018 and 2019 was higher than in 2016 and 2017, but YOY remained rare or absent. This variation in size distribution observed at this site indicates that successful recruitment may be limited in some years, and fish may migrate into or out of Site WFB-1-BIO depending on habitat suitability.

Population density and biomass values have fluctuated since 2007 (Figure 4-4; Figure 4-5) with the 2020 values being within the range previously observed (within Q4 and Q2, respectively; Figure 4-6; Figure 4-7). The density observed in 2020 is similar to that observed in 2007 and 2008 which were higher than during most sampling events from 2011 to 2019, aside from in 2015 (Figure 4-4; Figure 4-5). Biomass values were moderate in 2007 and 2008, and comparable to most values measured from 2011 through 2020, aside from the low biomass values measured during 2011 and 2016 (Figure 4-4; Figure 4-5). Both population density and biomass values have typically been lower than values observed for Site EFB-1-BIO.

Relative weight and condition factor values at this site were less than optimal ranges (Table 4-11) and relative weight has slightly decreased between years since 2007, although not significantly. In addition, abundance of Brook Trout less than 150 mm has been increasing since 2016. No increasing or decreasing trends since 2007 were observed for density or biomass and no significant trend was found for condition factor.

The suitability of habitat on the West Fork of False Bottom Creek may be strongly influenced by streamflow in a given year. For instance, the particularly dry years of 2016 and 2017 (Figure 4-1) coincided with very low Brook Trout densities. In addition, the percent surface fines has historically been moderately poor in Site WFB-1-BIO which reduces habitat suitability for fish. Iron deposits are also often visible on the substrate within WFB-1-BIO, indicating water quality issues that may impact the fish population during some years.

When compared to the reference site on Labrador Gulch, the West Fork revealed a greater density estimate while the reference site contained a larger biomass of Brook Trout (Table 4-9; Table 4-11). The relative weights and conditions factors were very similar between the sites and not significantly different, but this relationship is influenced by the paucity of larger trout in the West Fork False Bottom Creek.

4.2.8 McKinley Gulch

McKinley Gulch was dry during August 2020 and was not sampled. Electrofishing has never been performed at this site due to no stream flow.

4.2.9 Cleopatra Creek

In 2020, residual pockets of water were present at Site CC-1A-BIO, but no surface flow occurred over the riffles and most pools were dry. Therefore, the decision was made to not sample, the same as in past years (2016, 2017, and 2019) when no flowing water was present at the site. In years when flowing water was present (2006 through 2015 and 2018), no fish were collected at Site CC-1A-BIO (Table 4-11). Historically, Brook Trout density and biomass had been high at the former Cleopatra Creek site, CC-1-BIO, which is located further downstream near the confluence with the East Fork Cleopatra Creek (CEC 2006a). However, the current site location is in the headwaters of Cleopatra Creek, where the lack of perennial flows is not suitable for fish.

4.2.10 Fantail Creek

Sampling in 2020 was conducted at Site FC-1-BIO on Fantail Creek, but no fish were found (Table 4-12). No fish have been collected during sampling in Fantail Creek except for six Brook Trout sampled in 1998. The presence of fish in 1998 was probably due to higher than normal summer flows, which allowed fish to move upstream from Nevada Gulch or Whitetail Creek during the late summer sampling period (CEC 1999b). Usually, the small stream size and low flows make this site unsuitable for fish.

Table 4-12: Fish population metrics for Fantail Creek, Nevada Gulch, and Stewart Gulch, August 2020.

Site/Species	Number Collected	Mean Length (mm)	Mean Weight (g)	Density #/ha ± 95% C.I.	Biomass (kg/ha)	Relative Weight (W_r)	Condition (K)
FC-1-BIO	No Fish	--	--	--	--	--	--
NG-2-BIO	No Fish	--	--	--	--	--	--
SG-1-BIO							
Brook Trout	144	117.9	22.2	7,000 ± 238	155.40	88.6	0.93

4.2.11 Nevada Gulch

No fish were found during the 2020 sampling event at NG-2-BIO (Table 4-12). Similar to the Fantail Creek site, the only year in which fish were present in lower Nevada Gulch was 1998, when a single Brook Trout was collected at Site NG-2-BIO. The higher flows in that year likely allowed this fish to move upstream from Whitetail Creek into lower Nevada Gulch (CEC 1999b). During most years, the small stream size and low flows make this site unsuitable for fish.

4.2.12 Stewart Gulch

One hundred and forty-four Brook Trout were collected from Stewart Gulch in August 2020 (Table 4-12). The Brook Trout ranged in size from 66 to 237 mm, indicating the presence of multiple age classes of fish (Figure 4-12; Appendix A). In 2020, an abundant number of YOY, first year, and second year-plus age class Brook Trout were collected, but YOY were the most prevalent. YOY and first year age class fish have dominated abundance in many other years since 1990. In addition, the abundance of YOY and first and second year-plus age class Brook Trout in 2020 were similar to that sampled in previous years (within Q3 and Q4, respectively).

These data indicate successful reproduction occurs in the reach and that habitat and water quality in Stewart Gulch have been suitable to sustain fish populations. Numerous YOY and first year age class fish have been collected in many years at Stewart Gulch and were the most abundant age classes in some years, indicating that conditions at the Stewart Gulch site are suitable for successful spawning and rearing. The abundant macrophyte beds in portions of this site likely act as favorable rearing habitat for YOY Brook Trout and help to protect them from predation by larger fish, birds, or mammals.

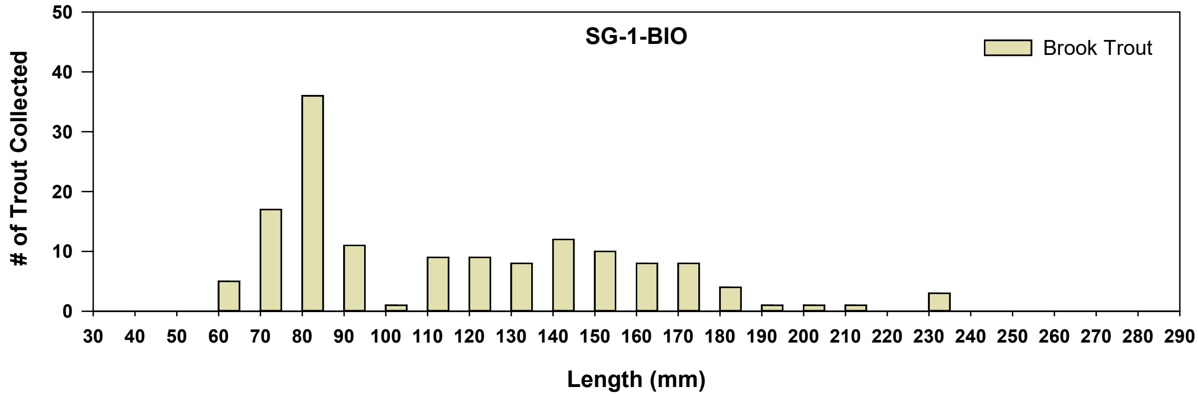

Figure 4-12: Length-frequency distribution for Brook Trout collected in Stewart Gulch, August 2020.

In 2012, two Brown Trout were collected in Stewart Gulch (GEI 2012), and one was collected during 2017 sampling (GEI 2018a). Brown Trout have been absent during all other years of sampling. These individuals likely moved upstream from the downstream reaches of Whitetail Creek or from Whitewood Creek.

Brook Trout density and biomass values have fluctuated since 1990 (Figure 4-4; Figure 4-5) and 2020 values were within the range previously sampled (both within Q3; Figure 4-6; Figure 4-7). The highest density of fish since 2006 was observed in 2014 (GEI 2015), and the highest observed biomass occurred in 2015 (Figure 4-4; Figure 4-5).

The average relative weight and condition factor values for Brook Trout were less than optimal ranges and relative weight has decreased, although not significantly (Table 4-12). No increasing or decreasing trends since 2006 were observed for abundance, density, biomass, or condition factor. Brown trout collected in 2012 and 2017 at SG-1-BIO (n = 2 and n = 1, respectively) are not displayed in the figures due to small sample size.

Density and biomass of Brook Trout at Site SG-1-BIO were both greater, although not significantly different from the reference site, Site LB-4-BIO, while relative weight and condition factor were roughly the same between the sites (Table 4-9; Table 4-12). In addition, relative weight and condition factor at both sites were below the optimal range of 95.0 to 105.0 and average value of 1.00, respectively. Generally healthy populations were found at both sites, even though some adult fish may be slightly below optimal weight. More robust fish condition values are often measured at the Stewart Gulch site. This is likely partially due to inputs of nitrogen from a spring upstream of the site, which facilitates the growth of watercress, creating both favorable habitat and enriching the lower levels of the food web (GEI 2015). Stewart Gulch also contains multiple deep pools and abundant aquatic vegetation, which act as favorable habitat for adult and juvenile Brook Trout, respectively.

4.3 Benthic Macroinvertebrate Populations

4.3.1 Labrador Gulch

4.3.1.1 2020 Data

In August 2020, richness, composition, tolerance, and trophic habit metric values were predominantly favorable at Site LB-4-BIO (Table 4-13; Table 4-14; Appendix C). Specifically, Density, Number of Taxa, Number of EPT Taxa, and EPT Index values were all good or moderate; Diversity indicated a healthy invertebrate community; the HBI score was "Excellent"; trophic habit metrics indicated a variety of feeding types; and life history metrics values indicated many short-lived and some long-lived taxa. In addition, Site LB-4-BIO has a greater Number of Plecoptera Taxa than any other site (Appendix B). Mayflies and caddisflies were abundant, however, 64% of the Ephemeroptera were *Baetis tricaudatus cx.* which indicate that many mayflies were relatively tolerant of environmental stressors. Overall, metric values for this site indicate that stream conditions (biotic and abiotic) in 2020 were suitable to support a rich and diverse benthic macroinvertebrate community, including numerous sensitive species.

Table 4-13: Macroinvertebrate Density (number of organisms/sample) at the reference sites on Labrador Gulch and Reno Creek, August 2020.

Taxa	LB-4-BIO	RC-1-BIO
INSECTA		
Collembola (springtails)	--	10
Ephemeroptera (mayflies)	995	835
Plecoptera (stoneflies)	555	715
Megaloptera (alderflies)	40	15
Coleoptera (beetles)	50	190
Trichoptera (caddisflies)	850	225
Diptera (true flies)	605	690
HYDRACARINA (water mites)	35	5
CRUSTACEA		
Amphipoda (Scuds)	--	700
TURBELLARIA (flatworms)	--	5
ANNELIDA (segmented worms)		
Oligochaeta (worms)	55	20

Table 4-14: Macroinvertebrate population metrics at the reference sites on Labrador Gulch and Reno Creek, August 2020. NA = Not applicable.

Metric	LB-4-BIO	RC-1-BIO
RICHNESS METRICS		
Density (#/sample)	3,185	3,410
Number of Taxa	44	45
Number of EPT Taxa	16	15

Metric	LB-4-BIO	RC-1-BIO
COMPOSITION METRICS		
Shannon-Weaver Diversity Index	4.04	4.18
Percent Sensitive EPT Taxa	27.3%	26.7%
EPT Index	36.4%	33.3%
Percent *Baetis sp.*	63.8%	29.3%
Number of non-*Baetis* Ephemeroptera	360	590
Percent Chironomidae	15.2%	16.6%
Number of Plecoptera Taxa	5	4
Percent Abundance of Oligochaetes & Hirudinea	1.7%	0.6%
Dominant Taxon (Tolerance value)	*Micrasema bactro* (1)	*Gammarus sp.* (4)
Percent Dominant Taxon	20.9%	20.5%
Number of Common Taxa	NA	NA
Community Loss Index	NA	NA
TOLERANCE METRICS		
Hilsenhoff Biotic Index	3.40	3.70
Percent Tolerant Taxa	27.3%	20.0%
Percent Intolerant Taxa	43.2%	48.9%
Number of Intolerant Taxa	19	22
TROPHIC HABIT METRICS		
Number of Predator Taxa	11	10
Percent Collector-Gatherers	43.6%	44.1%
Number of Shredder Taxa	8	8
LIFE HISTORY METRICS		
Number of Univoltine Taxa	20	23
Number of Merovoltine Taxa	1	0
Percent Semivoltine Taxa	2.3%	0.0%
Number of Semivoltine Taxa	3	1

4.3.1.2 Historic Data

The macroinvertebrate community at Site LB-4-BIO changed slightly from 2006 to 2020 and values were largely within the range of previous years. Richness metric values largely stayed consistent except for Density which significantly increased through the time period (Table 4-15; Figure 4-13; Appendix C). For composition metric values, Diversity has never been less than 2.5, indicating a history of a healthy invertebrate community. The Ephemeroptera assemblage was comprised mostly by *Baetis spp.*, a common and relatively tolerant mayfly genus. The only composition metrics with significant trends were Number of non-*Baetis* Ephemeroptera which has improved over time and Percent Chironomidae which has worsened (increased) since 2006.

Tolerance, trophic habit, and life history metric values have also shown few trends over time with the exception of HBI which has significantly worsened, ranging from "Excellent" (2.5 in 2007) to "Fair" (5.7 in 2019). The increasing HBI score indicates a greater abundance of more tolerant species such as the Chironomidae in recent years. Lastly, the Number of

Predator Taxa has significantly improved and the Percent Tolerant Taxa (27.3%) in 2020 was higher than any other year (previous maximum of 26.5% in 2009). Except for the significant improving trends in Density, Number of non-*Baetis* Ephemeroptera, and Number of Predator Taxa, and the significant worsening trends in Percent Chironomidae and the HBI score, the patterns in metrics over time showed no change.

Table 4-15: Slope of significant trends ($p < 0.05$) for benthic macroinvertebrate population metrics at the reference sites on Labrador Gulch and Reno Creek, 2006 - 2020. + = Positive slope. - = Negative slope. -- = Not significant. NA = Not applicable.

Taxa	Change Expected Following Environmental Disturbance	LB-4-BIO	RC-1-BIO
RICHNESS METRICS			
Density (#/sample)	Decrease	+ 266	--
Number of Taxa	Usually Decrease	--	+ 5.20
Number of EPT Taxa	Decrease	--	--
COMPOSITION METRICS			
Shannon-Weaver Diversity Index	Decrease	--	--
Percent Sensitive EPT Taxa	Decrease	--	+ 0.02
EPT Index	Decrease	--	--
Percent *Baetis sp.*	Increase	--	--
Number of non-*Baetis* Ephemeroptera	Decrease	+ 35.89	--
Percent Chironomidae	Increase	+ 0.02	--
Number of Plecoptera Taxa	Decrease	--	--
Percent Abundance of Oligochaetes & Hirudinea	Variable	--	--
Percent Dominant Taxon	Increase	--	--
Number of Common Taxa	Decrease	NA	NA
Community Loss Index	Increase	NA	NA
TOLERANCE METRICS			
Hilsenhoff Biotic Index	Increase	+ 0.10	--
Percent Tolerant Taxa	Increase	--	--
Percent Intolerant Taxa	Decrease	--	--
Number of Intolerant Taxa	Decrease	--	--
TROPHIC HABIT METRICS			
Number of Predator Taxa	Decrease	+ 0.38	--
Percent Collector-Gatherers	Variable	--	--
Number of Shredder Taxa	Decrease	--	+ 1.70
LIFE HISTORY METRICS			
Number of Univoltine Taxa	Increase	--	+ 2.30
Number of Merovoltine Taxa	Decrease	--	--
Number of Semivoltine Taxa	Decrease	--	--
Percent Semivoltine Taxa	Decrease	--	--

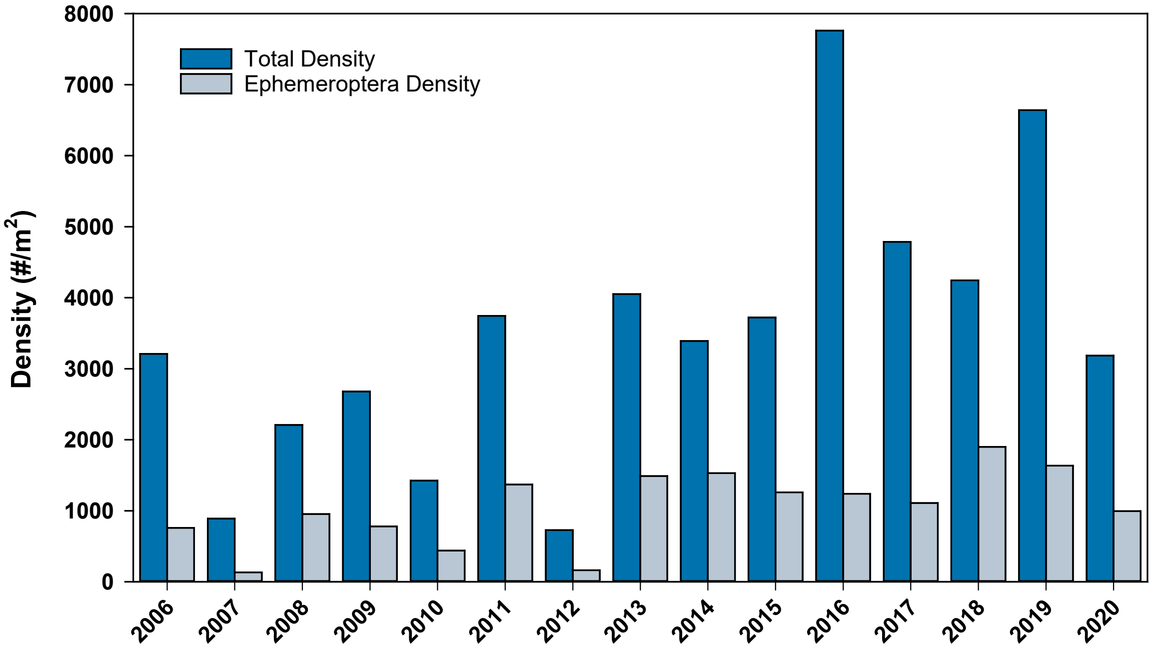

Figure 4-13: Macroinvertebrate density metrics for Site LB-4-BIO on Labrador Gulch, 2006 - 2020.

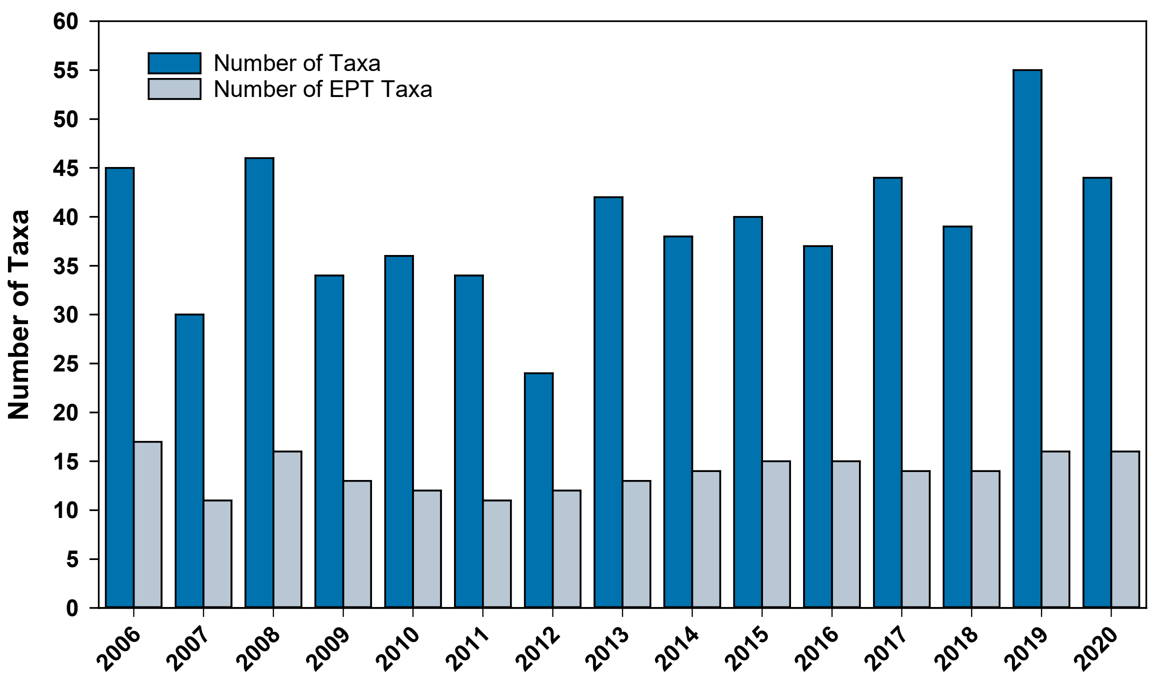

Figure 4-14: Macroinvertebrate taxa richness metrics for Site LB-4-BIO on Labrador Gulch, 2006 - 2020.

4.3.2 Reno Creek

4.3.2.1 2020 Data

Richness, composition, tolerance, and trophic habit metric values were predominantly favorable or moderately favorable at Site RC-1-BIO in August 2020 (Table 4-13; Table 4-14; Appendix C). Specifically, Density, Number of Taxa, Number of EPT Taxa, and EPT Index values were all moderate or good; Diversity indicated a healthy invertebrate community; the HBI indicated a “Very Good” benthic macroinvertebrate community including intolerant species; and a variety of feeding groups were present. However, life history metric values indicate that most taxa at the site have short life cycles. Overall, despite the life history metric values, stream conditions in 2020 were suitable to support a rich and diverse benthic macroinvertebrate community, including numerous sensitive species.

4.3.2.2 Historic Data

From 2017, when sampling began at Site RC-1-BIO, to 2020, the macroinvertebrate community has changed very little. Almost half of the 25 metric values in 2020 were outside the range observed in previous years (7 above and 4 below) but this frequency is to be expected with only four years of data collection (Figure 4-15; Figure 4-16; Appendix C). In the four years of sampling, the richness metric, Number of Taxa, has significantly improved (Table 4-15; Figure 4-16). For composition metrics, Diversity has been greater than 2.5 in all years of sampling indicating a healthy invertebrate community and the Ephemeroptera Density typically consisted of *Baetis spp.*, a common and relatively tolerant mayfly genus. In addition, Percent Sensitive EPT Taxa has significantly improved. The tolerance metric, HBI has ranged from “Fair” (5.64 in 2017) to “Very Good” (3.65 in 2020). Lastly, Number of Shredder Taxa, a trophic habit metric, has significantly improved over the years while Number of Univoltine Taxa, a life history metric, has significantly worsened. Overall, trends should be carefully interpreted at this site given the limited number of years this site has been sampled. However, the macroinvertebrate community appears to be consistently healthy.

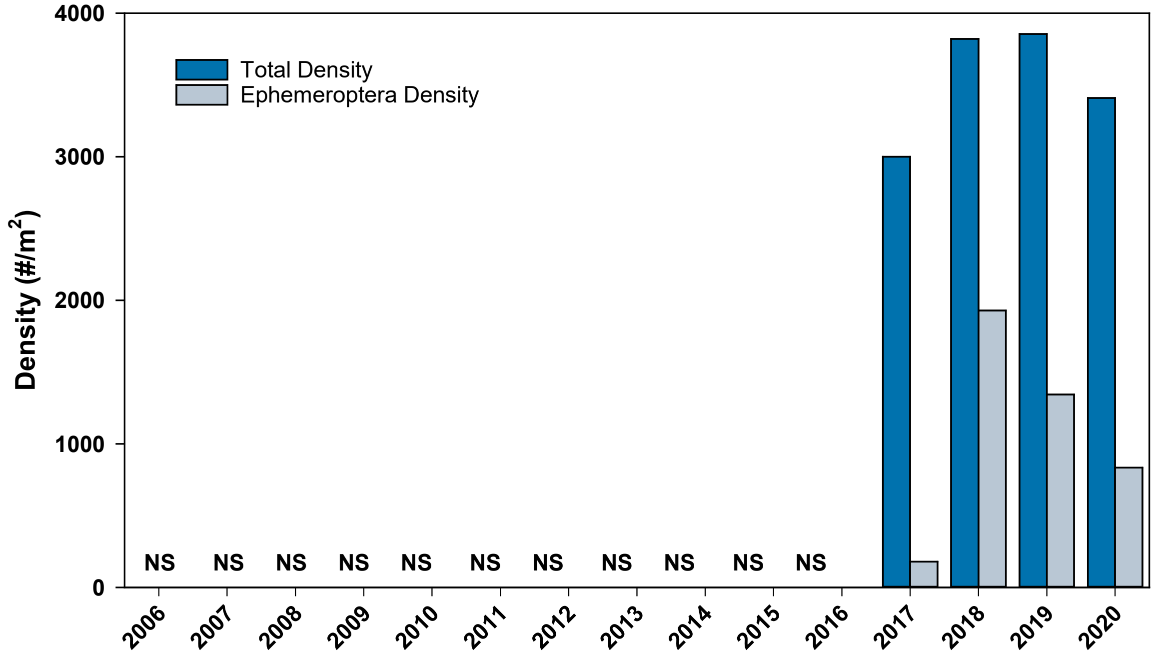

Figure 4-15: Macroinvertebrate density metrics at Site RC-1-BIO on Reno Creek, 2006 - 2020. NS = Not Sampled.

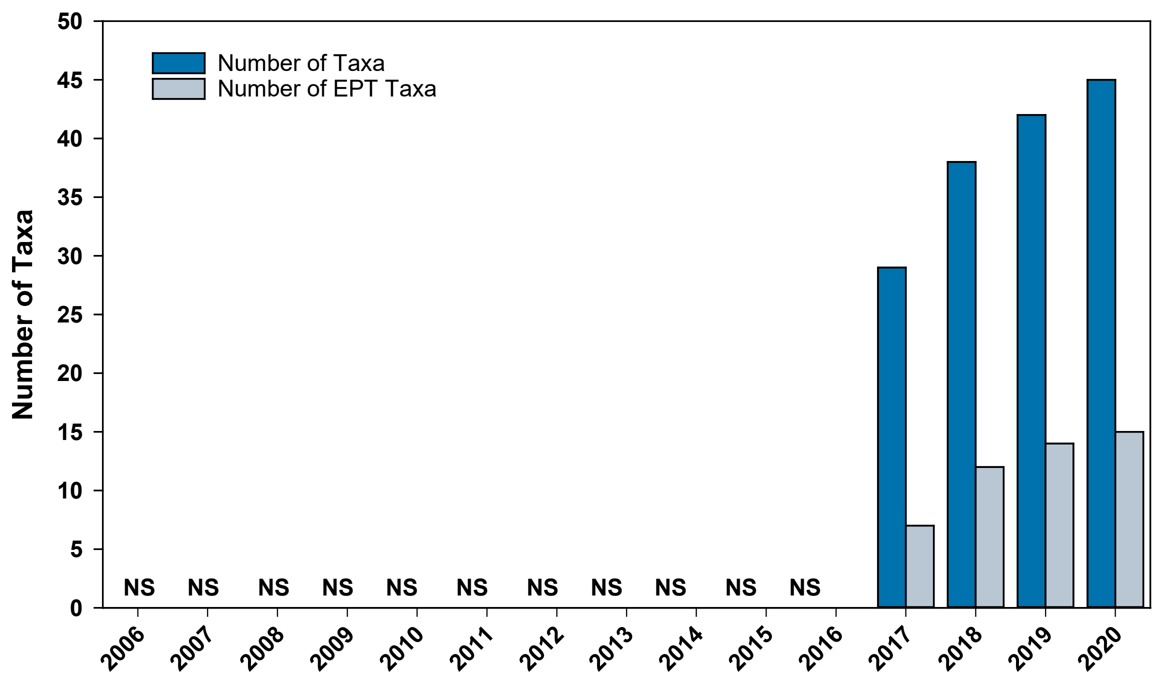

Figure 4-16: Macroinvertebrate taxa richness metrics for Site RC-1-BIO on Reno Creek, 2006 - 2020. NS = Not Sampled.

4.3.3 *Annie Creek*

4.3.3.1 Site AC-1-BIO

4.3.3.1.1 2020 Data

In August 2020, metric values were predominantly favorable or moderately favorable at Site AC-1-BIO (Table 4-16; Table 4-17; Appendix C). For example, Density, Number of Taxa, Number of EPT Taxa, and EPT Index values were all moderate or good; Diversity indicated a balanced invertebrate community; the HBI indicated an "Excellent" benthic macroinvertebrate community including intolerant species; and a diversity of feeding groups and life cycle lengths were present. Exceptions were the dominance of *Baetis tricaudatus cx.* at 75% of the Ephemeroptera population (Appendix B) and a relatively high Percent of Tolerant Taxa indicating that most mayflies were relatively tolerant of environmental stressors. Despite these less than favorable metric values, overall, stream conditions in 2020 were suitable to support a rich and diverse benthic macroinvertebrate community, including numerous sensitive species.

Table 4-16: Macroinvertebrate density (number of organisms/sample) at Annie Creek, August 2020.

Taxa	AC-1-BIO	AC-2-BIO
INSECTA		
Collembola (springtails)	5	--
Ephemeroptera (mayflies)	455	710
Plecoptera (stoneflies)	820	185
Coleoptera (beetles)	215	405
Trichoptera (caddisflies)	625	300
Diptera (true flies)	845	160
HYDRACARINA (water mites)	35	60
TURBELLARIA (flatworms)	935	--
NEMATODA (round worms)	--	5
ANNELIDA (segmented worms)		
Oligochaeta (worms)	80	30
MOLLUSCA		
Gastropoda (snails)	--	5
Pelecypoda (clams)	25	15

Benthic macroinvertebrate richness, composition, tolerance, trophic habit, and life history metric values at Site AC-1-BIO were comparable to those at the reference site, Site RC-1-BIO. Both sites contained favorable or moderately favorable Density, Number of Taxa, Number of EPT Taxa, Diversity, EPT Index, and HBI. However, the Ephemeroptera population at Site AC-1-BIO was dominated by *Baetis tricaudatus cx.* while the reference site contained a low percentage of *Baetis tricaudatus cx.* and a very high Number of non-*Baetis* Ephemeroptera. In addition, the life history metrics for Site AC-1-BIO were nearly identical to the reference Site RC-1-BIO metrics. The Community Loss Index indicates that approximately half of the taxa present at Site AC-1-BIO were also present at the reference site. Overall, despite the differences, the similarities between the site were numerous and both sites contained a healthy benthic macroinvertebrate community in August 2020 that was comparable to the community sampled at the reference site.

Table 4-17: Macroinvertebrate population metrics at Annie Creek, August 2020.

Metric	AC-1-BIO	AC-2-BIO
RICHNESS METRICS		
Density (#/sample)	4,040	1,875
Number of Taxa	44	48
Number of EPT Taxa	13	15
COMPOSITION METRICS		
Shannon-Weaver Diversity Index	4.17	3.88
Percent Sensitive EPT Taxa	20.5%	25.0%
EPT Index	29.5%	31.3%
Percent *Baetis sp.*	74.7%	82.4%
Number of non-*Baetis* Ephemeroptera	115	125
Percent Chironomidae	17.3%	6.4%
Number of Plecoptera Taxa	3	3
Percent Abundance of Oligochaetes & Hirudinea	2.0%	1.6%
Dominant Taxon (Tolerance value)	*Polycelis coronate* (1)	*Baetis tricaudatus cx.* (5)
Percent Dominant Taxon	23.1%	31.2%
Number of Common Taxa	21	26
Community Loss Index	55.0%	38.0%
TOLERANCE METRICS		
Hilsenhoff Biotic Index	3.10	4.10
Percent Tolerant Taxa	31.8%	27.1%
Percent Intolerant Taxa	45.5%	43.8%
Number of Intolerant Taxa	20	21
TROPHIC HABIT METRICS		
Number of Predator Taxa	12	13
Percent Collector-Gatherers	31.6%	52.3%
Number of Shredder Taxa	7	7
LIFE HISTORY METRICS		
Number of Univoltine Taxa	19	19
Number of Merovoltine Taxa	1	0
Percent Semivoltine Taxa	2.3%	0.0%
Number of Semivoltine Taxa	4	5

4.3.3.1.2 Historic Data

The macroinvertebrate community at Site AC-1-BIO has changed substantially from 2006 to 2020. The high concentrations of BOD, ammonia, and cyanide and the disturbance caused by removal of excess biomass from Annie Creek in 2007 resulted in most metric values being particularly poor in that and following years. Since then, richness metric values have significantly improved except for Density which has varied widely (1,247 in 2012 to 14,054 in 2017; Figure 4-17; Figure 4-18; Appendix C). For composition metric values, Diversity, EPT Index, Number of non-*Baetis* Ephemeroptera, Percent Dominant Taxon, Number of Common Taxa, and Community Loss Index have all significantly improved since 2006 (Table 4-18). The trend for Number of non-*Baetis* Ephemeroptera is the result of this metric being constantly zero prior to 2016. Diversity has been greater than 2.5 in all but two years, indicating a history of a healthy invertebrate community. Number of Common Taxa was also greater in 2020 than in previous years (maximum of 20 in 2019). The HBI tolerance metric has not significantly trended over time, ranging from “Fairly Poor” (6.79 in 2008) to “Excellent” (2.68 in 2012). The Percent and Number of Intolerant Taxa have both significantly improved with Number of Intolerant Taxa (20) greater in 2020 than any other year (previous maximum of 19 in 2017 and 2018). Two trophic habit metrics also significantly improved since 2006, Number of Predator Taxa, which was greater in 2020 than other years (previous maximum of 11 in 2017), and Number of Shredder Taxa, and one life history metric, Number of Merovoltine Taxa, was also greater in 2020 than other years (previous maximum of 3 in 2016). The only metric to decline in quality from 2006 to 2020 was the life history metric Number of Univoltine Taxa which exhibited an increase.

Overall, data in 2020 showed negligible change; metric values were similar to previous years. A number of metrics have improved from 2006 to 2020, indicating that the macroinvertebrate community has become healthier over time, particularly since the disturbances in 2007. As Site AC-1-BIO represents the headwaters of the drainage, there were limited populations of invertebrates in the immediate vicinity to repopulate the area. Upstream colonization (i.e., adult insects flying upstream to lay eggs near Site AC-1-BIO) by insects from areas downstream was responsible for slowly returning populations at Site AC-1-BIO to similar conditions observed prior to the 2007 disturbances (Williams and Hynes 1976; Williams 1980; Hawkins and Sedell 1990; Johnson and Vaughn 1995). In addition, historic median Abundance, Number of Taxa, Number of EPT Taxa, Diversity, EPT Index, HBI metric data between Site AC-1-BIO and its reference sites, Site RC-1-BIO, are not significantly different ($p > 0.05$). Overall, Site AC-1-BIO currently contains a rich and diverse community, with numerous intolerant taxa, indicative of healthy stream conditions.

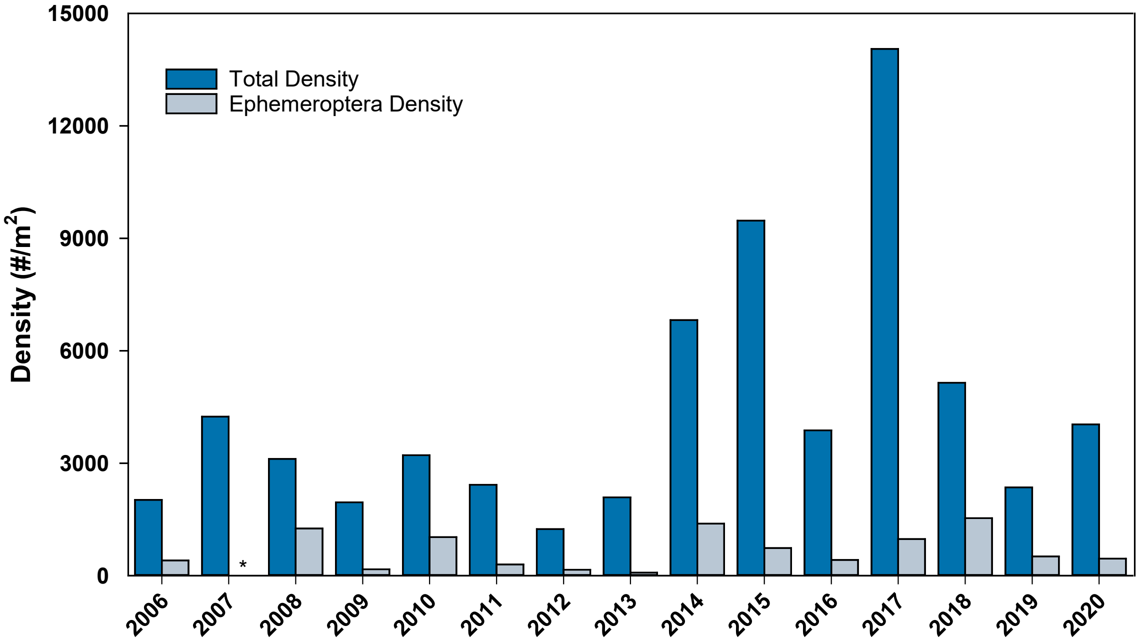

Figure 4-17: Macroinvertebrate density metrics for Site AC-1-BIO on Annie Creek, 2006 - 2020. * = Mayflies were present at low density.

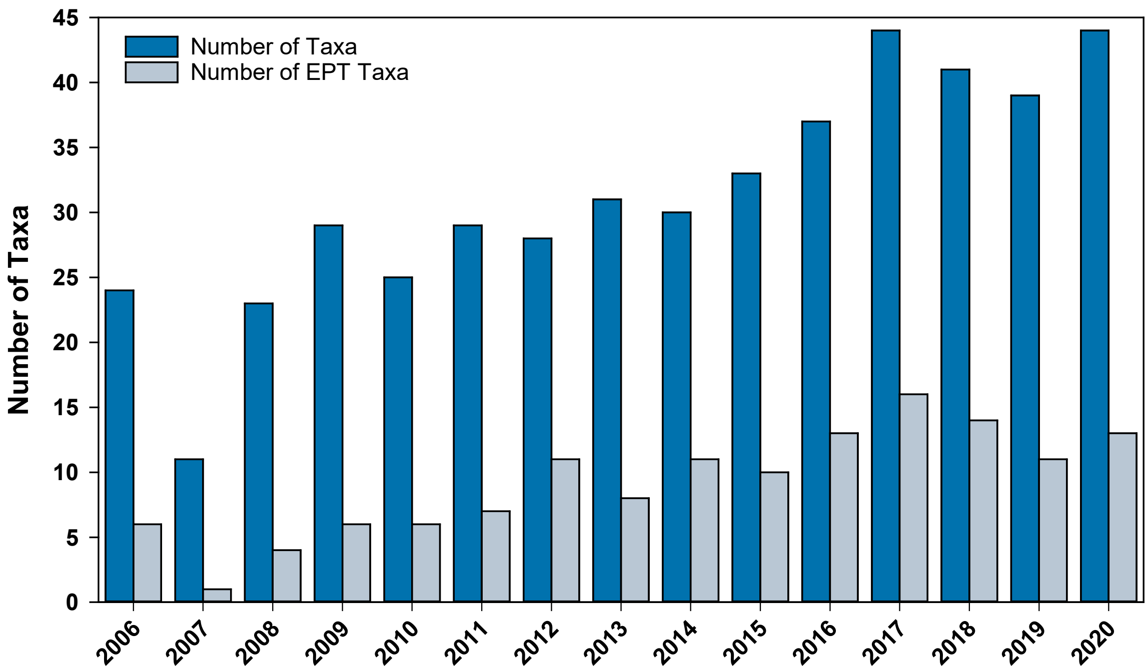

Figure 4-18: Macroinvertebrate taxa richness metrics for Site AC-1-BIO on Annie Creek, 2006 - 2020.

Table 4-18: Slopes of significant trends ($p < 0.05$) for macroinvertebrate population metrics at Annie Creek, 2006 - 2020. + = Positive slope. - = Negative slope. -- = Not significant.

Metric	Change Expected Following Environmental Disturbance	AC-1-BIO	AC-2-BIO	AC-3-BIO
RICHNESS METRICS				
Density (#/sample)	Decrease	--	--	--
Number of Taxa	Usually Decrease	+ 1.80	--	--
Number of EPT Taxa	Decrease	+ 0.81	--	- 0.38
COMPOSITION METRICS				
Shannon-Weaver Diversity Index	Decrease	+ 0.12	--	--
Percent Sensitive EPT Taxa	Decrease	--	--	- 0.01
EPT Index	Decrease	+ 0.01	--	- 0.01
Percent *Baetis sp.*	Increase	--	--	--
Number of non-*Baetis* Ephemeroptera	Decrease	+ 19.64	--	--
Percent Chironomidae	Increase	--	--	--
Number of Plecoptera Taxa	Decrease	--	--	- 0.16
Percent Abundance of Oligochaetes & Hirudinea	Variable	--	--	--
Percent Dominant Taxon	Increase	- 0.02	+ 0.01	--
Number of Common Taxa	Decrease	+ 1.32	--	--
Community Loss Index	Increase	- 0.10	--	--
TOLERANCE METRICS				
Hilsenhoff Biotic Index	Increase	--	--	+ 0.13
Percent Tolerant Taxa	Increase	--	--	+ 0.01
Percent Intolerant Taxa	Decrease	+ 0.01	--	- 0.01
Number of Intolerant Taxa	Decrease	+ 1.04	--	--
TROPHIC HABIT METRICS				
Number of Predator Taxa	Decrease	+ 0.60	--	--
Percent Collector-Gatherers	Variable	--	--	--
Number of Shredder Taxa	Decrease	+ 0.37	+ 0.28	+ 0.19
LIFE HISTORY METRICS				
Number of Univoltine Taxa	Increase	+ 1.01	--	--
Number of Merovoltine Taxa	Decrease	+ 0.15	--	--
Number of Semivoltine Taxa	Decrease	--	--	--
Percent Semivoltine Taxa	Decrease	--	--	--

Note: AC-3-BIO was not sampled in 2020 and trends are for 2006-2019 data.

4.3.3.2 Site AC-2-BIO

4.3.3.2.1 2020 Data

In August 2020, metric values were predominantly favorable or moderately favorable at Site AC-2-BIO (Table 4-16; Table 4-17; Appendix C). Density, Number of Taxa, Number of EPT Taxa, and EPT Index values were all moderate or good; Diversity indicated a balanced invertebrate community; the HBI indicated a "Very Good" benthic macroinvertebrate community including intolerant species; and a diversity of feeding groups and life cycle lengths were present. Metric values associated with the EPT community were better than in recent years but *Baetis tricaudatus cx.* was still the dominant Ephemeroptera at 82% indicating that many mayflies were relatively tolerant of environmental stressors. This high percentage is the result of increased sedimentation observed at the site in the past few years, which is tied to the dirt road adjacent to Lost Camp Gulch and Annie Creek immediately upstream of Site AC-2-BIO. Despite this metric value, overall, metrics for this site indicated that the stream conditions in 2020 were suitable to support a relatively abundant and diverse benthic macroinvertebrate community including intolerant species.

Benthic macroinvertebrate richness, composition, tolerance, trophic habit, and life history metric values at Site AC-2-BIO were comparable to those at the reference site, Site LB-4-BIO. Both sites contained favorable or moderately favorable Density, Number of Taxa, Number of EPT Taxa, Diversity, EPT Index, and HBI. Ephemeroptera populations at both sites were dominated by *Baetis tricaudatus cx.*; however, the Percent *Baetis sp.* and the Number of non-*Baetis* Ephemeroptera were higher at the reference site than at Site AC-2-BIO. HBI was also slightly better at the reference site. The Community Loss Index and Number of Common Taxa were the best of all sites monitored in 2020 and indicated that approximately 50% of the taxa present at Site AC-2-BIO were also present at the reference site. Overall, despite the differences, benthic macroinvertebrate communities from both sites in August 2020 were mostly comparable, rich, and diverse, with numerous intolerant taxa, indicative of good stream conditions.

4.3.3.2.2 Historic Data

From 2006 to 2020 at Site AC-2-BIO, the macroinvertebrate community exhibited a variable pattern in Density and taxa richness metrics, with the Number of Taxa and Number of EPT Taxa reaching a peak every four to five years. The water quality disturbance in Annie Creek in 2007 also affected Site AC-2-BIO but not to the same extent as Site AC-1-BIO. Total Density and Ephemeroptera Density were poor in 2007 but rebounded over the years; the Number of Taxa and Number of EPT Taxa rebounded much quicker (Figure 4-19; Figure 4-20; Appendix C).

These patterns in the data resulted in only a few significant trends in metric data (Table 4-18). Composition metrics which included Diversity has been greater than 2.5 in all years of sampling indicating a diverse invertebrate community. The only composition metric with a significant trend was the Percent Dominant Taxa which slightly declined in quality from 2006 to 2020. The very favorable Number of Common Taxa and Community Loss Index observed in 2020 were better than all other years (previous maximum of 23 in 2008 and previous minimum of 38.2% in 2013, respectively).

Tolerance, trophic habit, and life history metric values generally showed no trends over time. HBI has ranged from "Good" (5.4 in 2010) to "Very Good" (3.6 in 2009). The only trophic habit metric with a significant trend was the Number of Shredder Taxa which improved from 2006 to 2020. The life history metric, Number of Merovoltine Taxa was greater in 2020 than past years (previous maximum of 3 in 2009 and 2015). Overall, data in 2020 showed negligible change with metric values being similar to values observed in recent years.

Few median metric values were significantly different between these sites with median Number of EPT Taxa, EPT Index, and HBI values being significantly higher at the reference site, Site LB-4-BIO, than at Site AC-2-BIO from 2006 to 2020 ($p = 0.010$, $p = 0.002$, and $p = 0.002$, respectively). EPT taxa are sensitive to sedimentation, and sediments from the nearby dirt road has likely negatively impacted the suitability of this site for some EPT taxa.

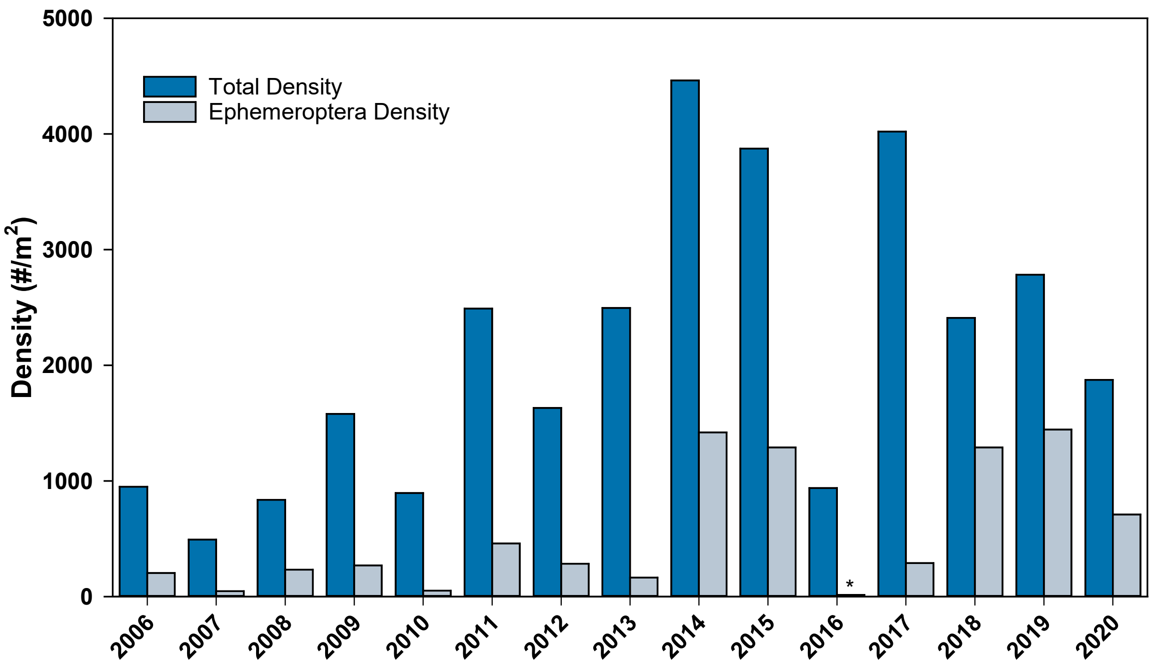

Figure 4-19: Macroinvertebrate density metrics for Site AC-2-BIO on Annie Creek, 2006 – 2020. * = Mayflies were present at low density.

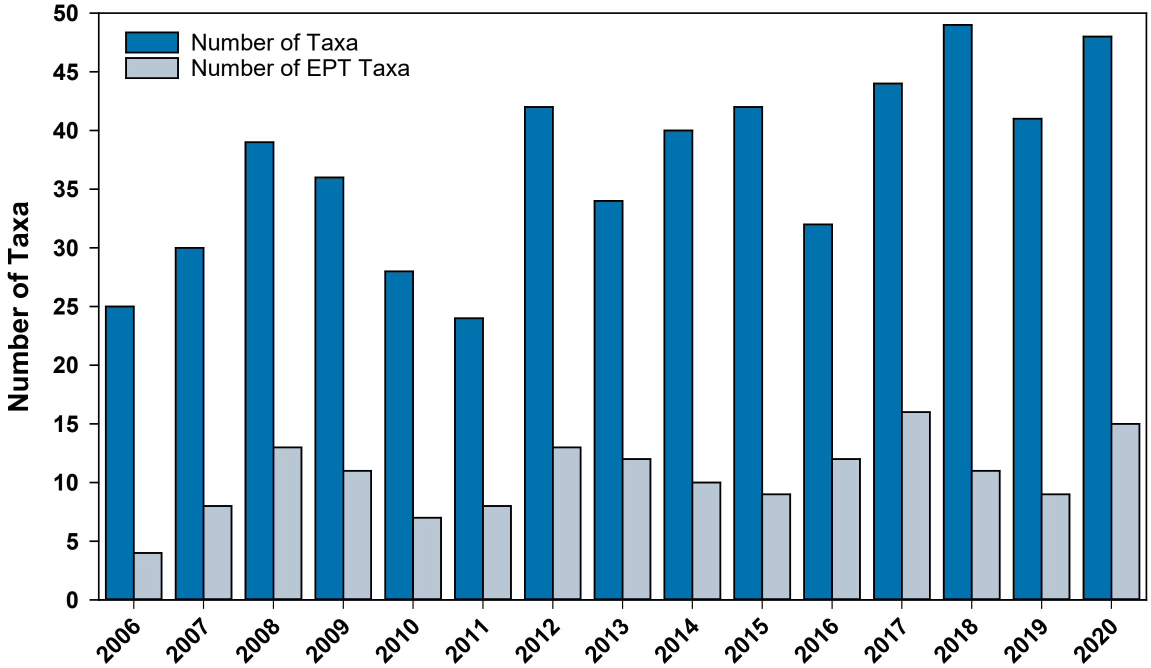

Figure 4-20: Macroinvertebrate taxa richness metrics for Site AC-2-BIO on Annie Creek, 2006 - 2020.

4.3.3.3 Site AC-3-BIO

4.3.3.3.1 2020 Data

The majority of Annie Creek at Site AC-3-BIO was not accessible for macroinvertebrate sampling in 2020 due to extensive deadfall from recent tornado activity, and samples were not collected (Photo 4-3).

4.3.3.3.2 Historic Data

The macroinvertebrate community at Site AC-3-BIO moderately changed from 2006 to 2019. However, these changes did not appear to be related to the water quality disturbance in 2007. Richness metric values largely stayed consistent with the Number of EPT Taxa significantly decreasing from 2006 to 2019 (Figure 4-21; Figure 4-22; Appendix C). For composition metrics, Diversity has never been less than 2.5 indicating a history of a healthy invertebrate community. Percent Sensitive EPT Taxa, EPT Index, and Number of Plecoptera values also significantly decreased from 2006 to 2019.

The tolerance metric HBI has ranged from “Excellent” (2.78 in 2007) to “Fair” (5.73 in 2003) but has significantly increased over time indicating an increase in more tolerant species. Percent Tolerant Taxa and Percent Intolerant Taxa have also both slightly but significantly declined in quality from 2006 to 2019. The only metric to improve at Site AC-3-BIO from 2006 to 2019 was the trophic habit metric Number of Shredder Taxa.

Overall, the EPT based-metrics have declined from 2006 to 2019, indicating that these assemblages have been stressed over this period. The reason for this decline is unknown at this time but the changes are specific to Site AC-3-BIO and are not representative of regional changes. Only the HBI metric trended in the same direction for Site AC-3-BIO and its reference site, Site LB-4-BIO. In fact, median values for Density, Number of Taxa, Number of EPT Taxa, Diversity, EPT Index, and HBI were not significantly different between the two sites ($p > 0.05$) indicating that the data sets were similar. Overall, historic benthic macroinvertebrate community metric data between the two sites are not different, despite the decrease in EPT based-metric values for Site AC-3-BIO. Site AC-3-BIO has maintained a rich and diverse community with numerous intolerant taxa, indicative of healthy stream conditions.

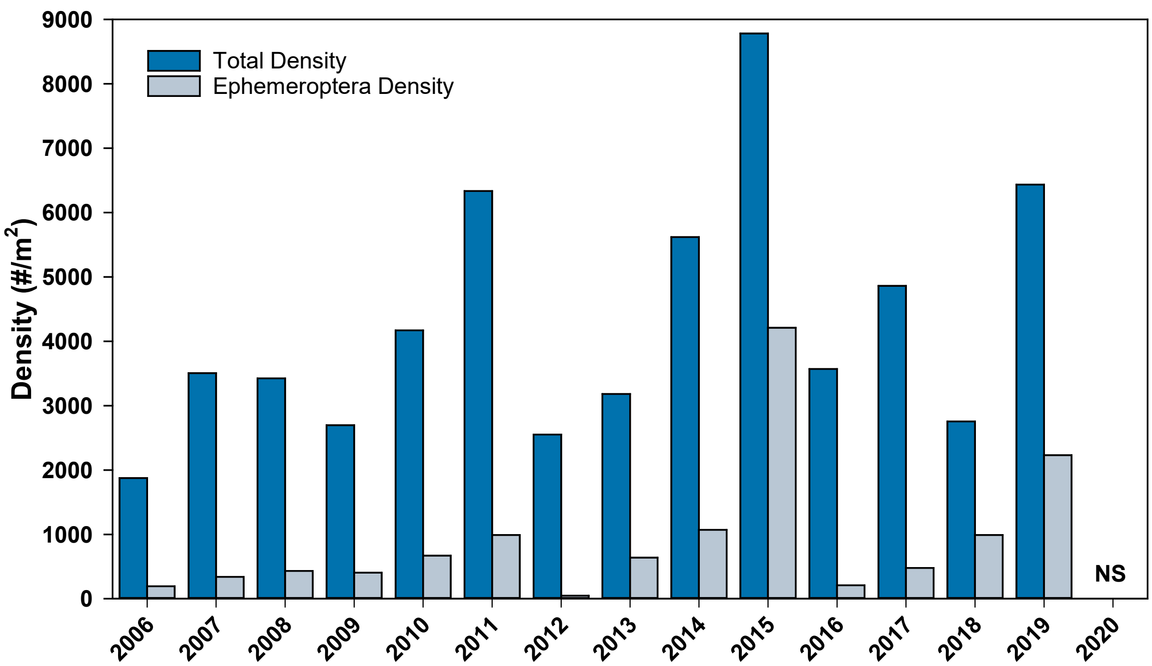

Figure 4-21: Macroinvertebrate density metrics for Site AC-3-BIO on Annie Creek, 2006 – 2020. NS = Not Sampled.

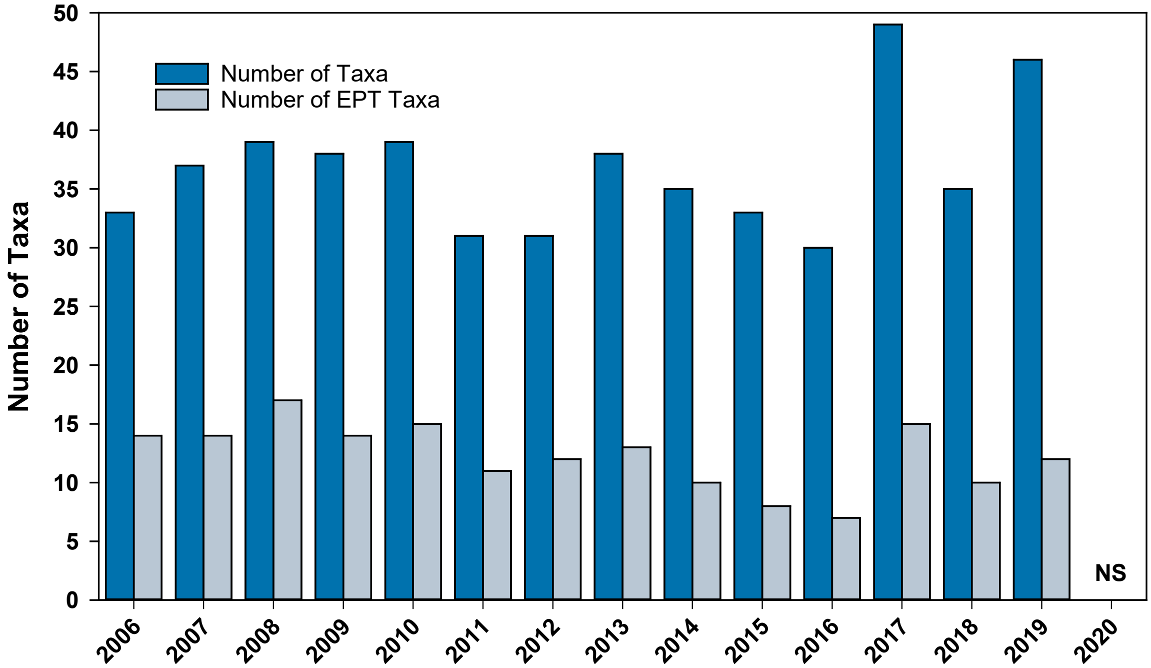

Figure 4-22: Macroinvertebrate taxa richness metrics for Site AC-3-BIO on Annie Creek, 2006 - 2020. NS = Not Sampled.

4.3.3.4 Site Comparisons

4.3.3.4.1 2020 Data

The metric results at the two Annie Creek sites sampled in 2020 were overall favorable and similar between sites with some distinct exceptions (Table 4-16; Table 4-17; Appendix C). Density at Site AC-1-BIO was roughly two times greater than at Site AC-2-BIO while Number of Taxa, Number of EPT Taxa, Diversity, EPT Index, and HBI were moderate or good at both sites. Both sites contain a diversity of feeding groups and life cycle lengths. The Percent *Baetis sp.* was unfavorable at both sites. Community Loss Index, HBI, and Percent Collector-Gatherers results were more favorable at Site AC-1-BIO than at Site AC-2-BIO. The differences in metrics between sites are likely the result of varying stream size and the presence of tributaries, primarily Lost Camp Gulch which impacted habitat quality at Site AC-2-BIO.

4.3.3.4.2 Historic Data

Even though differences in the macroinvertebrate communities along Annie Creek appear to be influenced by stream size and sedimentation issues, the long-term median values for Density, Number of Taxa, Number of EPT Taxa, Diversity, EPT Index, and HBI values are not significantly different among the three sites ($p < 0.05$).

4.3.4 Ross Valley

4.3.4.1 2020 Data

Richness, composition, tolerance, and trophic habit metric values were predominantly favorable or moderately favorable at Site RV-2-BIO in August 2020 (Table 4-19; Table 4-20; Appendix C). Specifically, Density, Number of Taxa, and Number of EPT Taxa values were all moderate or good; EPT Index was the best of any site; Diversity was indicative of a healthy invertebrate community; Percent Chironomidae was the lowest of any site; and the HBI and Percent Tolerant and Intolerant Taxa were better than all or most other sites and indicated an "Excellent" benthic macroinvertebrate community including intolerant species. An exception to the favorable values was the low Number of Predator Taxa. In addition, life history metrics indicated that most taxa at the site have a short life cycle. Overall, stream conditions in 2020 were suitable to support a rich and diverse benthic macroinvertebrate community (Appendix B) containing intolerant taxa.

Benthic macroinvertebrate richness, composition, tolerance, trophic habit, and life history metric values at Site RV-2-BIO were comparable to those at the reference site, Site RC-1-BIO. Both sites revealed favorable or moderately favorable richness metrics, Diversity, EPT Index, and HBI. The Number of Taxa and EPT Taxa, Diversity, Percent *Baetis sp.*, and the Number of non-*Baetis* Ephemeroptera were slightly better at the reference site than at Site RV-2-BIO indicating a slightly more favorable EPT community. However, Percent Chironomidae, HBI, Percent and Number Intolerant Taxa, and Number of Univoltine Taxa were more favorable at Site RV-2-BIO. These differences between the sites resulted in a Community Loss Index value of 104, indicating that Site RV-2-BIO contained considerably fewer taxa and had less taxa in common when compared to the reference site. Overall, despite the differences, some similarities between the sites were apparent with both sites containing a healthy benthic macroinvertebrate community in August 2020.

Table 4-19: Macroinvertebrate density (number of organisms/sample) at Ross Valley, Lost Camp Gulch, Deadwood Creek, and East and West Fork False Bottom Creek, August 2020.

Taxa	RV-2-BIO	LC-1-BIO	DC-2-BIO	EFB-1-BIO	WFB-1-BIO
INSECTA					
Collembola (springtails)	--	--	10	--	1
Ephemeroptera (mayflies)	380	1,310	165	570	--
Plecoptera (stoneflies)	243	10	310	745	20
Megaloptera (alderflies)	--	--	180	--	4
Coleoptera (beetles)	33	205	50	155	7
Trichoptera (caddisflies)	33	170	75	160	48
Diptera (true flies)	192	470	3,390	255	191
HYDRACARINA (water mites)	3	5	--	5	--
CRUSTACEA					
Amphipoda (Scuds)	13	--	--	--	--
TURBELLARIA (flatworms)	433	--	--	--	--
ANNELIDA (segmented worms)					
Oligochaeta (worms)	3	15	5	85	9
MOLLUSCA					
Pelecypoda (clams)	3	15	30	--	4

Table 4-20: Macroinvertebrate population metrics at Ross Valley, Lost Camp Gulch, Deadwood Creek, and East and West Fork False Bottom Creek, August 2020.

Metric	RV-2-BIO	LC-1-BIO	DC-2-BIO	EFB-1-BIO	WFB-1-BIO
RICHNESS METRICS					
Density (#/sample)	1,336	2,200	4,215	1,975	284
Number of Taxa	26	27	33	31	27
Number of EPT Taxa	10	8	11	11	6
COMPOSITION METRICS					
Shannon-Weaver Diversity Index	3.04	2.81	3.27	3.40	3.72
Percent Sensitive EPT Taxa	26.9%	14.8%	27.3%	29.0%	14.8%
EPT Index	38.5%	29.6%	33.3%	35.5%	22.2%
Percent *Baetis sp.*	54.5%	87.4%	18.2%	75.4%	0.0%
Number of non-*Baetis* Ephemeroptera	173	165	135	140	0
Percent Chironomidae	1.9%	19.3%	79.4%	4.6%	58.1%
Number of Plecoptera Taxa	4	1	3	4	1
Percent Abundance of Oligochaetes & Hirudinea	0.2%	0.7%	0.1%	4.3%	3.2%
Dominant Taxon (Tolerance value)	*Polycelis coronata* (1)	*Baetis tricaudatus cx.* (5)	*Trissopelopia sp.* (6)	*Zapada cinctipes* (2)	*Polypedilum sp.* (6)

Metric	RV-2-BIO	LC-1-BIO	DC-2-BIO	EFB-1-BIO	WFB-1-BIO
Percent Dominant Taxon	32.4%	52.0%	39.4%	32.4%	25.7%
Number of Common Taxa	18	12	19	15	12
Community Loss Index	104.0%	122.0%	76.0%	94.0%	119.0%
TOLERANCE METRICS					
Hilsenhoff Biotic Index	2.90	5.00	4.90	3.30	5.10
Percent Tolerant Taxa	15.4%	29.6%	15.2%	16.1%	22.2%
Percent Intolerant Taxa	61.5%	48.1%	54.5%	51.6%	40.7%
Number of Intolerant Taxa	16	13	18	16	11
TROPHIC HABIT METRICS					
Number of Predator Taxa	5	5	8	10	9
Percent Collector-Gatherers	41.1%	69.1%	19.7%	44.8%	19.4%
Number of Shredder Taxa	6	5	6	2	5
LIFE HISTORY METRICS					
Number of Univoltine Taxa	10	16	19	12	13
Number of Merovoltine Taxa	0	1	0	1	0
Percent Semivoltine Taxa	0.0%	3.7%	0.0%	3.2%	0.0%
Number of Semivoltine Taxa	2	1	1	3	3

4.3.4.2 Historic Data

From 2006 to 2020, the macroinvertebrate community at Site RV-2-BIO changed very little except for Density which was variable over time. Richness, composition, tolerance, trophic habit, and life history metric values have largely stayed consistent over these years (Figure 4-23; Figure 4-24; Appendix C) and not trended except for Number of Common Taxa and Percent Intolerant Taxa which both increased significantly (Table 4-21). In addition, the 2020 Percent Chironomidae, Percent Tolerant Taxa, and Number of Univoltine Taxa were all less than the values observed in previous years (minimums of 2.5% in 2009, 17.9% in 2014, and 11 in 2012, respectively) while Percent Intolerant Taxa was greater than in past years (previous maximum of 52.2% in 2012). Diversity has been greater than 2.5 in all years of sampling, indicating a healthy invertebrate community. In addition, the HBI metric fluctuated from "Good" (5.47) to "Excellent" (2.77). The subset of historic benthic macroinvertebrate community metric values (see Section 3.6) were not substantially different between Site RV-2-BIO and its reference site, Site RC-1-BIO. Overall, data in 2020 indicated negligible changes with the metric values similar to those in previous years.

Table 4-21: Slopes of significant trends ($p < 0.05$) for macroinvertebrate population metrics at Ross Valley, Lost Camp Gulch, Deadwood Creek, East Fork False Bottom Creek, and West Fork False Bottom Creek, 2006 - 2020. + = positive slope. - = negative slope. -- = not significant.

Metric	Change Expected Following Environ-mental Disturbance	RV-2-BIO	LC-1-BIO	DC-2-BIO	EFB-1-BIO	WFB-1-BIO
RICHNESS METRICS						
Density (#/sample)	Decrease	--	--	--	--	--
Number of Taxa	Usually Decrease	--	--	--	--	--
Number of EPT Taxa	Decrease	--	- 0.71	--	--	- 0.36
COMPOSITION METRICS						
Shannon-Weaver Diversity Index	Decrease	--	- 0.13	--	--	- 0.07
Percent Sensitive EPT Taxa	Decrease	--	- 0.02	--	--	- 0.01
EPT Index	Decrease	--	- 0.02	- 0.01	--	--
Percent *Baetis sp.*	Increase	--	--	- 0.05	--	--
Number of non-*Baetis* Ephemeroptera	Decrease	--	--	--	--	--
Percent Chironomidae	Increase	--	--	--	--	--
Number of Plecoptera Taxa	Decrease	--	- 0.26	--	--	- 0.25
Percent Abundance of Oligochaetes & Hirudinea	Variable	--	--	--	--	--
Percent Dominant Taxon	Increase	--	--	--	--	--
Number of Common Taxa	Decrease	+ 0.63	--	+ 0.58	--	--
Community Loss Index	Increase	--	--	--	--	--
TOLERANCE METRICS						
Hilsenhoff Biotic Index	Increase	--	--	--	--	--
Percent Tolerant Taxa	Increase	--	--	--	--	--
Percent Intolerant Taxa	Decrease	+ 0.01	--	--	--	--
Number of Intolerant Taxa	Decrease	--	--	--	--	- 0.42
TROPHIC HABIT METRICS						
Number of Predator Taxa	Decrease	--	--	--	+ 0.37	--
Percent Collector-Gatherers	Variable	--	--	--	--	--
Number of Shredder Taxa	Decrease	--	--	+ 0.37	--	--
LIFE HISTORY METRICS						
Number of Univoltine Taxa	Increase	--	--	+ 0.57	--	- 0.54
Number of Merovoltine Taxa	Decrease	--	--	--	--	--
Number of Semivoltine Taxa	Decrease	--	--	--	--	--
Percent Semivoltine Taxa	Decrease	--	--	--	--	--

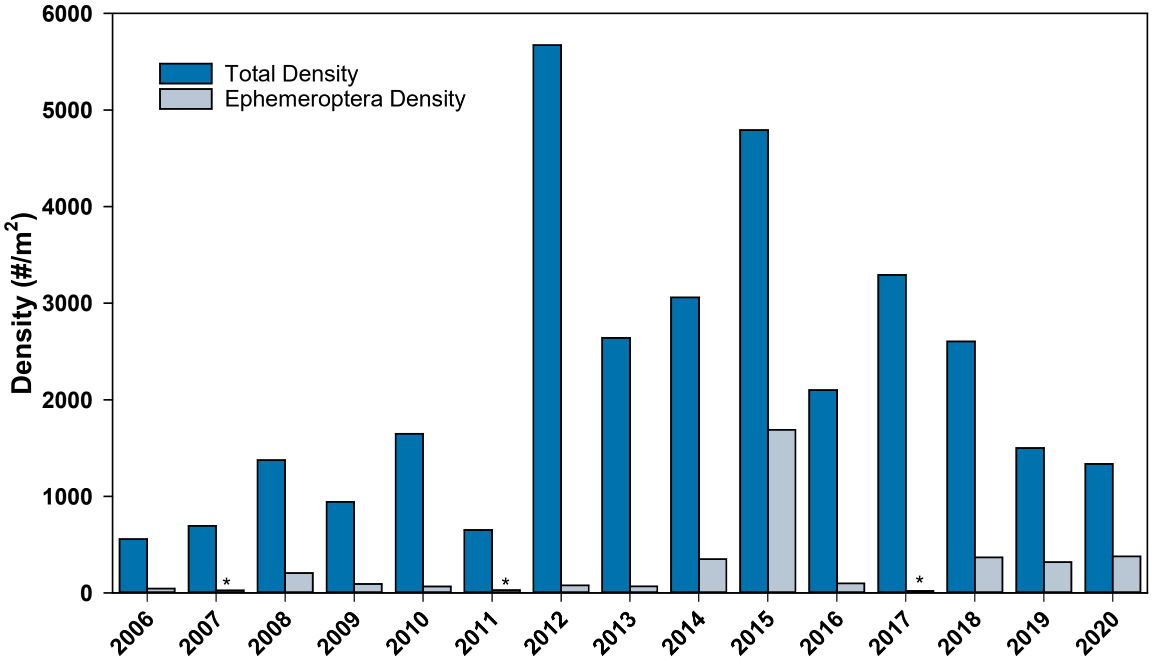

Figure 4-23: Macroinvertebrate density metrics for Site RV-2-BIO on Ross Valley, 2006 - 2020. * = Mayflies were present at low density.

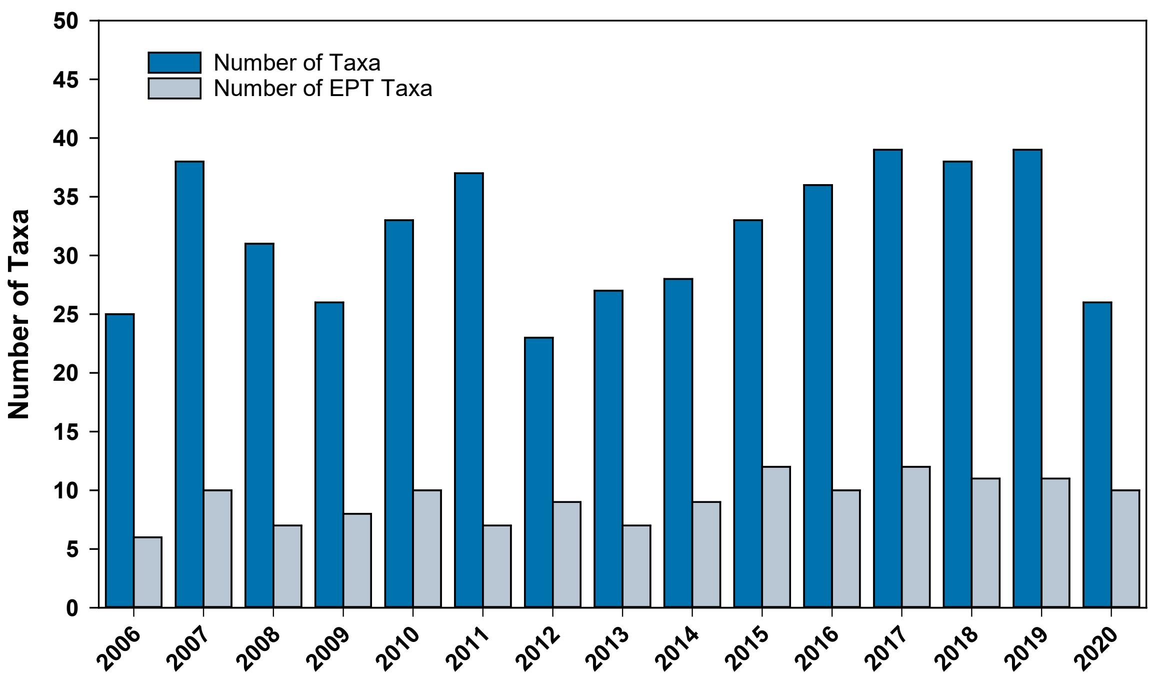

Figure 4-24: Macroinvertebrate taxa richness metrics for Site RV-2-BIO on Ross Valley, 2006 - 2020.

4.3.5 Lost Camp Gulch

4.3.5.1 2020 Data

In August 2020, richness, composition, and tolerance metric values were predominantly favorable or moderately favorable at Site LC-1-BIO (Table 4-19; Table 4-20; Appendix C). Density, Number of Taxa, Number of EPT Taxa, and EPT Index values were all moderate or good; Diversity indicated a balanced invertebrate community; and the HBI indicated a "Good" benthic macroinvertebrate community including intolerant species. Metric values associated with the EPT community were better than in recent years and still indicated a moderately healthy community. However, *Baetis tricaudatus cx.* was the dominant taxon at 87% (Appendix B), Sensitive EPT taxa comprised a low percentage of the population, and only one Plecoptera taxa was collected indicating that most EPT taxa were relatively tolerant of environmental stressors. Lastly, trophic habit metrics indicated that the community was dominated by collectors-gatherers and life history metrics indicated the community was dominated by short lived taxa. These deficiencies are the result of the low flows and resulting increased sedimentation observed in the past few years, which is strongly linked to the dirt road adjacent to Lost Camp Gulch. Despite the unfavorable EPT and related metric values, overall, metrics for this site indicated that the stream conditions in 2020 were suitable to support a relatively abundant and diverse benthic macroinvertebrate community including intolerant species.

Benthic macroinvertebrate richness, composition, tolerance, trophic habit, and life history metric values at Site LC-1-BIO were mostly not comparable to those at the reference site, Site RC-1-BIO. This difference is largely because the reference site contained a higher quality EPT community while Site LC-1-BIO contained far less non-*Baetis* Ephemeroptera individuals. Overall, only 12 taxa were shared between the sites with the reference site containing 33 taxa not found at Site LC-1-BIO (Appendix B). As a result, Number of Taxa and EPT Taxa, Diversity, Percent Sensitive EPT Taxa, Percent *Baetis sp.*, Number of non-*Baetis* Ephemeroptera, Number of Plecoptera Taxa, HBI, Number of Intolerant Taxa, Number of Predator Taxa, Number of Shredder Taxa, and Number of Univoltine Taxa metrics were all more favorable at the reference site. However, many of these metrics were still considered good at Site LC-1-BIO, and Diversity and HBI calculations, which are not solely dependent on EPT taxa, indicated a healthy benthic macroinvertebrate community at both sites.

The community at Site LC-1-BIO is more limited by the lack of flushing flows and resulting sedimentation than some other Wharf study sites. The site is still recovering from the low flow conditions in 2016 and 2017 which limited aquatic habitat for benthic macroinvertebrates. The benthic macroinvertebrate diversity has improved over the past year, and in 2020, the community included intolerant taxa which is indicative of better stream conditions.

4.3.5.2 Historic Data

The macroinvertebrate community at Site LC-1-BIO has moderately changed from 2010, when sampling began, to 2020. Density has fluctuated over time, often due to highly variable numbers of *Baetis* or *Fallceon* mayflies from year to year. These genera are widespread and moderately tolerant of water quality conditions. All richness metrics revealed poor values in 2019 but improved some in 2020 (Figure 4-25; Figure 4-26; Appendix C). Number of EPT Taxa was the only richness metric to significantly decrease from 2010 to 2020 (Table 4-21).

For composition metric values from 2010 to 2020, Diversity, Percent Sensitive EPT Taxa, EPT Index values, and Number of Plecoptera Taxa significantly declined in quality over time (Table 4-21). However, Diversity has been less than 2.5 only once in recent years indicating a history of a diverse invertebrate community. The 2020 HBI tolerance metric was within the range of previously recorded values, ranging from “Fair” (5.9 in 2014) to “Very Good” (3.7 in 2010). Ephemeroptera density was greater in 2020 than any other year (previous maximum of 1,165 in 2018). Lastly, Percent Intolerant Taxa in 2020 was greater than previous years (46.2% in 2010).

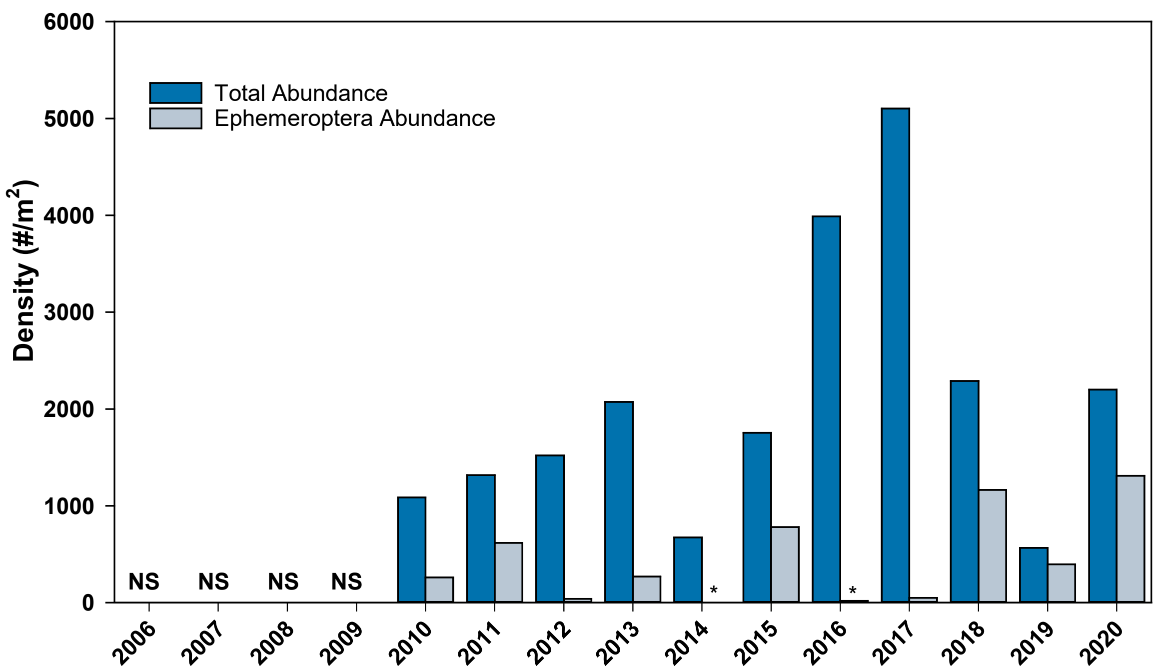

Figure 4-25: Macroinvertebrate density metrics for Site LC-1-BIO on Lost Camp Gulch, 2006 - 2020. NS = Not sampled. * = Mayflies absent or present at low density.

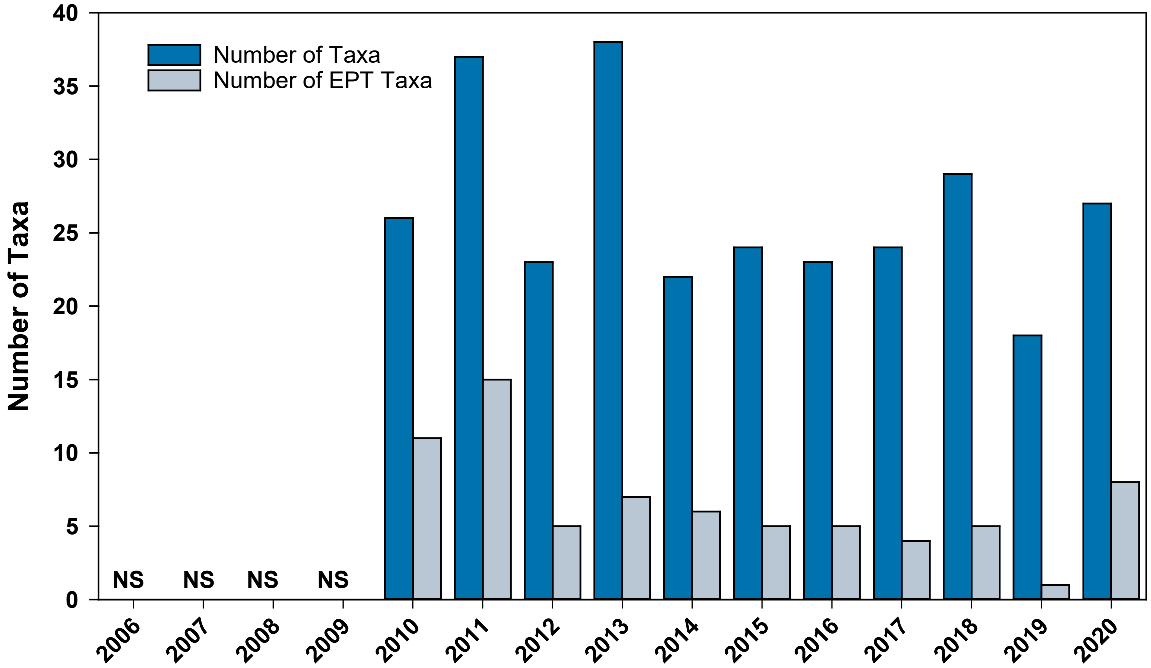

Figure 4-26: Macroinvertebrate taxa richness metrics for Site LC-1-BIO on Lost Camp Gulch, 2006 - 2020. NS = Not sampled.

Overall, a moderate number of metrics have declined in quality from 2010 to 2020 indicating that the macroinvertebrate community, specifically EPT taxa, has become less healthy over that period. In addition, historic median Number of Taxa and EPT Taxa data were significantly better at the reference site, Site RC-1-BIO than at Site LC-1-BIO. Periodic low flows at this site negatively impact the benthic macroinvertebrate community and are responsible for changes in metrics. In 2016 and 2017, portions of the site exhibited little to no flow, which likely limited available habitat and dissolved oxygen for more sensitive benthic macroinvertebrates. Sedimentation from the road adjacent to the site may also be negatively impacting the benthic macroinvertebrate community at Site LC-1-BIO in some years, as the percent surface fines were relatively high in most habitat units at this site when compared with surface fines values at other biomonitoring sites in 2017. The low flows during 2016 and 2017 limited the potential to scour and remove fine sediments that have settled in the substrate. Precipitation from 2018 to 2020 was higher (Figure 4-1), and the percentage of surface fines at this site decreased, but an appreciable improvement in metrics from 2017 to 2020 was not detected. With higher perennial flows at this site, the benthic macroinvertebrate community may improve during future sampling events.

4.3.6 Deadwood Creek

4.3.6.1 2020 Data

In August 2020, richness, composition, tolerance, trophic habit, and life history metric values were predominantly favorable or moderately favorable at Site DC-2-BIO (Table 4-19; Table 4-20; Appendix C). Specifically, Density, Number of Taxa and EPT Taxa, and EPT Index values were moderate or good; Diversity indicated of a healthy invertebrate community; the HBI indicated a "Good" benthic macroinvertebrate community including intolerant species; and a diversity of feeding groups were present. However, this site contained a very high percentage of Chironomids, much higher than any other site, owing to the large Diptera population (Appendix B), specifically the non-biting midge *Trissopelopia sp.* This subfamily, as well as many other Chironomid subfamilies, has a short life cycle leading to this site being dominated by univoltine taxa. Overall, despite the large midge population, stream conditions in 2020 were suitable to support a rich and diverse benthic macroinvertebrate community including intolerant species.

Benthic macroinvertebrate richness, composition, tolerance, trophic habit, and life history metric values at Site DC-2-BIO were comparable to those at the reference site, Site LB-4-BIO. Number of Taxa, Number of EPT Taxa, Diversity, Number of non-*Baetis* Ephemeroptera, HBI, and Number of Predator Taxa were more favorable at the reference site but not poor at either site. Percent Chironomidae was also more favorable at the reference site compared to a very low value at Site DC-2-BIO. At the same time, Percent *Baetis sp.*, Tolerant Taxa, and Intolerant Taxa was more favorable at Site DC-2-BIO. These differences between the sites resulted in a Community Loss Index of 76, indicating that the majority of the taxa present at the reference site were not present at Site DC-2-BIO. Overall, Site DC-2-BIO contained a healthy benthic macroinvertebrate community in August 2020 that was comparable to the community sampled at the reference site.

4.3.6.2 Historic Data

The macroinvertebrate community at Site DC-2-BIO changed slightly from 2010 to 2020. Richness metric values stayed consistent and did not trend (Table 4-21; Figure 4-27; Figure 4-28; Appendix C). Number of EPT Taxa exhibit a cyclical pattern where every three to four years the number of taxa peak and then decline for the next few years. Diversity has been above 2.5 in all years indicating a history of a diverse invertebrate community. The EPT Index has slightly, but significantly, decreased while Percent *Baetis sp*. and Number of Common Taxa have significantly increased since 2010 (Table 4-20). Percent Chironomidae was greater in 2020 than previous years (79.2% in 2012).

The 2020 HBI value was poorer than previously recorded at this site (4.85 in 2019) and has ranged from "Good" (4.9 in 2020) to "Excellent" (3.2 in 2010). Trophic habit metrics, Number of Predator and Percent Collector-Gatherers were lower than in past years (previous minimums of 9 in 2010 and 31.8% in 2015, respectively) and Number of Shredder Taxa significantly improved from 2010 to 2020. Lastly, the life history metric Number of Univoltine Taxa significantly worsened over time.

Overall, data in 2020 showed minimal changes with many metric values similar to previous years. Few median metric values were significantly different between Site DC-2-BIO and the reference site, Site LB-4-BIO, with only the median Number of EPT Taxa being significantly higher at the reference site than at Site DC-2-BIO from 2010 to 2020 ($p = 0.005$). Historic benthic macroinvertebrate community metric data (i.e., long-term median values) between the two sites are not different and both have been rich and diverse, with numerous intolerant taxa, indicative of good historic stream conditions.

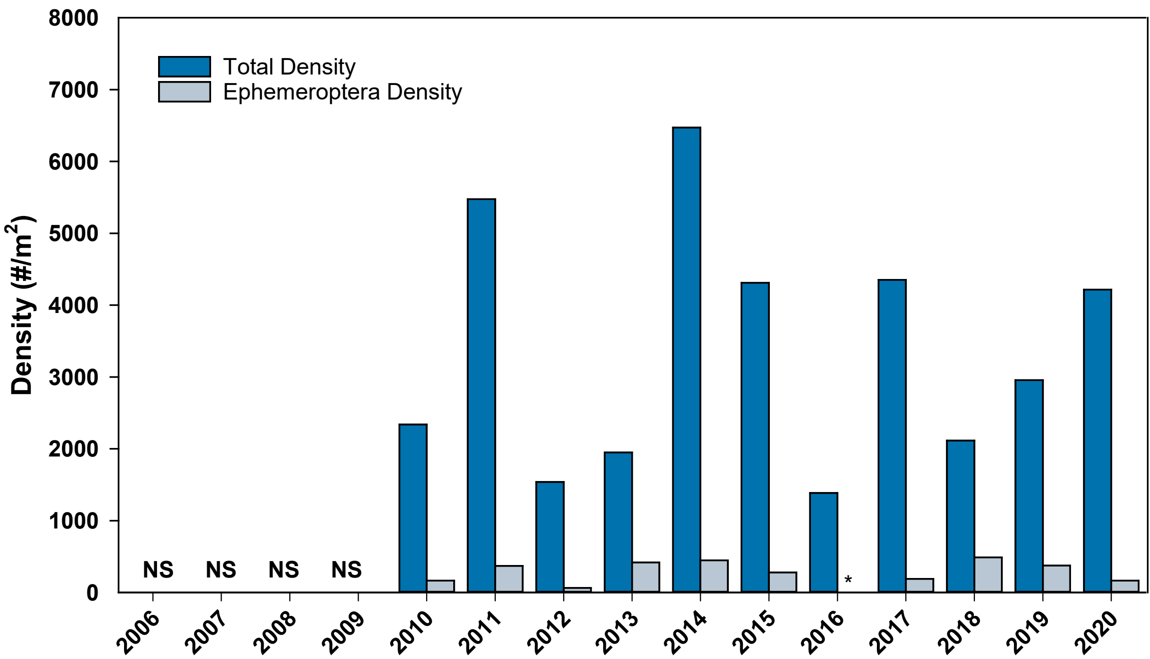

Figure 4-27: Macroinvertebrate density metrics for Site DC-2-BIO on Deadwood Creek, 2006 - 2020. NS = Not sampled. * = Mayflies not present.

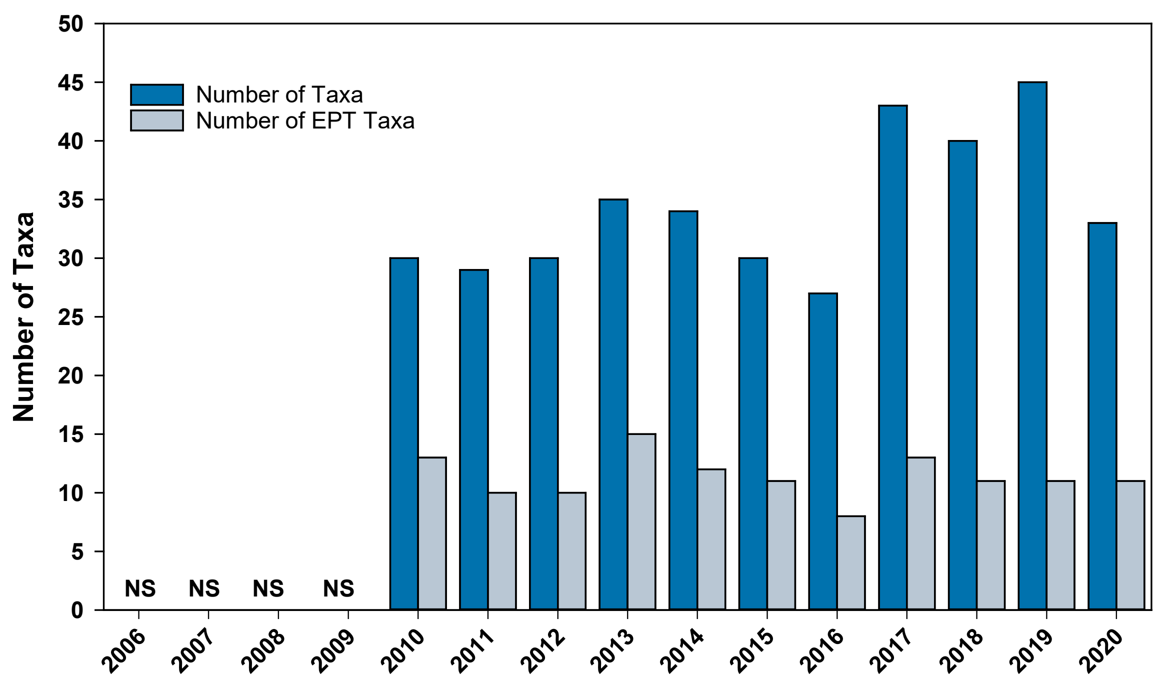

Figure 4-28: Macroinvertebrate taxa richness metrics for Site DC-2-BIO on Deadwood Creek, 2006 - 2020.

4.3.7 False Bottom Creek

4.3.7.1 Site EFB-1-BIO

4.3.7.1.1 2020 Data

Richness, composition, tolerance, and life history metric values were predominantly favorable or moderately favorable at Site EFB-1-BIO in August 2020 (Table 4-19; Table 4-20; Appendix C). Specifically, Density, Number of Taxa, Number of EPT Taxa, and EPT Index values were all moderate or good; Diversity indicated a healthy invertebrate community; the HBI indicated an "Excellent" benthic macroinvertebrate community that included intolerant species and a variety of life cycle lengths. Exceptions were the dominance of *Baetis tricaudatus cx.* at 75% (Appendix B) in the Ephemeroptera population indicating that the majority of Ephemeroptera were relatively tolerant of environmental stressors. Trophic habit metrics indicated that very few taxa consisted of shredders. Overall, despite these few unfavorable metric values, stream conditions in 2020 were suitable to support a rich and diverse benthic macroinvertebrate community including sensitive taxa.

Benthic macroinvertebrate richness, composition, tolerance, trophic habit, and life history metric values at Site EFB-1-BIO were comparable to those at the reference site, Site LB-4-BIO. Both sites contained favorable or moderately favorable Number of Taxa, Number of EPT Taxa, Diversity, EPT Index, and HBI metric values, however, they were slightly more favorable at the reference site. The Ephemeroptera population at both sites was dominated by *Baetis tricaudatus cx.,* however this metric and the Number of non-*Baetis* Ephemeroptera were, again, better at the reference site. In addition, Number of Intolerant and Shredder Taxa were better at the reference site while Percent Tolerant and Number of Univoltine Taxa were more favorable at the Site EFB-1-BIO. These differences between the sites resulted in the Community Loss Index of 94, indicating that the majority of taxa present at the reference site were not present at Site EFB-1-BIO. Despite the reference site containing a slightly healthier macroinvertebrate community, the community at Site EFB-1-BIO was also healthy in August 2020.

4.3.7.1.2 Historic Data

From 2006 to 2020 at Site EFB-1-BIO, the macroinvertebrate community metrics were relatively consistent, although only six of the last 14 years were sampled, so trends should be cautiously interpreted. Richness, composition, tolerance, trophic habit, and life history metric values have stayed relatively consistent over these years (Figure 4-29; Figure 4-30; Appendix C) and not significantly trended over time (Table 4-21). The 2020 Percent *Baetis sp.*, Percent Chironomidae, HBI, Percent Tolerant Taxa, and Number of Shredder Taxa metric data were all less than previous years (86.9% in 2009, 12.0% in 2006, 3.5 in 2019, 17.9% in 2010, and 4 in multiple years, respectively) while Number of non-*Baetis* Ephemeroptera, Community Loss Index, and Number of Merovoltine Taxa were greater (45 in 2006, 79.3% in 2009, and 2 in 2009, respectively). Diversity has been greater than 2.5 in all years of sampling indicating a healthy invertebrate community. In addition, HBI has fluctuated from “Good” (4.6 in 2009) to “Excellent” (3.5 in 2019). The only metric to trend over these years was the trophic habit metric, Number of Predator Taxa which significantly improved. Overall, macroinvertebrate data in 2020 showed negligible change with the metric values similar to those in previous years.

When compared to the reference site, Site LB-4-BIO, the long-term median Number of EPT Taxa and Diversity were significantly different with the reference site exhibiting higher metric values ($p = 0.003$ and $p = 0.004$), although the low number of sampling events at EFB-1-BIO, and differences between sample size, influences the robustness of these comparisons. There were no significant differences observed among Abundance, Number of Taxa, EPT Index, and HBI metrics for the two sites.

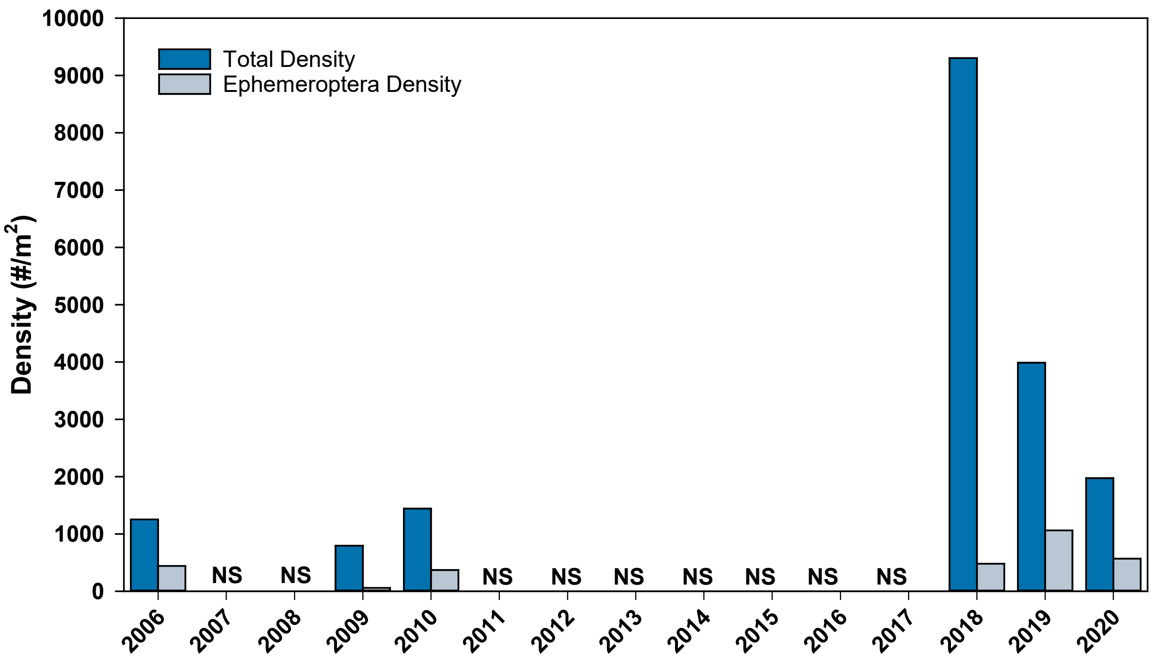

Figure 4-29: Macroinvertebrate density metrics for Site EFB-1-BIO in False Bottom Creek, 2006 - 2020. NS = Not Sampled.

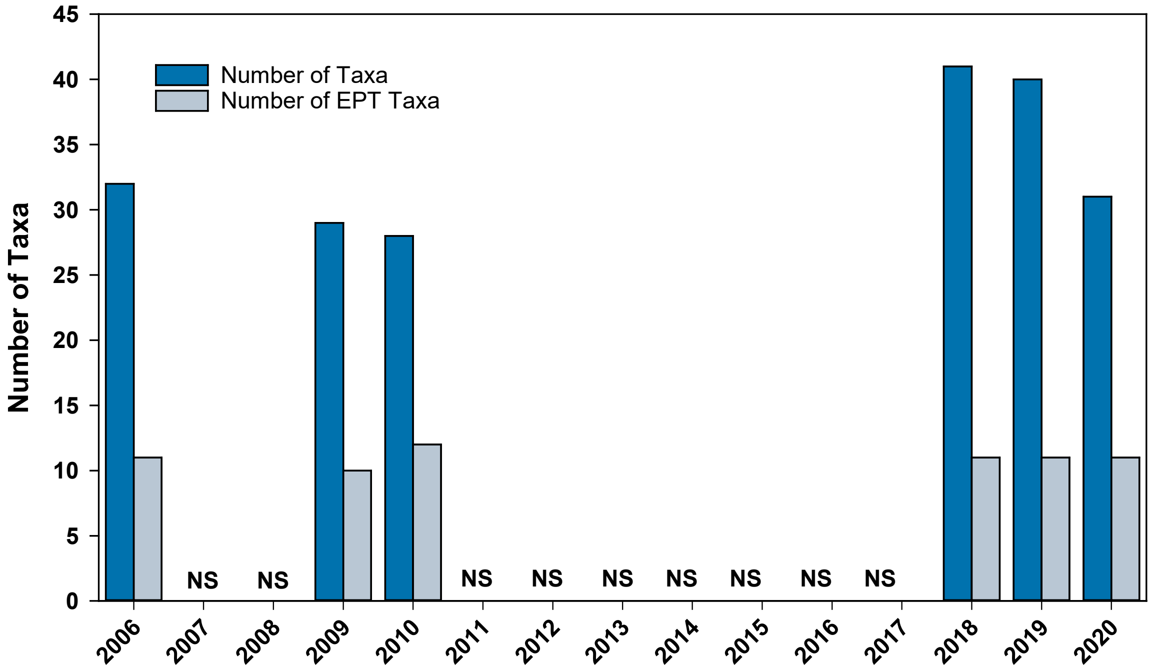

Figure 4-30: Macroinvertebrate taxa richness metrics for Site EFB-1-BIO on False Bottom Creek, 2006 - 2020. NS = Not Sampled.

4.3.7.2 Site WFB-1-BIO

4.3.7.2.1 2020 Data

No Ephemeroptera and low numbers of Plecoptera and Trichoptera were collected (68 total EPT organisms) at Site WFB-1-BIO in 2020 resulting in a poor EPT community and mostly unfavorable metric values. Density was very low, the lowest of any site, and, while Numbers of Taxa and EPT Taxa values were good, they were some of the lowest observed in 2020 sampling (Table 4-19; Table 4-20; Appendix C). Composition metrics were mostly poor, even though the Diversity value was 3.72. Percent Sensitive EPT Taxa, EPT Index, Number of non-*Baetis* Ephemeroptera, Percent Chironomidae, Number of Plecoptera Taxa, and Ephemeroptera Density were also poor and close to, or the poorest, of any Wharf site. In addition, the tolerance metrics of Percent and Number of Intolerant Taxa were moderate but the lowest of any site and life history metrics indicated a dominance of univoltine taxa.

Despite these low metric scores, the HBI tolerance-based metric scored as "Good," and the trophic habit metrics indicated a diversity of feeding types, although with a relatively low Number of Shredder Taxa. The majority of data indicated that the stream conditions resulted in a moderately poor benthic macroinvertebrate community in 2020.

Benthic macroinvertebrate richness metric values at Site WFB-1-BIO were all relatively poor when compared to the reference site, Site LB-4-BIO. Similarly, most composition metrics, specifically EPT related metrics, were poorer than the reference site metrics. Tolerance metrics, including HBI, and trophic habit metrics were also generally less favorable at

Site WFB-1-BIO than the reference site. These differences between the sites were reflected in the Community Loss Index of 119, which showed only 12 taxa common to both sites and 33 reference site taxa not found at Site WFB-1-BIO. In general, the metrics indicate that invertebrate communities at these sites are different, and the poor stream conditions at Site WFB-1-BIO, linked to the iron oxide deposition have negatively affected the macroinvertebrate assemblage.

4.3.7.2.2 Historic Data

The macroinvertebrate community at Site WFB-1-BIO has changed from 2007 to 2020. Density had been increasing until 2020 when fewer macroinvertebrates were collected than all other years (previous minimum of 357 /sample in 2011). The Number of EPT Taxa, Diversity, Percent Sensitive EPT Taxa, and Number of Plecoptera Taxa have significantly declined over time (Table 4-21; Figure 4-31; Figure 4-32; Appendix C). Ephemeroptera density continues to be poor and the mayflies population has either been absent or present in very low numbers during all years of sampling at Site WFB-1-BIO. The Percent Abundance of Oligochaetes and Hirudinea and Number of Merovoltine Taxa at Site WFB-1-BIO was greater in 2020 than previous years (maximum of 3.0% in 2008 and 1 in most years, respectively). The Number of Univoltine Taxa has improved over the years.

When Site WFB-1-BIO is compared to the reference site, Site LB-4-BIO, the six metrics tested are significantly worse than the reference site metrics (Density: $p = 0.002$, Number of Taxa: $p < 0.001$, Number of EPT Taxa: $p < 0.001$, Diversity: $p = 0.015$, EPT Index: $p = 0.001$, and HBI: $p < 0.001$) indicating a poorer macroinvertebrate community at Site WFB-1-BIO. Overall, data in 2020 were not remarkable and the metric values were similar to those in previous years. A moderate number of metrics have declined in quality since 2007, indicating that the macroinvertebrate community has become poorer over time and is stressed due to low flows and iron oxide deposition that negatively affects habitat quality.

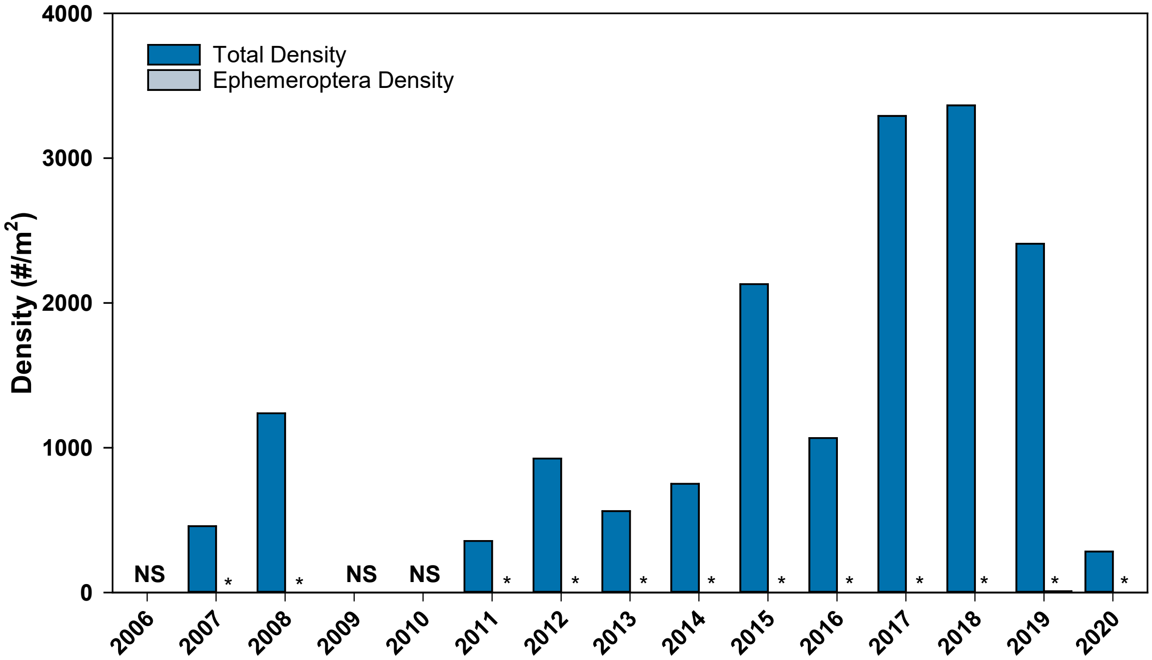

Figure 4-31: Macroinvertebrate density metrics for Site WFB-1-BIO in False Bottom Creek, 2006 - 2020. NS = Not Sampled. * = Mayflies absent or present at low density.

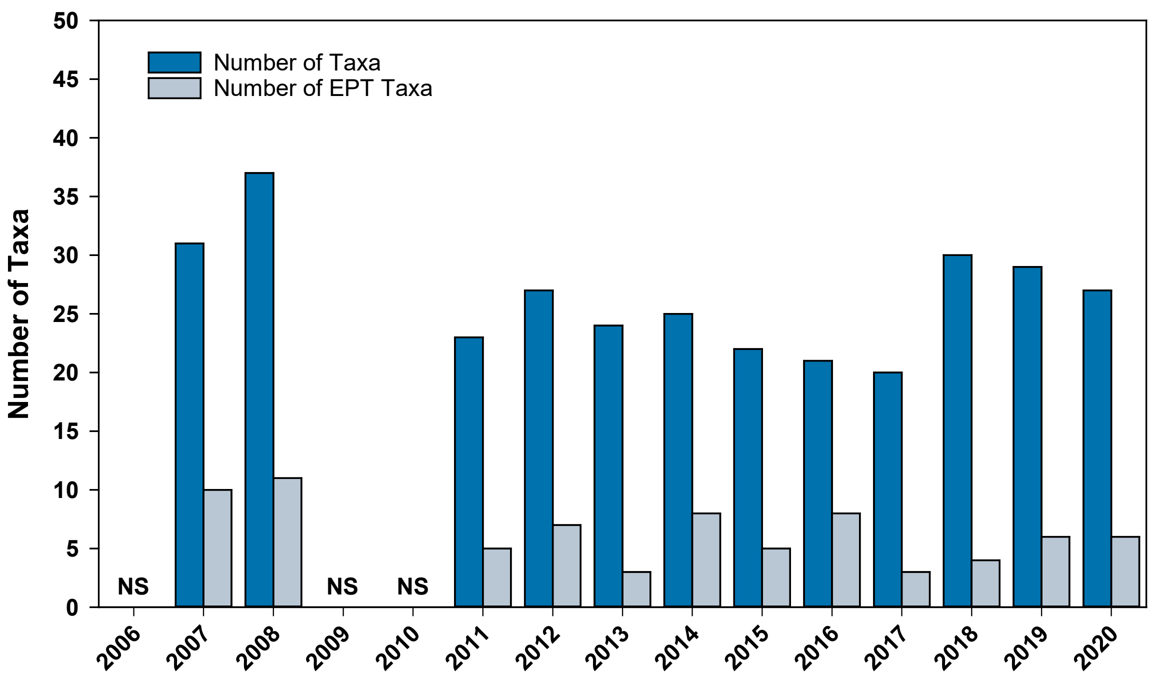

Figure 4-32: Macroinvertebrate taxa richness metrics for Site WFB-1-BIO on False Bottom Creek, 2006 - 2020. NS = Not Sampled.

4.3.8 McKinley Gulch

McKinley Gulch was dry during August 2020 and was not sampled. Macroinvertebrates have never been sampled at this site due to no stream flow.

4.3.9 Cleopatra Creek

4.3.9.1 2020 Data

Residual pockets of water were present, but water was not flowing through the riffles at Site CC-1A-BIO in 2019 and 2020. Therefore, macroinvertebrates were not sampled.

4.3.9.2 Historic Data

The macroinvertebrate community at Site CC-1A-BIO changed slightly from 2006 to 2018. Richness metrics, Density and Number of Taxa significantly increased over the years the site was sampled (Table 4-22; Figure 4-33; Figure 4-34; Appendix C). Similarly, the Number of Intolerant Taxa and Univoltine Taxa have significantly increased over time, which is largely attributed to a few dominant taxa collected in 2015 and 2018 that influenced the relationship.

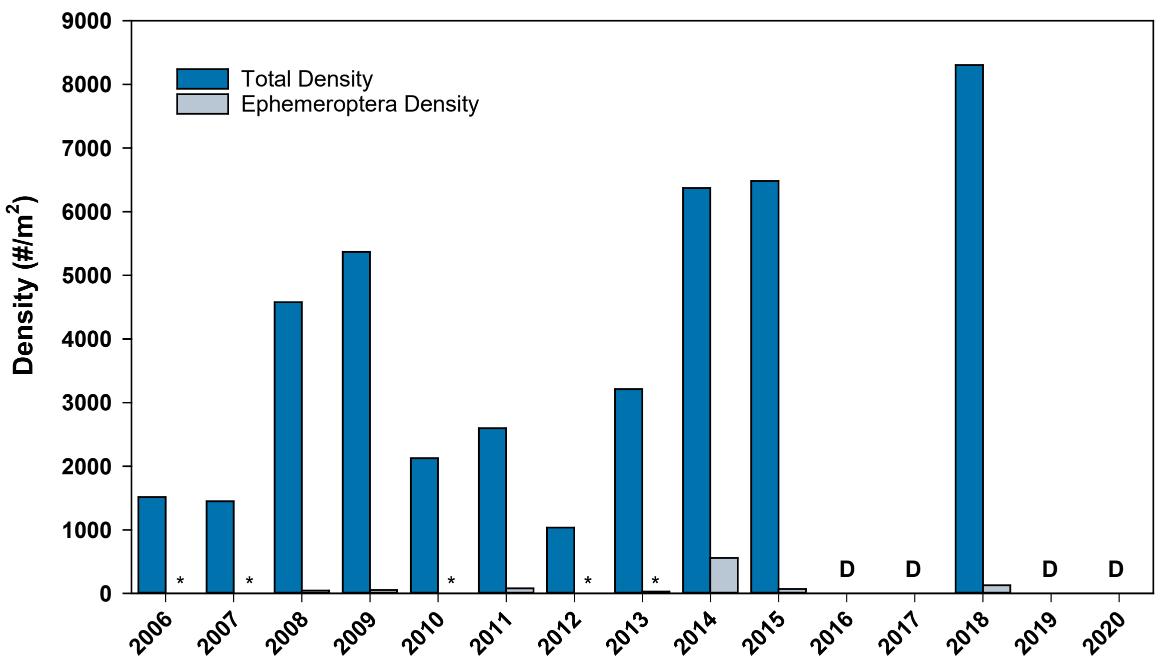

Figure 4-33: Macroinvertebrate density metrics for Site CC-1A-BIO on Cleopatra Creek, 2006 - 2020. * = Mayflies absent or present at low density. D = Dry.

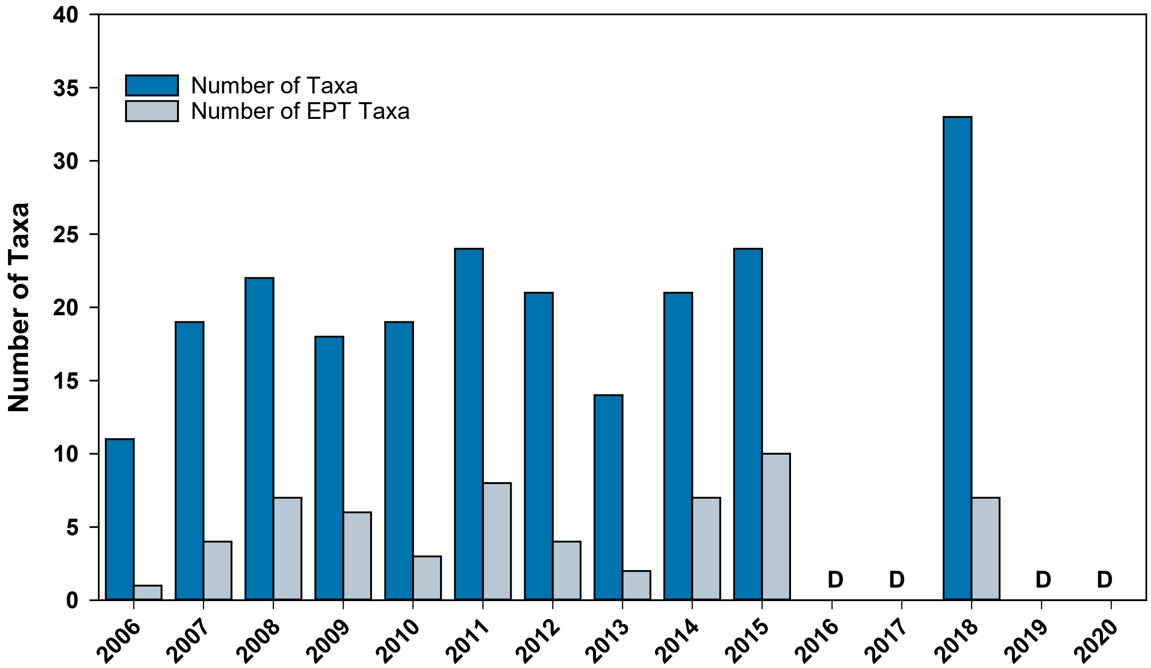

Figure 4-34: Macroinvertebrate taxa richness metrics for Site CC-1A-BIO on Cleopatra Creek, 2006 - 2020. NS = Not Sampled. D = Dry.

Table 4-22: Slopes of significant trends ($p < 0.05$) for macroinvertebrate population metrics at Cleopatra Creek, Fantail Creek, Nevada Gulch, and Stewart Gulch, 2006 - 2020. + = Positive slope. - = Negative slope. -- = Not significant.

Metric	Change Expected Following Environmental Disturbance	CC-1A-BIO	FC-1-BIO	NG-2-BIO	SG-1-BIO
RICHNESS METRICS					
Density (#/sample)	Decrease	+ 470	--	--	+ 354.42
Number of Taxa	Usually Decrease	+ 1.09	--	--	--
Number of EPT Taxa	Decrease	--	- 0.35	--	--
COMPOSITION METRICS					
Shannon-Weaver Diversity Index	Decrease	--	--	- 0.11	--
Percent Sensitive EPT Taxa	Decrease	--	- 0.01	--	--
EPT Index	Decrease	--	- 0.01	--	--
Percent *Baetis sp.*	Increase	--	--	+ 0.05	--
Number of non-*Baetis* Ephemeroptera	Decrease	--	--	- 14.57	--
Percent Chironomidae	Increase	--	--	- 0.04	--
Number of Plecoptera Taxa	Decrease	--	--		--
Percent Abundance of Oligochaetes & Hirudinea	Variable	--	--	--	--
Percent Dominant Taxon	Increase	--	--	+ 0.02	--

Metric	Change Expected Following Environmental Disturbance	CC-1A-BIO	FC-1-BIO	NG-2-BIO	SG-1-BIO
Number of Common Taxa	Decrease	--	--	--	--
Community Loss Index	Increase	- 0.09	--	--	--
TOLERANCE METRICS					
Hilsenhoff Biotic Index	Increase	--	--	--	--
Percent Tolerant Taxa	Increase	--	--	--	--
Percent Intolerant Taxa	Decrease	--	--	--	--
Number of Intolerant Taxa	Decrease	+ 0.60	--	--	--
TROPHIC HABIT METRICS			--		
Number of Predator Taxa	Decrease	--	--	--	+ 0.31
Percent Collector-Gatherers	Variable	--	--	- 0.02	--
Number of Shredder Taxa	Decrease	--	--	--	--
LIFE HISTORY METRICS					
Number of Univoltine Taxa	Increase	+ 0.68	--	--	--
Number of Merovoltine Taxa	Decrease	--	--	--	--
Number of Semivoltine Taxa	Decrease	--	--	--	--
Percent Semivoltine Taxa	Decrease	--	--	--	--

Note: CC-1A-BIO was sampled in 2006-2015 and 2018.

4.3.10 Fantail Creek

4.3.10.1 2020 Data

At Site FC-1-BIO in August 2020, richness, tolerance, and trophic habit metric values were all favorable or moderately favorable (Table 4-23; Table 4-24; Appendix C). Specifically, Density, Number of Taxa, and Number of EPT Taxa values were all good; Diversity indicated a healthy invertebrate community; the HBI indicated an “Excellent” benthic macroinvertebrate community including intolerant species; and diversity of feeding types were present.

Composition metric values, however, were not consistently favorable. EPT related metric values indicated a poor EPT assemblage that was dominated by *Baetis tricaudatus cx.* (99%) mayflies. This percentage resulted in poor metric values for Percent Sensitive EPT Taxa and Number of non-*Baetis* Ephemeroptera. Life history metric values indicated that most taxa at the site have short life cycles. This section of the stream exhibits low flow, and the retention pond limits the drift of benthic invertebrates from upstream. Despite the poor Ephemeroptera community (Appendix B), metrics for this site indicate that the stream conditions in 2020 were suitable to support a diverse benthic macroinvertebrate community that included intolerant species.

Table 4-23: Macroinvertebrate density (number of organisms/sample) at Fantail Creek, Nevada Gulch, Stewart Gulch, August 2020.

Taxa	FC-1-BIO	NG-2-BIO	SG-1-BIO
INSECTA			
Collembola (springtails)	5	2	5
Ephemeroptera (mayflies)	1,310	6	1,020
Plecoptera (stoneflies)	980	47	2,275
Coleoptera (beetles)	235	265	1,190
Trichoptera (caddisflies)	155	3	810
Diptera (true flies)	410	10	900
HYDRACARINA (water mites)	--	5	120
TURBELLARIA (flatworms)	835	3	15
ANNELIDA (segmented worms)			
Oligochaeta (worms)	20	14	30

Benthic macroinvertebrate richness, composition, tolerance, and trophic habit metric values at Site FC-1-BIO were moderately comparable to those at the reference site, Site RC-1-BIO. Both sites contained favorable Number of Taxa, Number of EPT Taxa, Diversity, and Number of Predator Taxa metric values. However, all were better at the reference site. Percent *Baetis sp.* and Number of non-*Baetis* Ephemeroptera were favorable at the reference site but poor at Site FC-1-BIO. Alternatively, Percent Chironomidae, HBI, trophic habit, and life history metrics were generally better at Site FC-1-BIO. The Community Loss Index indicated that approximately 55 percent of the taxa present at the reference site were also found at Site FC-1-BIO. Generally, the benthic macroinvertebrate community in Fantail Creek was less healthy than the Reno Creek site but differences were minimal and both sites displayed a healthy macroinvertebrate community.

Table 4-24: Macroinvertebrate population metrics at Fantail Creek, Nevada Gulch, Stewart Gulch, August 2020.

Metric	FC-1-BIO	NG-2-BIO	SG-1-BIO
RICHNESS METRICS			
Density (#/sample)	3,950	355	6,365
Number of Taxa	37	25	42
Number of EPT Taxa	10	8	12
COMPOSITION METRICS			
Shannon-Weaver Diversity Index	2.96	2.37	3.41
Percent Sensitive EPT Taxa	18.9%	24.0%	23.8%
EPT Index	27.0%	32.0%	28.6%
Percent *Baetis sp.*	99.2%	83.3%	97.1%
Number of non-*Baetis* Ephemeroptera	10	1	30
Percent Chironomidae	4.1%	1.1%	12.8%
Number of Plecoptera Taxa	3	4	4
Percent Abundance of Oligochaetes & Hirudinea	0.5%	3.9%	0.5%

Metric	FC-1-BIO	NG-2-BIO	SG-1-BIO
Dominant Taxon (Tolerance value)	*Baetis tricaudatus cx.* (5)	*Optioservus divergens* (4)	*Zapada cinctipes* (2)
Percent Dominant Taxon	32.9%	45.6%	30.3%
Number of Common Taxa	25	12	19
Community Loss Index	54.0%	132.0%	60.0%
TOLERANCE METRICS			
Hilsenhoff Biotic Index	3.20	3.70	3.40
Percent Tolerant Taxa	18.9%	24.0%	23.8%
Percent Intolerant Taxa	54.1%	52.0%	47.6%
Number of Intolerant Taxa	20	13	20
TROPHIC HABIT METRICS			
Number of Predator Taxa	7	8	11
Percent Collector-Gatherers	36.7%	7.6%	47.0%
Number of Shredder Taxa	8	4	5
LIFE HISTORY METRICS			
Number of Univoltine Taxa	16	9	19
Number of Merovoltine Taxa	0	0	0
Percent Semivoltine Taxa	0.0%	0.0%	0.0%
Number of Semivoltine Taxa	3	1	1

4.3.10.2 Historic Data

The macroinvertebrate community at Site FC-1-BIO has slightly changed between 2006 to 2020. Richness metric values largely stayed consistent (Figure 4-35; Figure 4-36; Appendix C) except for the Number of EPT Taxa which significantly decreased from 2006 to 2020 (Table 4-22). The 2020 composition metric value for Percent Chironomidae was less and the Number of Common Taxa was greater than those previously measured at the site (previous minimum of 4.7% in 2019 and maximum of 22 in 2008 and 2011, respectively). Percent Sensitive EPT Taxa and EPT Index significantly decreased since 2006, indicating poorer conditions for EPT taxa in recent years. The 2020 HBI tolerance metric was better than previously recorded with data ranging from “Good” (5.4 in 2012) to “Excellent” (3.2 in 2020). In addition, the Percent of Tolerant Taxa was greater the previously recorded (maximum of 53.1% in 2007). Historic median data for the select benthic macroinvertebrate community metrics were not significantly different between Site FC-1-BIO and its reference site, Site RC-1-BIO ($p < 0.05$).

The combination of low flow and increased amount of fine-grained sediment in recent years have likely influenced the macroinvertebrate community at Site FC-1-BIO. However, historical data exhibited negligible change with many metric values being similar to those in previous years and not different than the reference site.

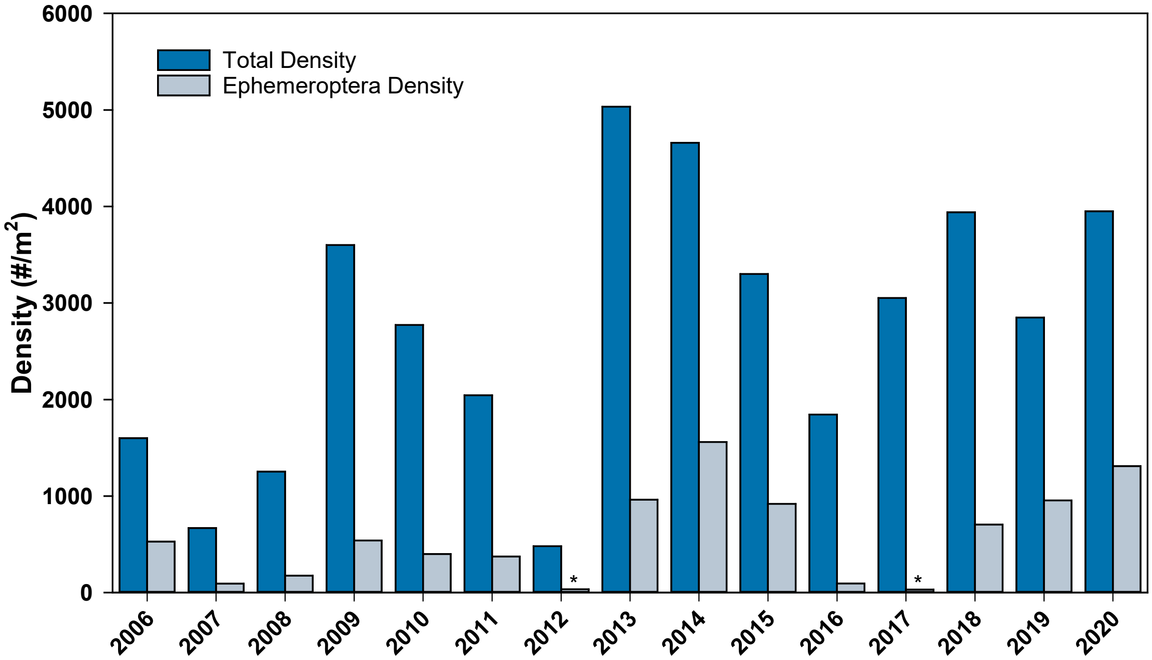

Figure 4-35: Macroinvertebrate density metrics for Site FC-1-BIO on Fantail Creek, 2006 - 2020. * = Mayflies present at low density.

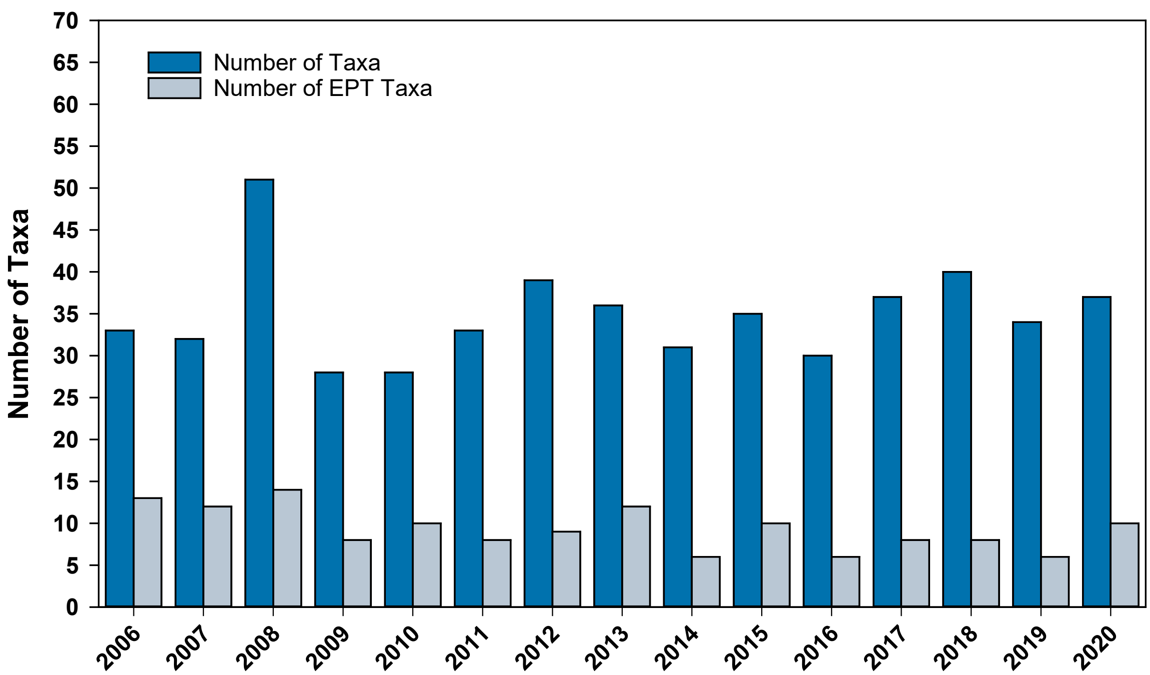

Figure 4-36: Macroinvertebrate taxa richness metrics for Site FC-1-BIO on Fantail Creek, 2006 - 2020.

4.3.11 Nevada Gulch

4.3.11.1 2020 Data

In August 2020, metric values at Site NG-2-BIO were variable (Table 4-23; Table 4-24; Appendix C) with a very low number of EPT taxa collected (56 total macroinvertebrates). As a result, overall Density was very low, and the Diversity metric indicated an unhealthy invertebrate community. The Number of Taxa and EPT Taxa were lower than almost all other sites but still not considered poor. In addition, Percent Sensitive EPT Taxa and EPT Index values were moderate while Percent *Baetis sp.* and Number of non-*Baetis* values were poor indicating that almost all Ephemeroptera were relatively tolerant of environmental stressors. Life history metrics indicate that macroinvertebrates at the site had predominantly short life cycles.

Percent Chironomidae at Site NG-2-BIO was lower than all other sites, HBI at this site indicated a "Very Good" benthic macroinvertebrate community, and the Percent of Intolerant Taxa was high. Despite the favorable metric values, many values for this site indicated that the stream conditions in 2020 supported a moderately poor benthic macroinvertebrate community (Appendix B).

Benthic macroinvertebrate richness and composition metric values were generally worse at Site NG-2-BIO than at the reference site, Site RC-1-BIO, with Diversity at the reference site being almost two times greater as at Site NG-2-BIO. Tolerance, trophic habit, and life history metrics were generally similar between the two sites except for Number of Intolerant and Shredder Taxa which were greater at the reference site. However, EPT Index and HBI were very similar between the sites and Percent Chironomidae and Number of Univoltine Taxa were better at Site NG-2-BIO. These differences between the sites resulted in a Community Loss Index of 132, indicating that the community present at Site NG-2-BIO was the most dissimilar of all of the sites compared to the Reno Creek community . The poor condition of Site NG-2-BIO is likely the result of salting and sanding and general run-off from Nevada Gulch road. In general, the metrics indicate that invertebrate communities at this site is different than the reference site, and the poor stream conditions at Site NG-2-BIO have affected the macroinvertebrate assemblage.

4.3.11.2 Historic Data

The macroinvertebrate community at Site NG-2-BIO has slightly changed from 2006 to 2020. Richness metric values have not trended in this time despite 2020 values for Density being far lower than measured in previous years (minimum of 843 in 2013; Figure 4-37; Figure 4-38; Table 4-22; Appendix C).

The 2020 composition metrics Diversity, Percent *Baetis sp.*, Number of non-*Baetis* Ephemeroptera, and Percent Dominant Taxa have significantly worsened since 2006 while Percent Chironomidae has significantly improved. In 2020, Diversity and Percent

Chironomidae metrics were less than in other years (previous minimums of 2.47 in 2016 and 4.1% in 2018, respectively) and Community Loss Index was greater (previous maximum of 69.0% in 2017). Diversity has only been less than 2.5 in two of 14 years of sampling indicating a healthy invertebrate community was present in most years. The trophic habit metric, Percent Collector-Gatherers has significantly decreased over time and was lower in 2020 than any other year (previous minimum of 10.1% in 2010). No significant trends were apparent for tolerance or life history metrics but HBI was also lowest in 2020 (previous minimum of 4.08% in 2009) and ranged from “Fair” (5.68 in 2013) to “Very Good” (3.75 in 2020). In addition, 2006 to 2020 median Abundance and Number of Taxa were significantly worse at Site NG-2-BIO than at the reference site. Overall, historic benthic macroinvertebrate community metric data between the two sites are not different, despite the decrease in quality.

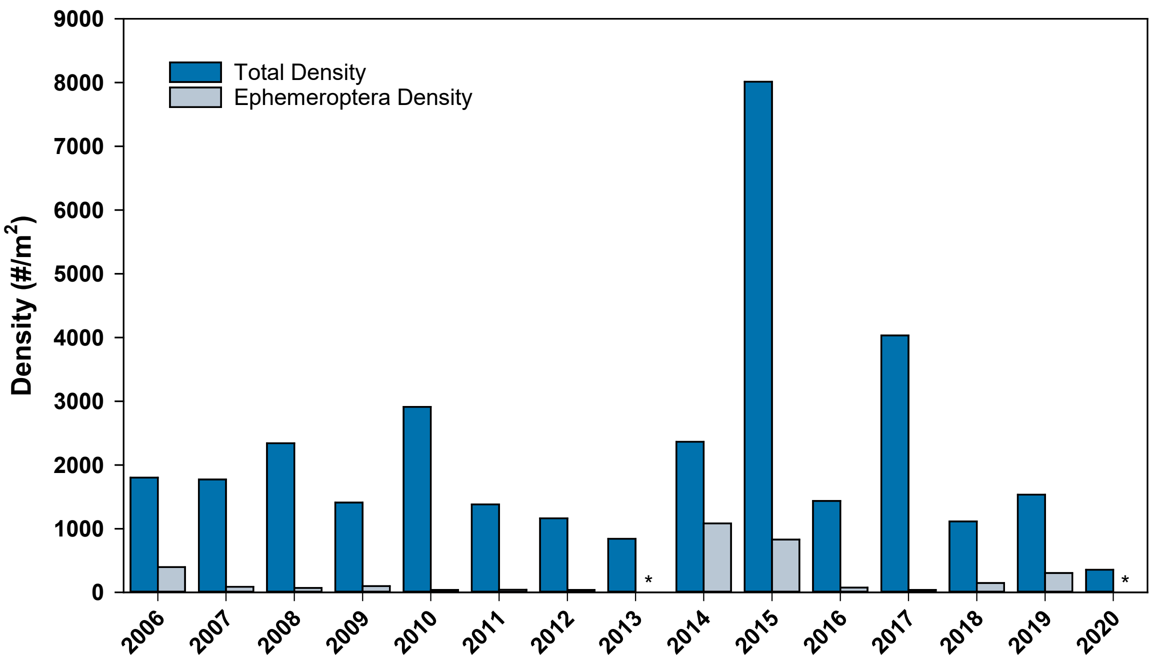

Figure 4-37: Macroinvertebrate density metrics for Site NG-2-BIO on Nevada Gulch, 2006 - 2020. * = Mayflies present at low density. D= Dry.

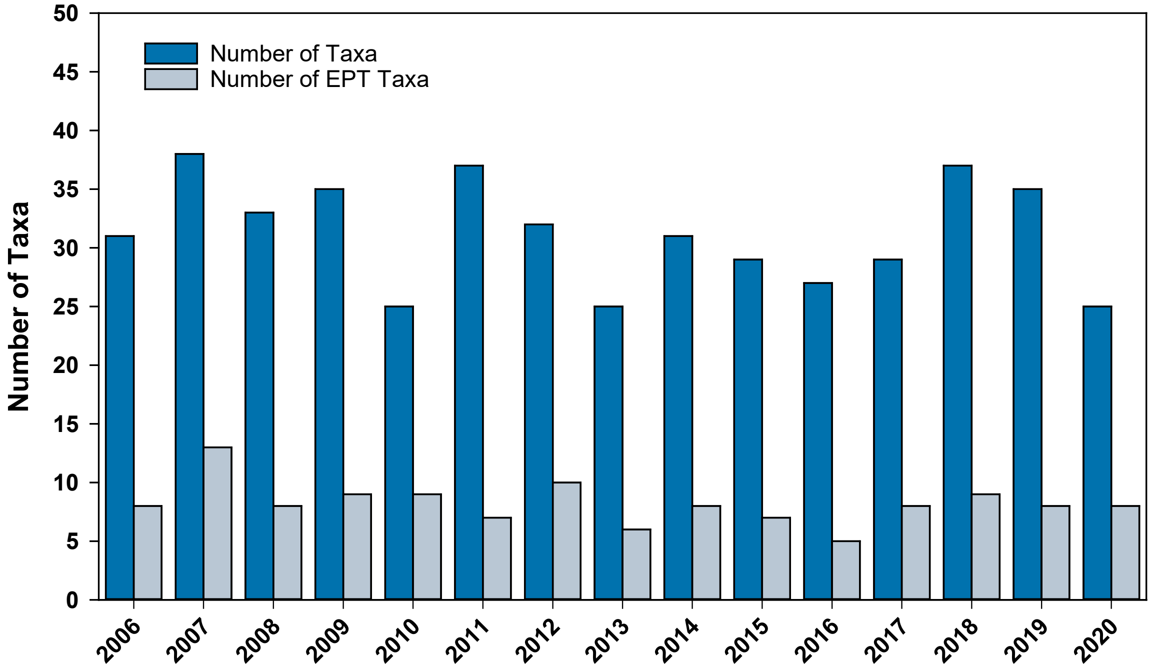

Figure 4-38: Macroinvertebrate taxa richness metrics for Site NG-2-BIO on Nevada Gulch, 2006 - 2020. NS = Not sampled. D= Dry.

4.3.12 Stewart Gulch

4.3.12.1 2020 Data

In August 2020, richness, composition, tolerance, and trophic habit metric values were predominantly favorable or moderately favorable at Site SG-1-BIO (Table 4-23; Table 4-24; Appendix C). Specifically, Density, Number of Taxa, Number of EPT Taxa, and EPT Index values were moderate or good; Diversity indicated a healthy invertebrate community; and the HBI indicated an "Excellent" benthic macroinvertebrate community including intolerant species. However, the Percent *Baetis sp.* metric indicated that the Ephemeroptera assemblage was comprised almost entirely of tolerant mayflies and that Number of non-*Baetis* Ephemeroptera was very low. In addition, the life history metric values indicated that most taxa at the site have short life cycles. Overall, despite a few poor metric values, the stream conditions in 2020 were suitable to support a rich and diverse benthic macroinvertebrate community (Appendix B) including many intolerant taxa.

Benthic macroinvertebrate richness, tolerance, and trophic habit metric values at Site SG-1-BIO were similar to those at the reference site, Site LB-4-BIO. Both sites revealed favorable or moderately favorable metric values for Density, Number of Taxa, Number of EPT Taxa, Diversity, EPT Index, and HBI. Of these, Density was greater at Site SG-1-BIO while Diversity was greater at the reference site. In addition, Percent *Baetis sp.*, Number of non-*Baetis* Ephemeroptera, Number of Shredder Taxa, and Number of Merovoltine Taxa values were more favorable at the reference site than at Site SG-1-BIO. Despite these differences between the sites, the Community Loss Index of 60, indicated that nearly half of the taxa present at the reference site were also observed at Site SG-1-BIO. Overall, Site SG-1-BIO contained a healthy benthic macroinvertebrate community in August 2020 that was comparable to the community sampled at the reference site.

4.3.12.2 Historic Data

From 2006 to 2020 at Site SG-1-BIO, the macroinvertebrate community exhibited variability in Density; although, most of the richness, composition, tolerance, trophic habit, and life history metric values remained consistent over time (Figure 4-39; Figure 4-40; Appendix C). All metric values in 2020 were within measurements from 2006 to 2019. Only Density and Number or Predator Taxa have significantly increased from 2006 to 2020 with no other metric revealing any trend (Table 4-22). Diversity has been greater than 2.5 in all years of sampling indicating a healthy invertebrate community and HBI has fluctuated from "Good" (4.71 in 2017) to "Excellent" (3.24 in 2009).

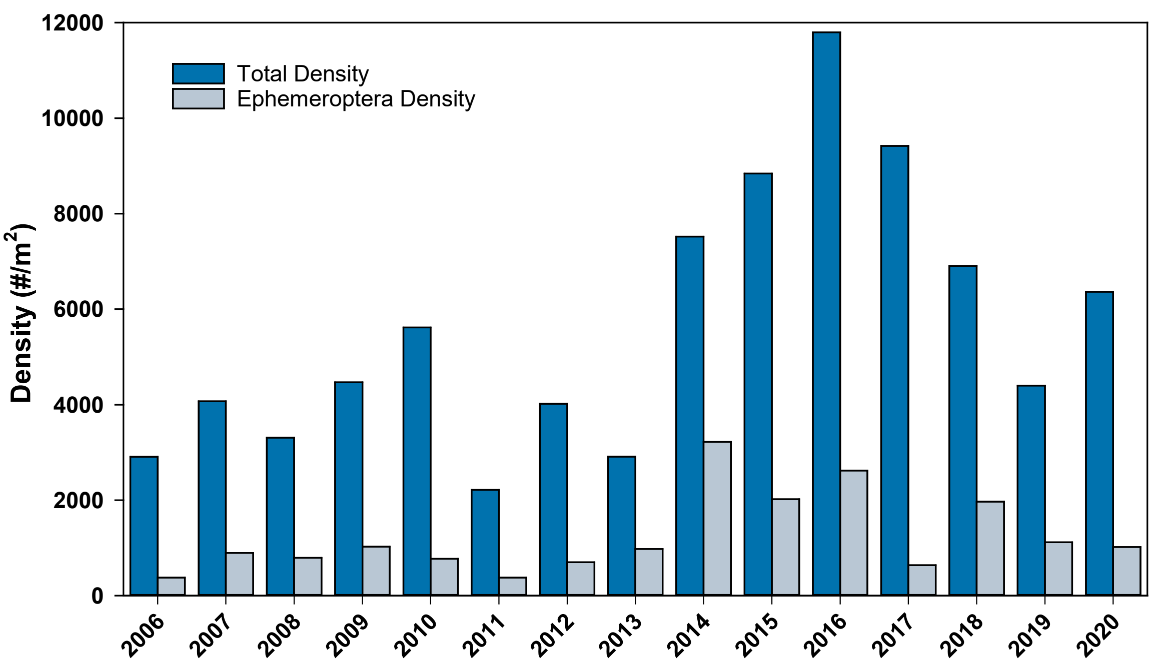

Figure 4-39: Macroinvertebrate density metrics for Site SG-1-BIO on Stewart Gulch, 2006 - 2020.

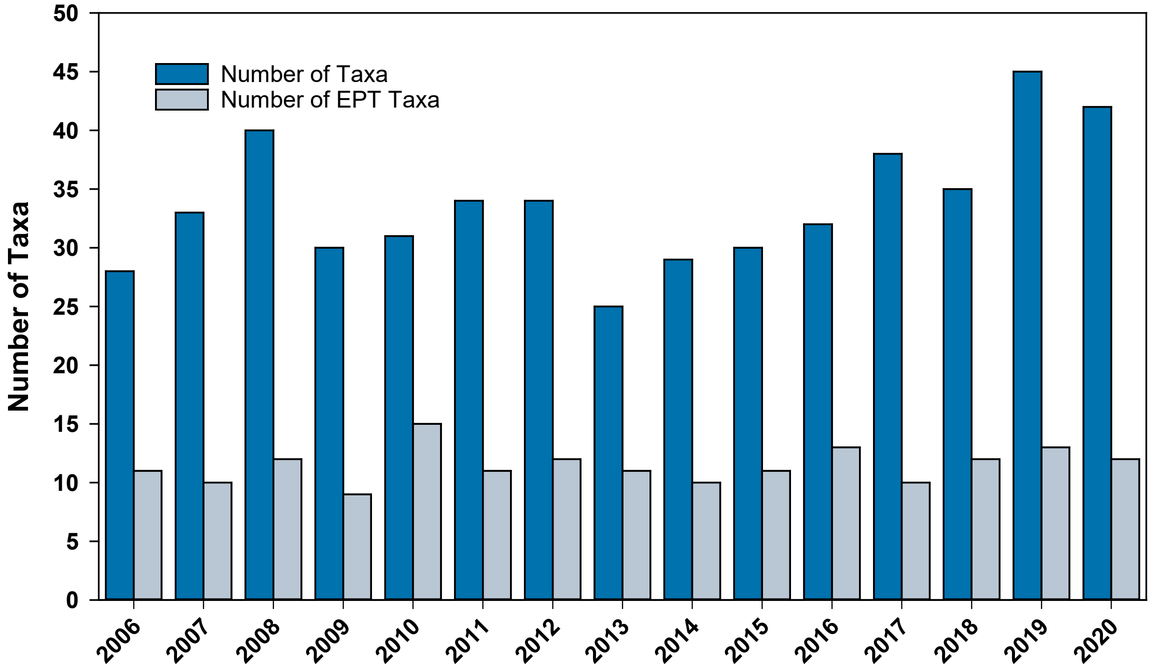

Figure 4-40: Macroinvertebrate taxa richness metrics for Site SG-1-BIO on Stewart Gulch, 2006 - 2020. NS = Not Sampled. D= Dry.

Overall, the 2020 data showed little change with metric values being similar to those in previous years. The long-term median Density was, however, greater at Site SG-1-BIO than at the reference site ($p = 0.029$) while the Number of Taxa and EPT Taxa and Diversity were significantly better at the reference site from 2006 to 2020 ($p = 0. 026$, $p = 0.001$, and $p = 0.044$ respectively). The benthic macroinvertebrate community at Site SG-1-BIO is influenced by elevated nitrate concentrations from the spring upstream of the site causing the increased growth of watercress since 2011. The increased habitat provided by the macrophyte growth may also have contributed to the increased benthic macroinvertebrate density over time. Generally, historic benthic macroinvertebrate community metric data at Site SG-1-BIO reveals rich and diverse macroinvertebrate communities, with numerous intolerant taxa.

4.4 Periphyton Populations

4.4.1 Labrador Gulch

4.4.1.1 2020 Data

In August 2020, the periphyton community at Site LB-4-BIO consisted completely of Pennate diatoms (Table 4-25; Appendix D). The Diversity value for diatoms was above the 2.5 threshold, indicating a diverse community (Table 4-26). The Autotrophic Index was very high, greater than most other sites, and indicated that organic matter may be influencing the site, although chlorophyll-a was lower in 2020 than all other years since 2006. In addition, motile diatoms comprised a large portion of the total diatom density indicating siltation. However, Pollution tolerant diatoms comprised a low proportion of the total diatom density indicating low organic matter deposition. The Pollution Index value also showed that a relatively large proportion of the periphyton community was comprised of sensitive diatoms and that no organic enrichment occurred.

Table 4-25: Relative periphyton density (%) and biomass estimates for sites at the reference sites on Labrador Gulch and Reno Creek, August 2020.

Taxa/Metric	LB-4-BIO	RC-1-BIO
BACILLARIOPHYTA		
Pennales (Pennate diatoms)	100.00	99.12
CRYPTOPHYTA (Cryptomonads)	--	0.88
BIOMASS		
AFDM (mg/m^2)	4,545	6,198
Chlorophyll-a (mg/m^2)	3.7	1.8

Table 4-26: Periphyton population metrics for sites at the reference sites on Labrador Gulch and Reno Creek, August 2020.

Metric	LB-4-BIO	RC-1-BIO
RICHNESS		
Density ($cells/cm^2$)	33,888	115,261
Relative Diatom Density	100%	99%
Number of Taxa (species)	15	24
Number of Diatom Taxa	15	23
Number of Periphyton Divisions	1	2
Number of Periphyton Genera	9	13
COMPOSITION		
Shannon-Weaver Diversity Index for Diatoms	2.60	3.14
Bahls Similarity Index	--	--
Autotrophic Index	1,228	3,443
TOLERANCE		
Percent Tolerant Diatoms	3.7%	6.2%
Lange-Bertalot Pollution Index	2.83	2.64
TROPHIC HABIT		
Percent Eutrophic Diatoms	46.7%	47.8%
Percent Acidiphilic Diatoms	0.0%	0.0%
Percent Alkaliphilic Diatoms	46.7%	52.2%
Percent Nitrogen Heterotrophs	20.0%	17.4%
Percent High Oxygen Diatoms	20.0%	39.1%
Percent Motile Diatoms	66.7%	56.5%
Percent Saprobic Diatoms	13.3%	8.7%

In headwaters streams, such as the ones surveyed for the Wharf Biomonitoring project, organic inputs are often influenced by allochthonous (i.e., outside of the stream) sources, particularly leaf litter from within the watershed. This detritus can then settle to the substrate, be collected as part of the periphyton sample, and potentially skew the Autotrophic Index value. This scenario likely leads to the disagreement between the Pollution Index and Autotrophic Index metrics observed at this and other Wharf sites. Site LB-4-BIO, specifically, contains a large amount of low, overhanging vegetation, log jams, and leaf litter which may have contributed to the relatively higher Autotrophic Index in 2020. Taking this into account, this site appeared to have a healthy periphyton community in 2020.

4.4.1.2 Historic Data

The periphyton community at Site LB-4-BIO changed moderately from 2006 to 2020. Pennate diatoms have been the dominant group for every year, with centric diatoms and cyanobacteria also occasionally found at this site. Richness metric values for Numbers of Taxa significantly increased while the Number of Periphyton Divisions decreased over the time period (Figure 4-41; Table 4-27; Appendix E). In addition, the 2020 Density was lower than that previously recorded (38,956 cells/cm^2 in 2013) while all other metric values were within the range from previous years. For the composition metrics, Diversity significantly improved from 2006 to 2020 and the Autotrophic Index remained consistently high at this reference site. Tolerance metric values have not trended while the trophic habit metric, Percent Motile Diatoms significantly increased over time and the Percent of High Oxygen Diatoms significantly declined from 2006 to 2020, albeit slightly. Percent of High Oxygen Diatoms was also lower in 2020 than other years (previous minimum of 22.2% in 2013). Overall, despite these few trends, data in 2020 revealed negligible changes with metric values being similar to those observed in recent years.

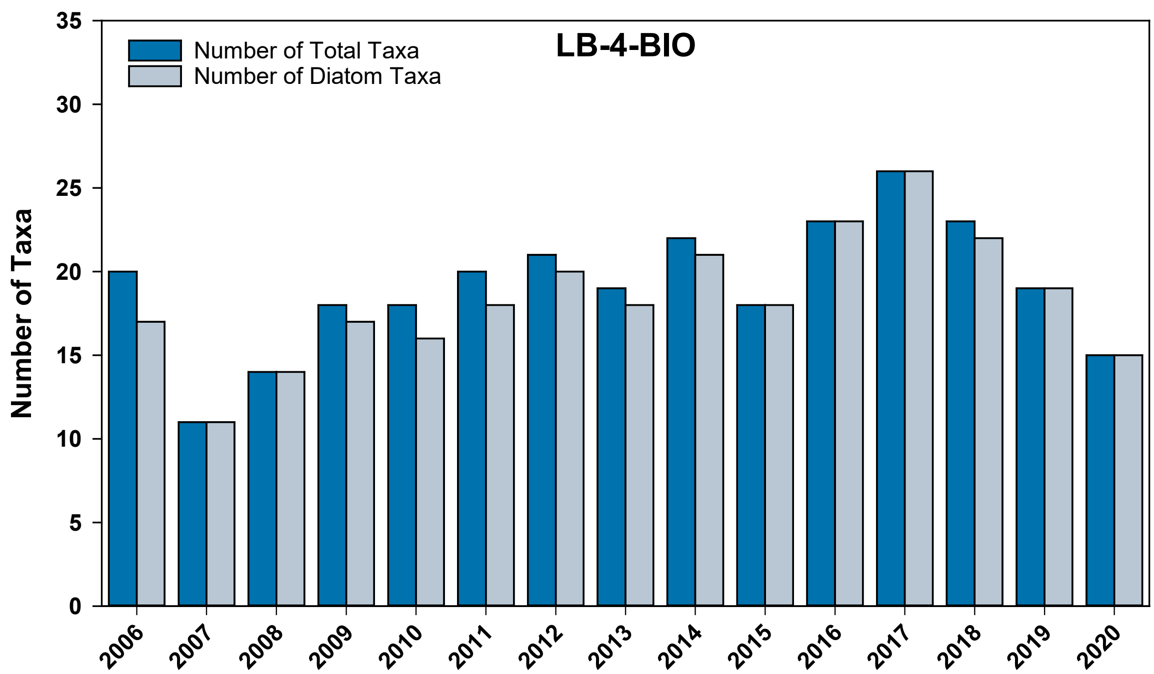

Figure 4-41: Periphyton taxa richness metrics at Site LB-4-BIO on Labrador Gulch, 2006 – 2020.

Table 4-27: Slopes of significant trends ($p < 0.05$) for periphyton population parameters at the reference sites on Labrador Gulch and Reno Creek, 2006 - 2020. + = Positive slope. - = Negative slope. -- = Not significant. NA = Not applicable.

Metric	Change Expected Following Environmental Disturbance	LB-4-BIO	RC-1-BIO
RICHNESS			
Density (cells/cm^2)	Variable	--	--
Relative Diatom Density	Variable	--	--
Number of Taxa (species)	Decrease	--	--
Number of Diatom Taxa	Decrease	+ 0.47	--
Number of Periphyton Divisions	Variable	- 0.21	--
Number of Periphyton Genera	Variable	--	--
COMPOSITION			
Shannon-Weaver Diversity Index for Diatoms	Decrease	+ 0.05	--
Bahls Similarity Index	Variable	NA	NA
Autotrophic Index	Increase	--	--
TOLERANCE			
Percent Tolerant Diatoms Density	Increase	--	--
Lange-Bertalot Pollution Index	Decrease	--	--
TROPHIC HABIT			
Percent Eutrophic Diatoms	Variable	--	--
Percent Acidiphilic Diatoms	Variable	--	--
Percent Alkaliphilic Diatoms	Variable	--	--
Percent Nitrogen Heterotrophs	Variable	--	--
Percent High Oxygen Diatoms	Variable	- 0.01	+ 0.06
Percent Motile Diatoms	Increase	+ 0.01	--
Percent Saprobic Diatoms	Variable	--	--

4.4.2 Reno Creek

4.4.2.1 2020 Data

Pennate diatoms comprised 99.1% of the periphyton community at Site RC-1-BIO in 2020 (Table 4-25; Appendix D). The Diversity value for diatoms was well above the threshold of 2.5 (Table 4-26), which is an improvement over the last three years. The Autotrophic Index was roughly half of that in 2019 but still very poor, the highest of any site, and indicated that organic matter deposition was affecting the site. The AFDM was far less than in 2019 but remained greater than in 2017 and 2018, while the chlorophyll-a content remained relatively consistent. As a headwater stream, there appears to have been some allochthonous loading to the reach which inflated the Autotrophic Index as is the case with Site LB-4-BIO. Pollution tolerant and motile diatoms were present at low numbers and indicated low siltation. The

Pollution Index value also showed that a relatively large proportion of the periphyton community was comprised of sensitive diatoms and that no organic matter pollution occurred. Overall, this site appeared to have a healthy periphyton community in 2020.

4.4.2.2 Historic Data

The periphyton community at Site RC-1-BIO changed slightly from 2017, when sampling began, to 2020. Pennate diatoms have been the dominant group for every year. Richness and composition metric values have not trended (Table 4-27). The only metric to trend was the trophic habit metric, Percent High Oxygen Diatoms which significantly increased from 2017 to 2020, although the rate of change was small. In addition, 9 of the 18 metrics were greater than in previous years, and Diatom Density was less. However, this is not surprising as only four years of data have been collected. Overall, the presence/absence of trends at Site RC-1-BIO should be cautiously interpreted as only four years of data have been collected.

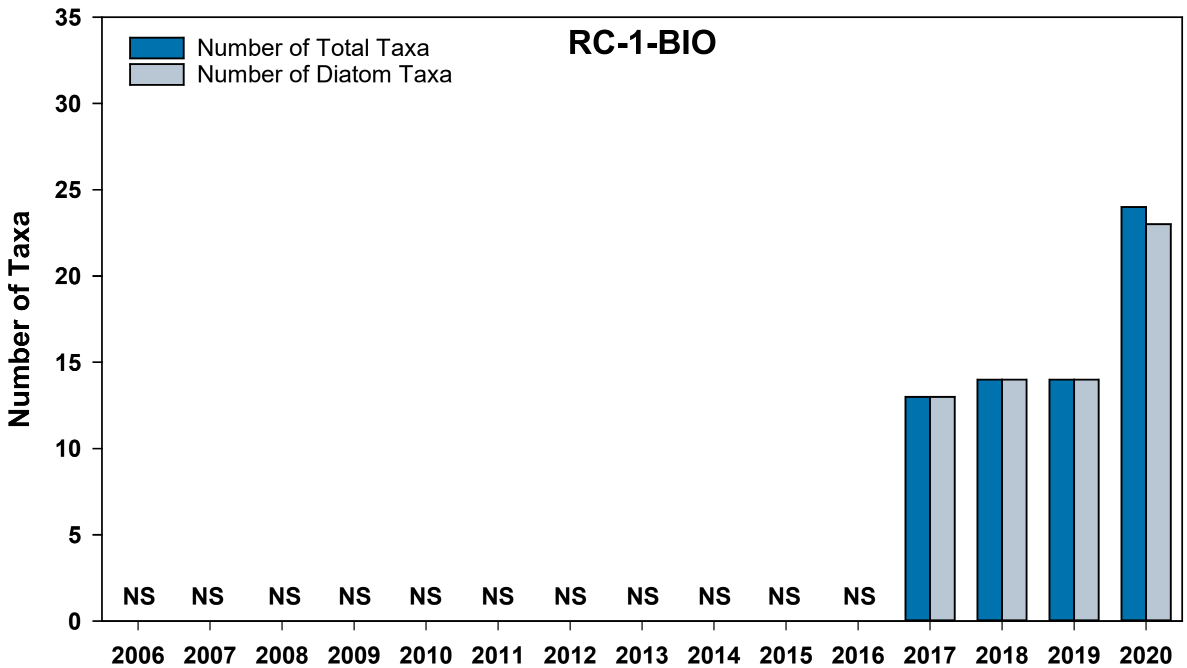

Figure 4-42: Periphyton taxa richness metrics at Site RC-1-BIO on Labrador Gulch, 2006 – 2020. NS = not sampled.

4.4.3 Annie Creek

4.4.3.1 Site AC-1-BIO

4.4.3.1.1 2020 Data

In August 2020 at Site AC-1-BIO, the periphyton assemblage consisted of pennate diatoms, green algae, and cryptomonads (Table 4-28; Appendix D). The Diversity value for diatoms was much greater than in 2019 and well above the 2.5 threshold, indicating a diverse community (Table 4-29). The Autotrophic Index was moderate and indicated that organic enrichment likely occurred in this reach. Pollution tolerant and motile diatoms were present and indicated some organic matter deposition occurs in this reach. However, the Pollution Index value indicated that a relatively large proportion of the periphyton community was comprised of sensitive diatoms. Again, the disparity between these metrics indicates that some organic matter deposition is likely from the heavily vegetated stream banks.

Table 4-28: Relative periphyton Density (%) and biomass estimates for sites on Annie Creek, August 2020.

Taxa/Metric	AC-1-BIO	AC-2-BIO
BACILLARIOPHYTA		
Pennales (Pennate diatoms)	93.97	100.00
CHLOROPHYTA (Green algae)	2.59	--
CRYPTOPHYTA (Cryptomonads)	3.45	--
BIOMASS		
AFDM (mg/m^2)	13,223	2,617
Chlorophyll-a (mg/m^2)	56.0	8.7

Table 4-29: Periphyton population metrics for sites on Annie Creek, August 2020.

Metric	AC-1-BIO	AC-2-BIO
RICHNESS		
Density ($cells/cm^2$)	173,223	22,535
Relative Diatom Density	94%	100%
Number of Taxa (species)	22	16
Number of Diatom Taxa	19	16
Number of Periphyton Divisions	3	1
Number of Periphyton Genera	12	8
COMPOSITION		
Shannon-Weaver Diversity Index for Diatoms	3.28	2.82
Bahls Similarity Index	38.4%	53.3%
Autotrophic Index	236	301
TOLERANCE		
Percent Tolerant Diatoms Density	12.8%	7.7%
Lange-Bertalot Pollution Index	2.57	2.68
TROPHIC HABIT		
Percent Eutrophic Diatoms	52.6%	50.0%
Percent Acidiphilic Diatoms	0.0%	0.0%
Percent Alkaliphilic Diatoms	47.4%	43.8%
Percent Nitrogen Heterotrophs	15.8%	18.8%
Percent High Oxygen Diatoms	36.8%	25.0%
Percent Motile Diatoms	52.6%	56.3%
Percent Saprobic Diatoms	10.5%	18.8%

Periphyton richness, composition, tolerance, and trophic habit metric values at Site AC-1-BIO were similar to those at the reference site, Site RC-1-BIO, in 2020. Number of Diatom Taxa was slightly greater at the reference site, but the other richness metrics were comparable. Composition metrics indicated that Diversity was similar, and the Bahls Similarity Index revealed a "Somewhat Dissimilar" assemblage between Site AC-1-BIO and the reference site. Tolerance and trophic habit metrics were also similar between the sites. Overall, Site AC-1-BIO appeared to have a healthy periphyton community in 2020.

4.4.3.1.2 Historic Data

The periphyton community at Site AC-1-BIO has been variable over the years with most metrics indicating no significant trends from 2006 to 2020. Pennate diatoms have been the dominant group in most years, although green algae were dominant in 2010 and 2011. Cyanobacteria and cryptomonads have also been present in small numbers in some years. Richness, composition, and tolerance metric values have not significantly trended from 2006 and 2020 and the only metric value outside of its range recorded in previous years was Autotrophic Index (less than 239 in 2014; Figure 4-43; Table 4-30; Appendix E). Two trophic habit metrics, Percent Eutrophic and Saprobic Diatoms significantly improved, albeit slightly from 2006 to 2020. Only long-term Autotrophic Index data, of the eight metrics assessed, was significantly different ($p = 0.007$) between Site AC-1-BIO ($n = 15$) and reference Site RC-1-BIO ($n = 4$) with Site AC-1-BIO being lower. Overall, Site AC-1-BIO has supported a healthy periphyton assemblage since 2006 similar to that found at the reference site.

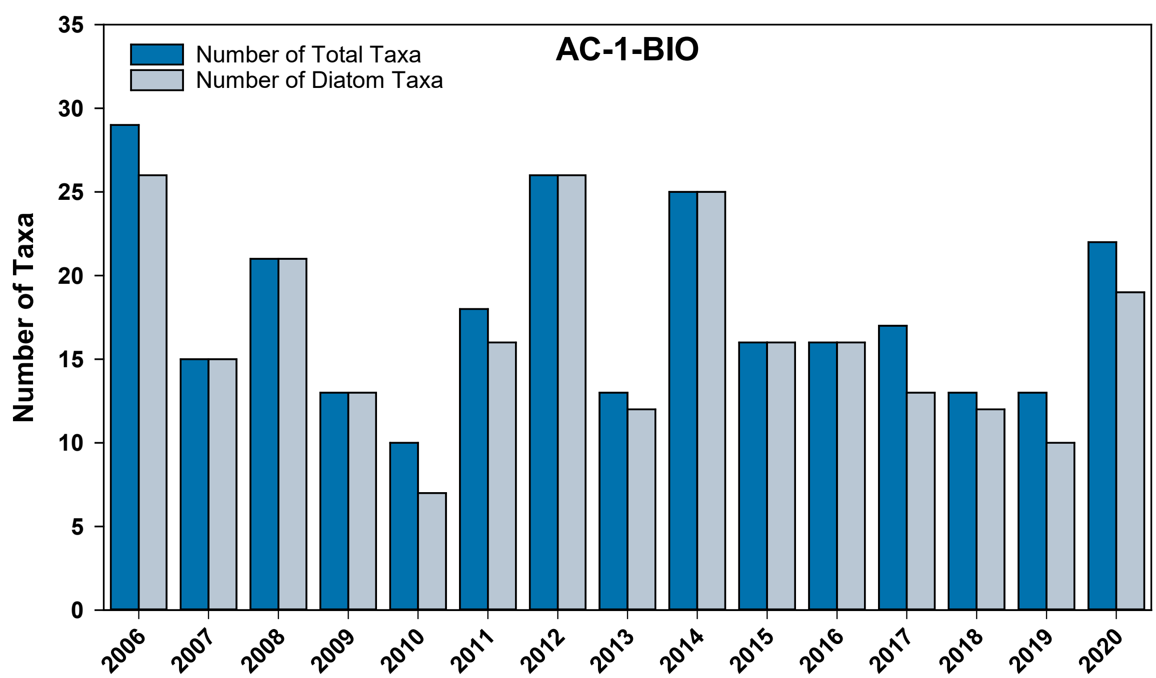

Figure 4-43: Periphyton taxa richness metrics at Site AC-1-BIO on Annie Creek, 2006 – 2020.

Table 4-30: Slopes of significant trends ($p < 0.05$) for periphyton population parameters at Annie Creek, 2006 - 2020. + = Positive slope. - = Negative slope. -- = Not significant. * = Site not sampled in 2020; 2006 – 2019 trends.

Metric	Change Expected Following Environmental Disturbance	AC-1-BIO	AC-2-BIO	AC-3-BIO*
RICHNESS				
Density (cells/cm^2)	Variable	--	--	--
Relative Diatom Density	Variable	--	--	--
Number of Taxa (species)	Decrease	--	--	--
Number of Diatom Taxa	Decrease	--	--	--
Number of Periphyton Divisions	Variable	--	--	--
Number of Periphyton Genera	Variable	--	--	--
COMPOSITION				
Shannon-Weaver Diversity Index for Diatoms	Decrease	--	--	--
Bahls Similarity Index	Variable	--	--	--
Autotrophic Index	Increase	--	--	--
TOLERANCE				
Percent Tolerant Diatoms Density	Increase	--	--	--
Lange-Bertalot Pollution Index	Decrease	--	--	--
TROPHIC HABIT				
Percent Eutrophic Diatoms	Variable	- 0.01	--	--
Percent Acidiphilic Diatoms	Variable	--	--	--
Percent Alkaliphilic Diatoms	Variable	--	- 0.01	--
Percent Nitrogen Heterotrophs	Variable	--	--	--
Percent High Oxygen Diatoms	Variable	--	--	--
Percent Motile Diatoms	Increase	--	--	--
Percent Saprobic Diatoms	Variable	- 0.01	--	--

4.4.3.2 Site AC-2-BIO

4.4.3.2.1 2020 Data

The periphyton assemblage consisted of all pennate diatoms at Site AC-2-BIO in August 2020 (Table 4-28; Appendix D). The diatom Diversity value was above the 2.5 threshold, indicating a diverse community (Table 4-29). Tolerant and motile diatoms were present, indicating a response to siltation. The Pollution Index indicated that a large proportion of the periphyton community was comprised of sensitive diatoms and that no organic enrichment occurred. However, the Autotrophic Index for 2020 was moderate due to a very low AFDM and indicted some allochthonous enrichment.

In 2020 metric values at Site AC-2-BIO were comparable to those at the reference site, Site LB-4-BIO. Richness, composition, tolerance, and trophic habit metrics were similar between the sites. Differences between the sites resulted in a Bahls Similarity Index of “Somewhat Similar” taxa between Site AC-2-BIO and the reference Site LB-4-BIO. Overall, both sites support healthy periphyton communities with Site AC-2-BIO likely affected by the increased siltation in recent years.

4.4.3.2.2 Historic Data

The periphyton community at Site AC-2-BIO changed little from 2006 to 2020. Pennate diatoms have been the dominant group in all years while green algae, cyanobacteria, and cryptomonads were present in small numbers in some years. Significant trends were not observed for richness, composition, and tolerance metrics (Table 4-30). Only the trophic habit metric, Percent Alkaliphilic Diatoms significantly decreased from 2006 to 2020, albeit slightly, and was lower in 2020 than previous years (previous minimum of 45.5% in 2011). Number of Periphyton Genera was also less in 2020 than in past years (8 in 2011; Table 4-29; Appendix E). When Site AC-2-BIO metrics were compared to the reference Site LB-4-BIO metrics, only two of the eight tests indicated significant differences between the long-term median values. The Number of Taxa was significantly lower ($p = 0.025$) at Site AC-2-BIO ($n = 15$) than at the reference site ($n = 15$), while all other metrics showed no differences. Metric data in 2020 revealed negligible annual changes with many of the metric values being similar to those in previous years.

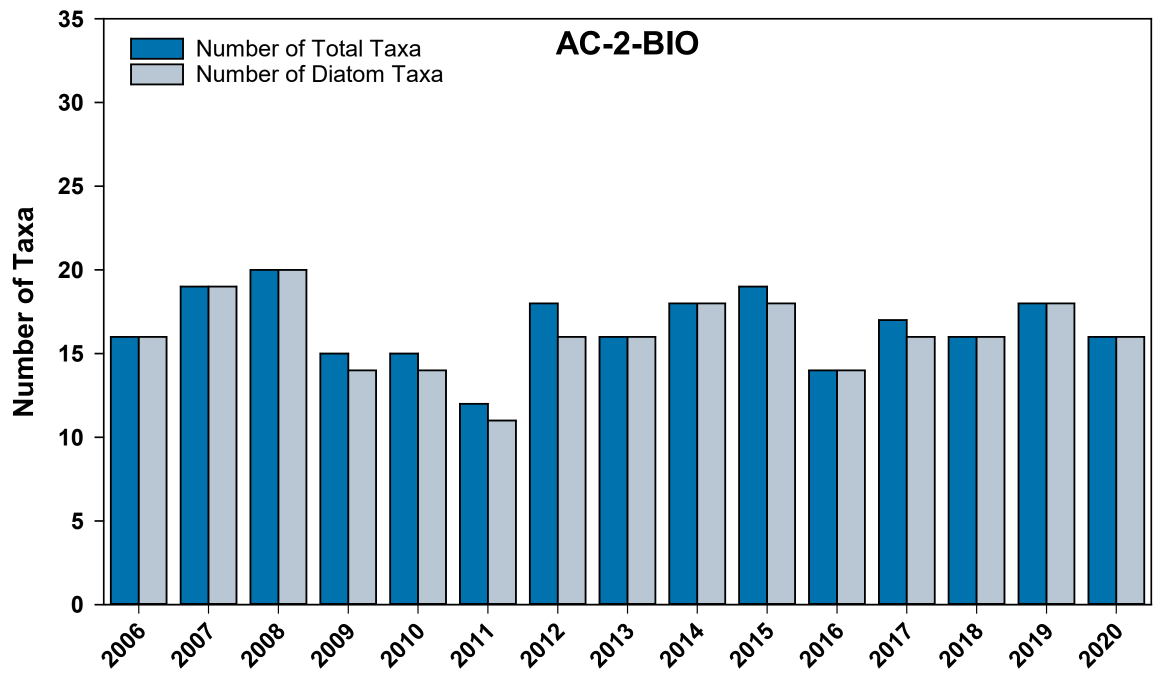

Figure 4-44: Periphyton taxa richness metrics at Site AC-2-BIO on Annie Creek, 2006 - 2020.

4.4.3.3 Site AC-3-BIO

4.4.3.3.1 2020 Data

The majority of Annie Creek at Site AC-3-BIO was not accessible for periphyton monitoring in 2020 due to extensive deadfall from recent tornado activity and samples were not collected (Photo 4-3).

4.4.3.3.2 Historic Data

From 2006 to 2019, the periphyton community at Site AC-3-BIO was variable with no significant trends (Table 4-30; Appendix E). Pennate diatoms have been the dominant group in all years with green algae and cyanobacteria present in small numbers in some years. When Site AC-3-BIO metrics were compared to the reference Site LB-4-BIO metrics, only two of the eight tests indicated significant differences between the long-term median values. Density was significantly higher and Autotrophic Index was significantly better ($p = 0.029$ and $p = 0.003$, respectively) at Site AC-3-BIO ($n = 14$) than at the reference site ($n = 15$). Overall, periphyton communities at both sites have had good diversity with little organic enrichment from 2006 to 2019.

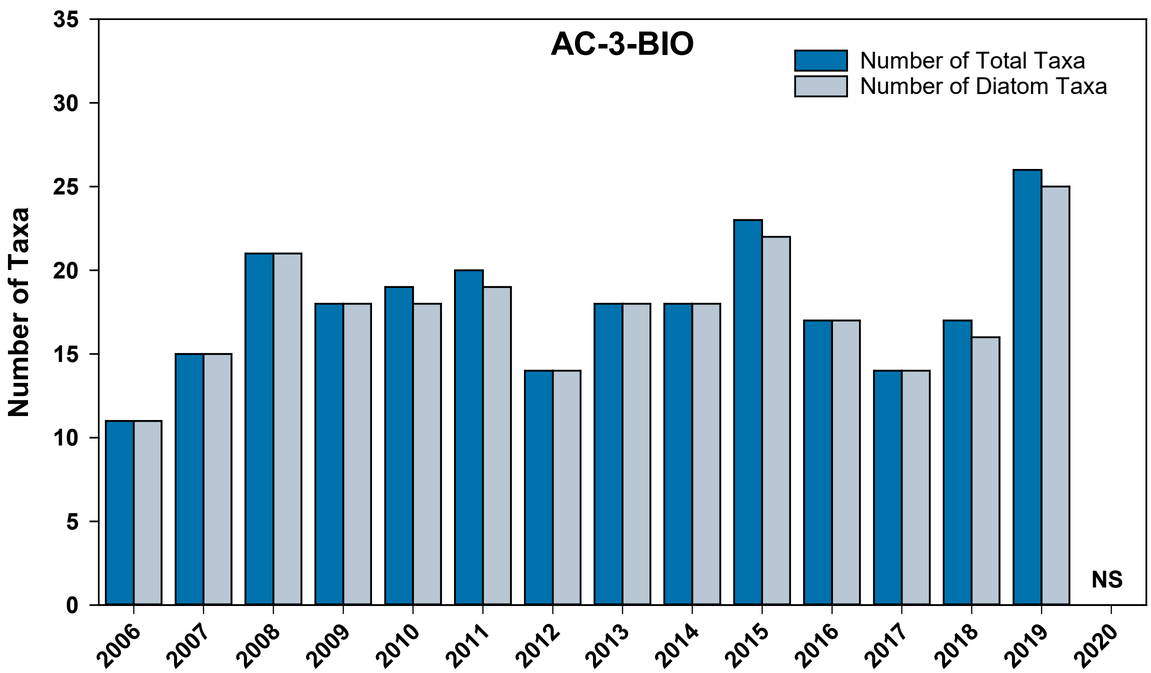

Figure 4-45: Periphyton taxa richness metrics at Site AC-3-BIO on Annie Creek, 2006 – 2020.

4.4.3.4 Site Comparisons

4.4.3.4.1 2020 Data

Periphyton metric values were different between the two Annie Creek sites in 2020. Density, Number of Taxa and Diatom Taxa, Diversity, and multiple trophic metrics were more favorable at Site AC-1-BIO while only Pollution Index was slightly more favorable at Site AC-2-BIO in 2020. The Autotrophic Index was moderate at both sites, but this value may be influenced by organic matter present in the stream. Diversity at both sites was above the 2.5 threshold, indicating that balanced diatom assemblages were present.

4.4.3.4.2 Historic Data

Median 2006 to 2020 metric values were similar between the three Annie Creek sites. Only Autotrophic Index at Site AC-3-BIO (n = 14) was significantly better (p = 0.027) than at sites AC-1-BIO (n = 15) and AC-2-BIO (n = 15) sites indicating less organic pollution at this site.

4.4.4 Ross Valley

4.4.4.1 2020 Data

In August 2020, the periphyton assemblage consisted of 94% pennate diatoms, 3% green algae, and 3% Cryptomonads at Site RV-2-BIO (Table 4-31; Appendix D). The Diversity value for diatoms was well above the 2.5 threshold, indicating a diverse community (Table 4-32), and the Pollution Index was high and Percent Tolerant Diatoms low, indicated that the periphyton community contained sensitive diatoms and no organic enrichment was occurring. However, the Autotrophic Index and Percent Motile Diatom metrics were relatively high in 2020 indicating allochthonous inputs, increased algal growth, and siltation. Again, the disparity between these metrics suggests that some organic matter deposition occurs in the stream, likely caused by the large amount of overhanging vegetation and woody debris at the site.

Table 4-31: Relative periphyton Density (%) and biomass estimates for sites on Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, and Cleopatra Creek, August 2020.

Taxa/Metric	RV-2-BIO	LC-1-BIO	DC-2-BIO	EFB-1-BIO	WFB-1-BIO
BACILLARIOPHYTA					
Pennales (Pennate diatoms)	94.52	100.00	98.28	99.07	100.00
Centrales (Centric diatoms)			0.86	--	--
CHLOROPHYTA (Green algae)	2.74	--	0.86	0.93	--
CRYPTOPHYTA (Cryptomonads)	2.74	--	--		--
BIOMASS					
AFDM (mg/m^2)	7,576	3,719	10,193	6,336	3,719
Chlorophyll-a (mg/m^2)	5.9	8.9	24.8	6.1	4.5

Periphyton richness, composition, tolerance, and trophic habit metric values at Site RV-2-BIO were comparable to those at the reference site, Site RC-1-BIO, in 2020. Density, Number of Taxa, and Number of Diatom Taxa were greater at the reference site than Site RV-2-BIO. However, composition metrics indicated that Diversity was better at Site RV-2-BIO. Tolerance metrics were also similar between the two sites while trophic habit metrics were slightly better at Site RV-2-BIO. These differences between the sites resulted in a Bahls Similarity Index of "Somewhat Similar" taxa between Site RV-2-BIO and the reference site. Overall, both sites appeared to have healthy periphyton communities in 2020.

Table 4-32: Periphyton population metrics for sites on Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, and Cleopatra Creek, August 2020.

Metric	RV-2-BIO	LC-1-BIO	DC-2-BIO	EFB-1-BIO	WFB-1-BIO
RICHNESS					
Density (cells/cm^2)	52,101	36,665	589,501	145,259	38,391
Relative Diatom Density	95%	100%	99%	99%	100%
Number of Taxa (species)	19	16	21	20	11
Number of Diatom Taxa	17	16	20	19	11
Number of Periphyton Divisions	3	1	3	2	1
Number of Periphyton Genera	12	8	12	11	8
COMPOSITION					
Shannon-Weaver Diversity Index for Diatoms	3.58	3.34	3.37	3.56	1.41
Bahls Similarity Index	40.2%	40.4%	38.4%	43.3%	2.3%
Autotrophic Index	1,284	418	411	1,039	826
TOLERANCE					
Percent Tolerant Diatoms Density	1.4%	25.5%	2.6%	7.5%	1.1%
Lange-Bertalot Pollution Index	2.68	2.28	2.51	2.39	2.84
TROPHIC HABIT					
Percent Eutrophic Diatoms	35.3%	31.3%	35.0%	47.4%	18.2%
Percent Acidiphilic Diatoms	0.0%	0.0%	0.0%	0.0%	27.3%
Percent Alkaliphilic Diatoms	35.3%	43.8%	40.0%	47.4%	27.3%
Percent Nitrogen Heterotrophs	0.0%	12.5%	10.0%	15.8%	0.0%
Percent High Oxygen Diatoms	29.4%	18.8%	40.0%	47.4%	63.6%
Percent Motile Diatoms	64.7%	50.0%	30.0%	47.4%	18.2%
Percent Saprobic Diatoms	5.9%	18.8%	5.0%	21.1%	0.0%

4.4.4.2 Historic Data

The periphyton community at Site RV-2-BIO has been variable over the years, and as a result, no significant trends were observed from 2006 to 2020. Pennate diatoms have been the dominant group in all years while green algae, cyanobacteria, cryptomonads, and golden algae were present in small numbers in some years. The 2020 metric values were within the range sampled in previous years except for the trophic habit metrics of Percent Eutrophic, Nitrogen Heterotrophic, and Saprobic Diatom Taxa which were lower than in previous years (previous minimums of 38.5% in 2007, 6.7% in 2017, and 7.1% in 2016, respectively; Table 4-33; Figure 4-46; Appendix E). Only two of the eight tests comparing median metric values were significantly different between Site RV-2-BIO and the reference Site RC-1-BIO. Diversity was significantly better (p = 0.021) and Percent Motile Diatoms was significantly worse (p = 0.011) at Site RV-2-BIO (n = 15) than at the reference site (n = 4). Despite some poor metrics as a result of allochthonous inputs, the 2020 metric values were similar to those in previous years and to the reference site. The periphyton community has remained relatively consistent in Ross Valley with good diversity with little organic enrichment.

Table 4-33: Slopes of significant trends (p < 0.05) for periphyton population metrics at Ross Valley, Lost Camp Gulch, Deadwood Creek, East Fork False Bottom Creek, and West Fork False Bottom Creek, 2006 - 2020. + = Positive slope. - = Negative slope. -- = Not significant.

Metric	Change Expected Following Environmental Disturbance	RV-2-BIO	LC-1-BIO	DC-2-BIO	EFB-1-BIO	WFB-1-BIO
RICHNESS						
Density (cells/cm^2)	Variable	--	--	--	--	--
Relative Diatom Density	Variable	--	--	--	--	--
Number of Taxa (species)	Decrease	--	--	--	--	--
Number of Diatom Taxa	Decrease	--	--	--	--	--
Number of Periphyton Divisions	Variable	--	--	--	--	--
Number of Periphyton Genera	Variable	--	--	--	--	- 0.57
COMPOSITION						
Shannon-Weaver Diversity Index for Diatoms	Decrease	--	--	--	--	--
Bahls Similarity Index	Variable	--	--	--	--	- 0.01
Autotrophic Index	Increase	--	--	--	--	--
TOLERANCE						
Percent Tolerant Diatoms Density	Increase	--	+ 0.02	- 0.01	--	- 0.003
Lange-Bertalot Pollution Index	Decrease	--	--	--	- 0.02	--
TROPHIC HABIT						
Percent Eutrophic Diatoms	Variable	--	--	--	--	- 0.02
Percent Acidiphilic Diatoms	Variable	--	--	--	--	
Percent Alkaliphilic Diatoms	Variable	--	--	--	--	- 0.02
Percent Nitrogen Heterotrophs	Variable	--	--	--	--	- 0.01
Percent High Oxygen Diatoms	Variable	--	- 0.02	--	--	+ 0.01
Percent Motile Diatoms	Increase	--	--	--	--	- 0.03
Percent Saprobic Diatoms	Variable	--	--	--	--	- 0.01

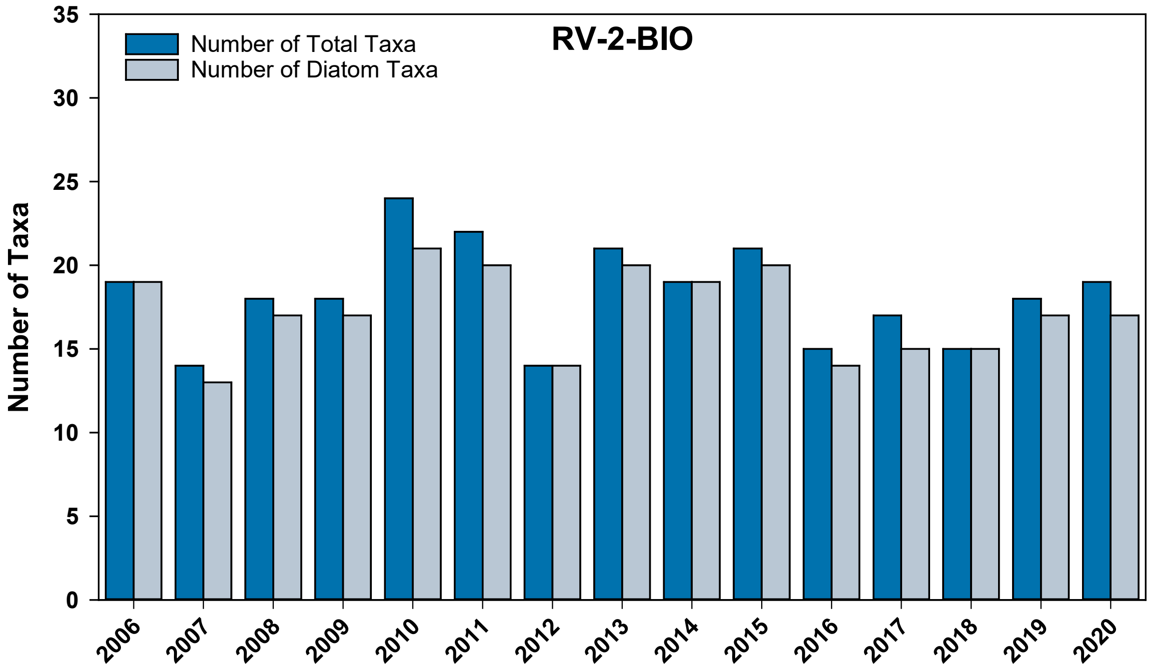

Figure 4-46: Periphyton taxa richness metrics at Site RV-2-BIO on Ross Valley, 2006 – 2020.

4.4.5 Lost Camp Gulch

4.4.5.1 2020 Data

The periphyton assemblage at Site LC-1-BIO in August 2020 consisted of 100% pennate diatoms (Table 4-31; Appendix D). The Diatom Diversity value was well above the 2.5 threshold, indicating a balanced periphyton community (Table 4-32) and the Pollution Index was indicative of only minor organic enrichment. The Autotrophic Index indicated organic pollution but was relatively low compared to the other sites. Roughly 25% of diatoms were tolerant, more than any other site, motile diatoms comprised over half of the assemblage at this site, indicating that siltation was affecting the assemblage. The adjacent dirt roadway acts as a source of sediment for this site.

In 2020, periphyton richness, composition, tolerance, and trophic habit metric values at Site LC-1-BIO were comparable to those at the reference site, Site RC-1-BIO. Most richness metrics were greater at the reference site while Diversity was good and comparable at both sites. Tolerance metrics were more favorable at the reference site while trophic habit metrics were not more favorable at either site. These differences between the sites resulted in a Bahls Similarity Index of "Somewhat Similar" taxa between Site LC-1-BIO and the reference site. Overall, both sites appeared to have healthy periphyton communities in 2020 while Site LC-1-BIO may be influenced by low flows and siltation.

4.4.5.2 Historic Data

The periphyton community at Site LC-1-BIO changed little from 2010, when sampling began, to 2020. Pennate diatoms have been the dominant group in all years with green algae, cyanobacteria, and cryptomonads present in small numbers in some years. Richness and composition metric values have not significantly trended over the years and only Number of Periphyton Genera is less than the range of those previously recorded (previous minimum of 9 in 2011; Table 4-33; Figure 4-47; Appendix E). The tolerance metric, Percent Tolerant Diatoms, and the trophic habit metric, Percent High Oxygen Diatoms, have slightly, but significantly, declined in quality since 2010. Percent Eutrophic and High Oxygen Diatom Taxa were lower in 2020 than any other year (previous minimums of 35.3% in 2010 and 26.7% in 2018, respectively). The Autotrophic Index from 2010 to 2020 was significantly better (p = 0.026) at Site LC-1-BIO (n = 11) than at the reference site (n = 4) while no other long-term metrics were different between the sites. Overall, the metrics indicate that periphyton conditions have remained relatively favorable at the Lost Camp Gulch site for the duration of the study period, although periodic low flows, sedimentation, and organic enrichment do occur.

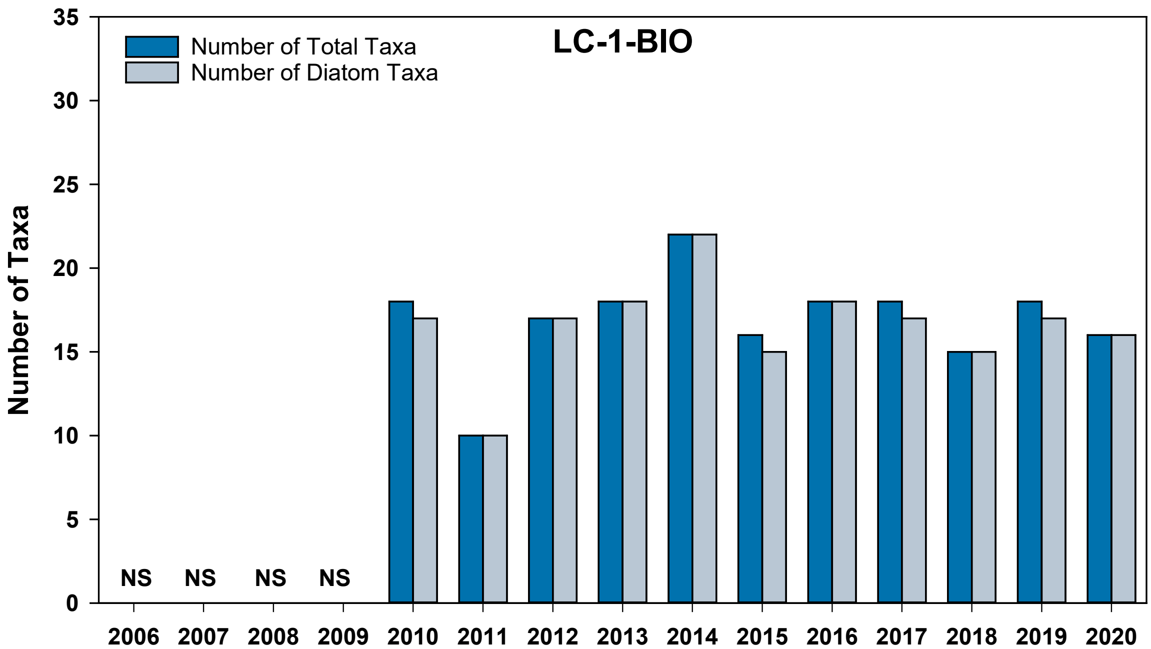

Figure 4-47: Periphyton taxa richness metrics at Site LC-1-BIO on Lost Camp Gulch, 2006 – 2020. NS = Not Sampled.

4.4.6 Deadwood Creek

4.4.6.1 2020 Data

The periphyton assemblage consisted of 99% pennate diatoms with the remainder being centric diatoms and green algae at Site DC-2-BIO in August 2020 (Table 4-31; Appendix D).

The Diversity value for diatoms was well above the 2.5 threshold and indicates a diverse periphyton community (Table 4-32). The Autotrophic Index value was slightly above 400, indicating that the community is being affected by organic matter inputs; although this is relatively low compared to many other sites. The Pollution Index value also indicated that almost no organic enrichment occurred. Percent Tolerant Diatoms and all trophic habit metrics were favorable indicating little siltation or pollution.

In 2020, periphyton richness, composition, tolerance, and trophic habit, metric values at Site DC-2-BIO were comparable to those at the reference site, Site LB-4-BIO. Most richness metrics were greater at Site DC-2-BIO than the reference site. Diversity was higher at Site DC-2-BIO, while Pollution Index was greater at the reference site; however, both metrics were good at both sites. The Bahls Similarity Index indicated a "Somewhat Dissimilar" community at Site DC-2-BIO. Trophic habit metrics were more favorable at Site DC-2-BIO. Overall, the metrics for Site DC-2-BIO indicates that this reach supports a moderate number of taxa with a relatively diverse periphyton community.

4.4.6.2 Historic Data

The periphyton community at Site DC-2-BIO has remained relatively stable since 2010. Pennate diatoms have been the dominant periphyton group in all years with green algae present in small numbers in some years. Richness, composition, and trophic habit metric values have not significantly trended over the years (Figure 4-48; Table 4-33; Appendix E). For tolerance metrics, Percent Tolerant Diatoms significantly decreased over time. Lastly, Percent Motile Diatoms were lower than those previously observed (33.3% in 2017).

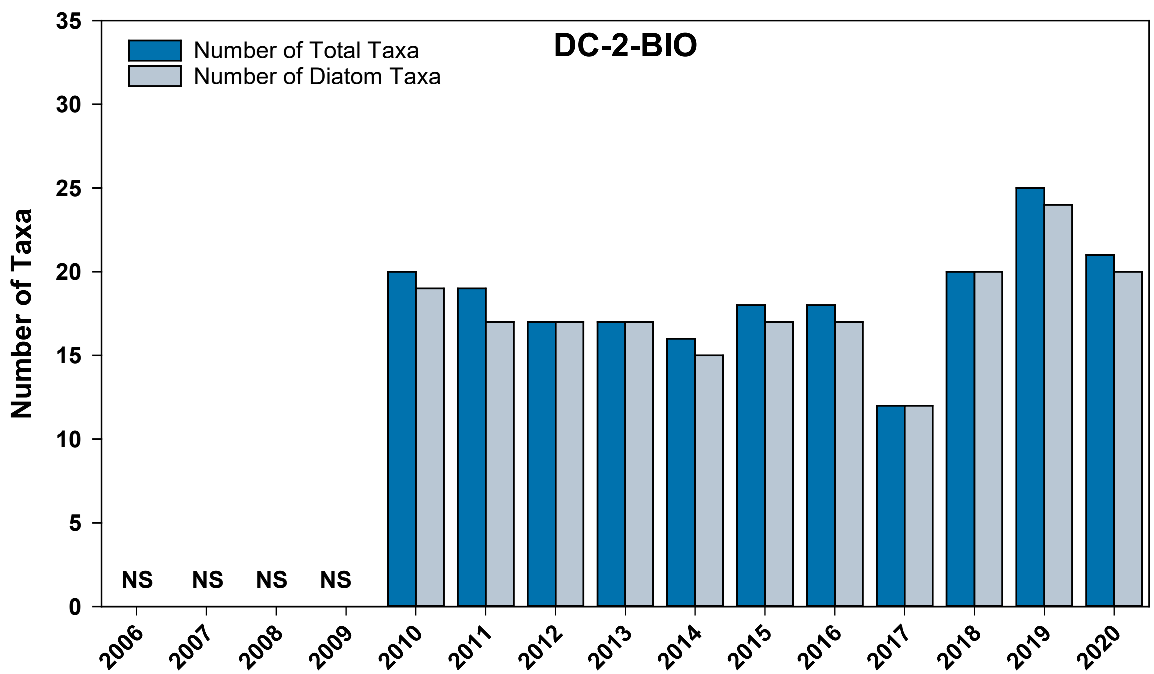

Figure 4-48: Periphyton taxa richness metrics at Site DC-2-BIO on Deadwood Creek, 2006 – 2020. NS = Not Sampled.

When Site DC-2-BIO metrics were compared to the metrics for reference site (LB-4-BIO), only three of the eight tests indicated a significant difference between the long-term median values. Density has been significantly higher and Percent Motile Diatom metrics have been significantly better ($p = 0.002$, $p < 0.001$, respectively) at Site DC-2-BIO ($n = 10$), while the Pollution Index has been significantly worse ($p = 0.027$) at Site DC-2-BIO when compared to the reference site ($n = 15$). Overall, periphyton communities at both sites have shown good diversity with few differences between the assemblages.

4.4.7 False Bottom Creek

4.4.7.1 Site EFB-1-BIO

4.4.7.1.1 2020 Data

The periphyton assemblage at Site EFB-1-BIO in August 2020 consisted of 99% pennate diatoms and 1% green algae and cryptomonads (Table 4-31; Appendix D). The Diatom Diversity value was far greater than the 2.5 threshold, indicating a balanced community (Table 4-32). The chlorophyll-a content was typical for this site while the AFDM was high. As a result, the Autotrophic Index was poor and indicated that organic matter inputs affected the site. The Pollution Index value also indicated that minor organic enrichment occurred. A relatively low Percent of Pollution Tolerant Diatoms and Motile Diatoms were present.

In 2020, periphyton richness, composition, tolerance, and trophic habit metric values at Site EFB-1-BIO were similar to those at the reference site, Site LB-4-BIO. Most richness metrics and Diversity were greater at Site EFB-1-BIO than at the reference site, while tolerance and trophic habit metrics were similar between the sites. Similarity Index revealed a “Somewhat Similar” community between Site EFB-1-BIO and the reference site, Site LB-4-BIO. In general, Site EFB-1-BIO exhibited a diverse periphyton community similar to the reference site.

4.4.7.1.2 Historic Data

The periphyton community at Site EFB-1-BIO has revealed some variable patterns in the metrics due to limited sampling ($n = 6$) which has limited the value of trend analyses. Pennate diatoms have been the dominant group in all years with green algae, cyanobacteria, and cryptomonads being present in small numbers in some years. Only one significant trend, a decrease in the Pollution Index, was observed for the periphyton metrics due to the sporadic sampling events. However, Number of Taxa and Diatom Taxa; Diversity; and Percent Tolerant, Eutrophic, Nitrogen Heterotrophic, Motile, and Saprobic Diatoms were all greater in 2020 than the maximum values in previous year (19 in 2010, 18 in 2009 and 2010, 3.29 in 2010, 1.8% in 2006, 44.4% in 2009 and 2010, 11.1% in 2009, 25.0% in 2018, and 16.7% in 2009, respectively; Table 4-32; Figure 4-49; Appendix E). Number of Periphyton Genera and Pollution Index values were less than previously recorded (13 in 2019, 2.47 in 2019, respectively).

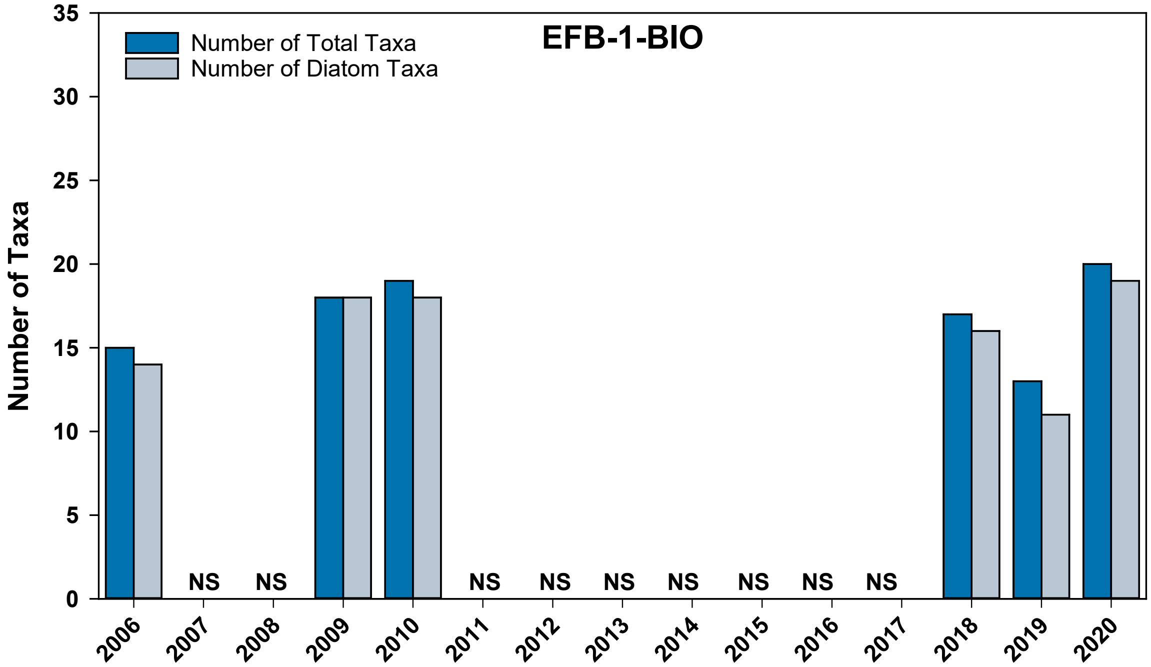

Figure 4-49: Periphyton taxa richness metrics at Site EFB-1-BIO on East Fork False Bottom Creek, 2006-2020. NS = Not Sampled.

When Site EFB-1-BIO metrics were compared to the reference Site LB-4-BIO metrics, three of the eight tests indicated significant differences between the long-term median values. However, these tests were similarly limited by the fewer sampling events at Site EFB-1-BIO. Nonetheless, Autotrophic Index was significantly greater and the metrics for Percent Tolerant and Motile Diatoms were significantly less ($p = 0.006$, $p = 0.013$ and $p = 0.002$, respectively) at Site EFB-1-BIO ($n = 6$) than at the reference site ($n = 15$). Overall, periphyton communities at both sites have shown good diversity with few differences between the assemblages.

4.4.7.2 Site WFB-1-BIO

4.4.7.2.1 2020 Data

The periphyton assemblage consisted of 100% pennate diatoms at Site WFB-1-BIO in August 2020 (Table 4-31; Appendix D). The Diversity value for diatoms was well below the 2.5 threshold, indicating an unbalanced community (Table 4-32). In addition, the Autotrophic Index was poor. However, Percent Tolerant and Motile Diatoms were low, and the Pollution Index indicated no organic enrichment. This mix of favorable and unfavorable metric values included a very high Percent of Acidiphilic and High Oxygen Diatoms and extremely low percentages of all other trophic habit diatoms at Site WFB-1-BIO.

In 2020, metric values at Site WFB-1-BIO were different than those at the reference site, Site LB-4-BIO. Number of Taxa and Diatom Taxa and Diversity were greater at the reference site than at Site WFB-1-BIO. Trophic habit metrics were favorable at Site WFB-1-BIO when compared to the reference site except for Percent Acidiphilic Diatoms which was very high and not found at any other site. These differences between these two sites resulted in a Bahls Similarity Index of a "Very Dissimilar" community between the two sites. Overall, Site WFB-1-BIO was very different from the reference site and contained a limited periphyton community that was considered in poor health for 2020. This site continued to be influenced by iron oxide deposition which impacts the periphyton community.

4.4.7.2.2 Historic Data

The periphyton community at Site WFB-1-BIO has changed considerably over the years with many metrics revealing significant trends. Pennate diatoms have been the dominant group for all years except 2018 when green algae were dominant. Richness and composition metric values have remained relatively consistent (Table 4-33; Figure 4-50; Appendix E) with only Number of Periphyton Genera and Bahls Similarity Index significantly decreasing since 2007. Percent Tolerant Diatom metric and all trophic habit metrics, except for Percent Acidiphilic Diatoms have slightly, but significantly, improved in recent years yet remain in relatively poor conditions due to the iron oxide deposition. Percent High Oxygen Diatom was greater in 2020 than other years of sampling (previous max of 62.5% in 2015).

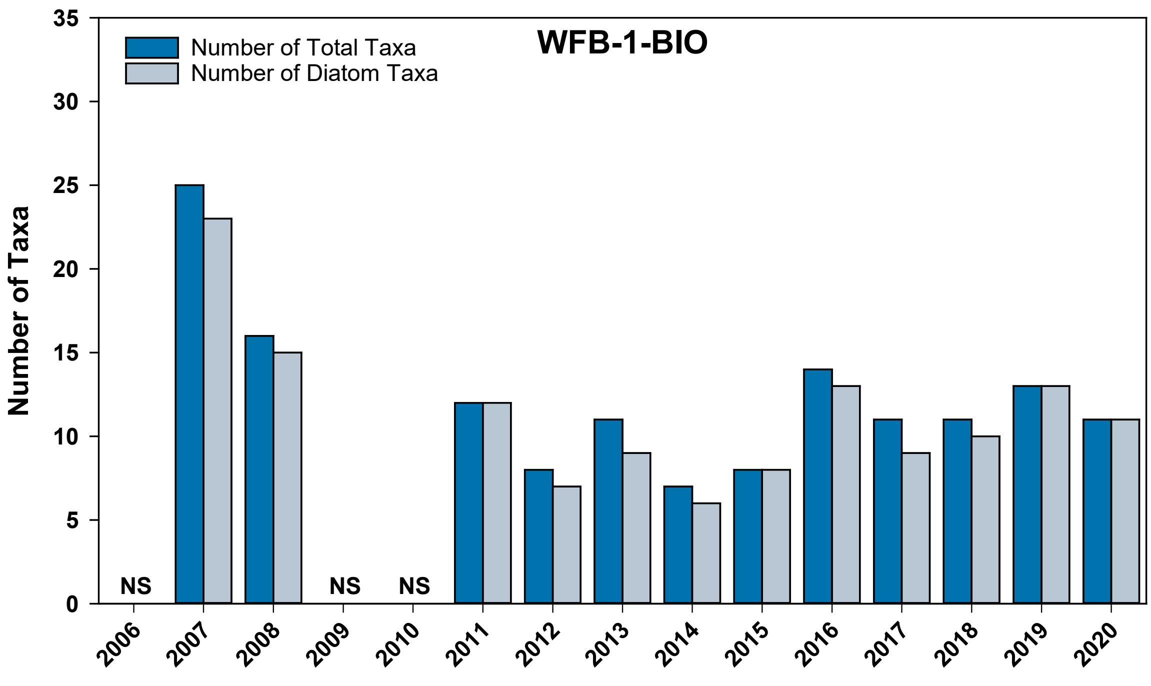

Figure 4-50: Periphyton taxa richness metrics at Site WFB-1-BIO on West Fork False Bottom Creek, 2006 – 2020. NS = Not Sampled.

When Site WFB-1-BIO metrics were compared to the reference Site LB-4-BIO metrics, six of the eight tests indicated a significant difference between the sites. The Number of Taxa and Diatom Taxa, Diversity, and Autotrophic Index values were all significantly worse (p = 0.001, p = 0.001, p = 0.002, and p = 0.028, respectively) at Site WFB-1-BIO (n = 12) than compared to the reference site (n = 15). Only the metrics for Percent Tolerant and Motile Diatoms were significantly better ($p < 0.001$ and $p < 0.001$, respectively) at Site WFB-1-BIO (n = 12) than the reference site (n = 15). These trends and comparisons should be cautiously interpreted because of the poor periphyton assemblage at the site. Conditions at Site WFB-1-BIO are less favorable to support a diverse diatom community in recent years than they were during 2007 and 2008. A combination of very low flows and iron oxide precipitates contribute to the poor periphyton metrics observed in recent years.

4.4.8 McKinley Gulch

McKinley Gulch was dry during August 2020 and was not sampled. Periphyton has never been sampled at this site due to no stream flow.

4.4.9 Cleopatra Creek

4.4.9.1 2020 Data

The residual pockets of water and no flowing water precluded periphyton sampling at Site CC-1A-BIO in 2019 and 2020.

4.4.9.2 Historic Data

The periphyton community at Site CC-1A-BIO has been highly variable from 2006 to 2018. Pennate diatoms have been the dominant group in all years with cyanobacteria present in small numbers in some years. Richness, composition, and tolerance metric values have not significantly trended over time, partially due to the high variability observed in the metrics (Table 4-34; Figure 4-51; Appendix E). The Percent Nitrogen Heterotrophic Diatoms was the only trophic habit metric to reveal a significant increasing trend over time (Table 4-34).

Table 4-34: Slopes of significant trends ($p < 0.05$) for periphyton population metrics at Cleopatra Creek, Fantail Creek, Nevada Gulch, and Stewart Gulch, 2006 - 2020. + = Positive slope. - = Negative slope. -- = Not significant.

Metric	Change Expected Following Environmental Disturbance	CC-1A-BIO	FC-1-BIO	NG-2-BIO	SG-1-BIO
RICHNESS					
Density (cells/cm^2)	Variable	--	--	--	--
Relative Diatom Density	Variable	--	--	--	--
Number of Taxa (species)	Decrease	--	--	--	--
Number of Diatom Taxa	Decrease	--	--	--	--
Number of Periphyton Divisions	Variable	--	+ 0.09	--	--
Number of Periphyton Genera	Variable	--	--	- 0.45	--

Metric	Change Expected Following Environmental Disturbance	CC-1A-BIO	FC-1-BIO	NG-2-BIO	SG-1-BIO
COMPOSITION					
Shannon-Weaver Diversity Index for Diatoms	Decrease	--	--	--	--
Bahls Similarity Index	Variable	--	- 0.02	--	--
Autotrophic Index	Increase	--	--	--	--
TOLERANCE					
Percent Tolerant Diatoms Density	Increase	--	+ 0.01	--	--
Lange-Bertalot Pollution Index	Decrease	--	--	--	--
TROPHIC HABIT					
Percent Eutrophic Diatoms	Variable	--	--	--	--
Percent Acidiphilic Diatoms	Variable	--	--	--	--
Percent Alkaliphilic Diatoms	Variable	--	--	--	--
Percent Nitrogen Heterotrophs	Variable	+ 0.01	--	--	--
Percent High Oxygen Diatoms	Variable	--	--	--	--
Percent Motile Diatoms	Increase	--	--	--	--
Percent Saprobic Diatoms	Variable	--	+ 0.01	--	--

Note: CC-1A-BIO was sampled in 2006-2015 and 2018.

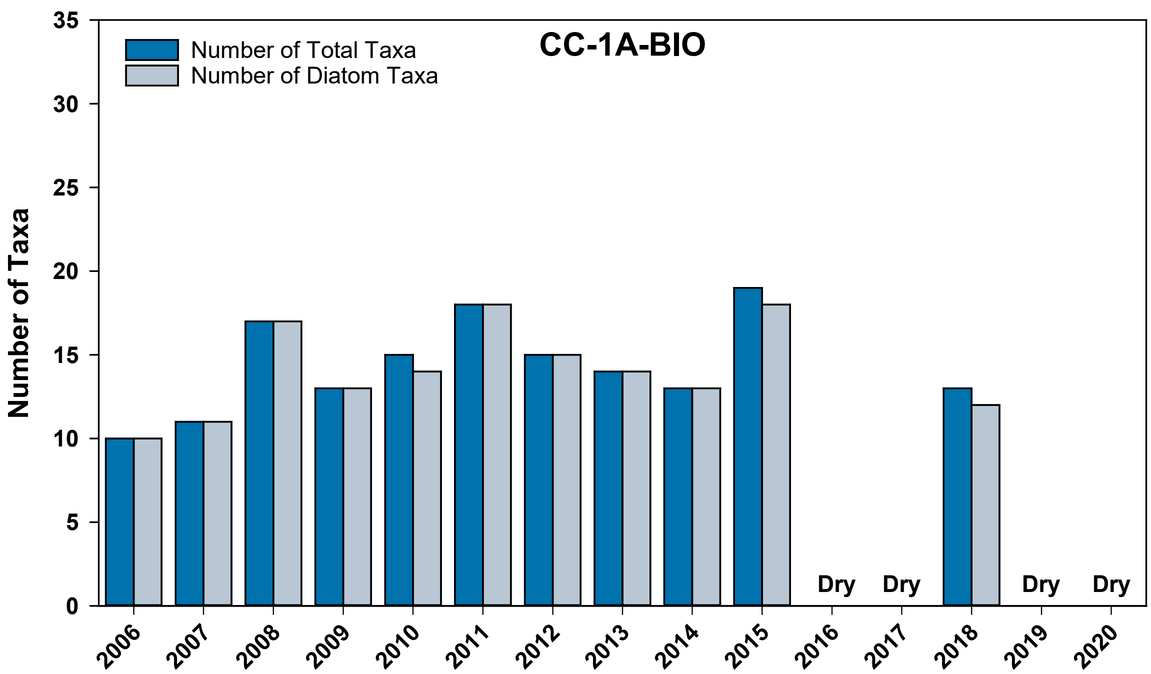

Figure 4-51: Periphyton taxa richness metrics at Site CC-1A-BIO on Cleopatra Creek, 2006-2020.

4.4.10 Fantail Creek

4.4.10.1 2020 Data

The periphyton assemblage consisted of 99% pennate diatoms and 1% golden algae at Site FC-1-BIO in August 2020 (Table 4-35; Appendix D). The Diatom Diversity value was greater than the 2.5 threshold, indicating a balanced periphyton community (Table 4-36). The Autotrophic Index was high but was lower than the long-term median value for the site. The Percent Tolerant and Motile Diatoms were relatively higher in 2020 indicating a likely response to the siltation and organic matter content in this site. The Pollution Index also indicated that a majority of the periphyton community was indifferent to organic enrichment and that minor organic enrichment influenced the site. Lastly, Percent Eutrophic and Motile Diatoms were both very high and unfavorable. In 2013, vegetation and trees were cut down as part of the powerline maintenance along Fantail Creek, and the organic debris was left in place. Over the years, the natural decay of organic matter has likely influenced the organic inputs to this stream. High sedimentation from the adjacent dirt road was also noted at this site since 2018.

In 2020, periphyton richness, composition, tolerance, and trophic habit, metric values at Site FC-1-BIO were comparable to those at the reference site, Site RC-1-BIO. Total Density was greater at the reference site, but other richness metrics were similar. Composition metrics indicated that Diversity was greater at Site FC-1-BIO in 2020. The Pollution Index was poorer at Site FC-1-BIO than at the reference and trophic habit metrics were not consistently better at either site. The Bahls Similarity Index indicated a “Somewhat Dissimilar” community between Site FC-1-BIO and the reference site. Overall, the metrics for Site FC-1-BIO indicate that this reach supports a high number of taxa with a relatively diverse periphyton assemblage.

Table 4-35: Relative periphyton density (%) and biomass estimates for sites on Fantail Creek, Nevada Gulch, and Stewart Gulch, August 2020.

Taxa/Metric	FC-1-BIO	NG-2-BIO	SG-1-BIO
BACILLARIOPHYTA			
Pennales (Pennate diatoms)	98.92	99.16	100.00
CHLOROPHYTA (Green algae)	--	0.84	--
CHRYSOPHYTA (Golden algae)	1.08	--	--
BIOMASS			
AFDM (mg/m^2)	3,168	6,474	3,581
Chlorophyll-a (mg/m^2)	7.1	45.5	9.3

Table 4-36: Periphyton population metrics for sites on Fantail Creek, Nevada Gulch, and Stewart Gulch, August 2020.

Metric	FC-1-BIO	NG-2-BIO	SG-1-BIO
RICHNESS			
Density (cells/cm^2)	33,939	563,447	192,701
Relative Diatom Density	99%	99%	100%
Number of Taxa (species)	23	21	10
Number of Diatom Taxa	22	20	10
Number of Periphyton Divisions	2	2	1
Number of Periphyton Genera	12	9	7
COMPOSITION			
Shannon-Weaver Diversity Index for Diatoms	3.46	3.53	2.03
Bahls Similarity Index	33.1%	34.7%	47.4%
Autotrophic Index	446	142	385
TOLERANCE			
Percent Tolerant Diatoms Density	9.8%	5.9%	7.4%
Lange-Bertalot Pollution Index	2.49	2.61	2.58
TROPHIC HABIT			
Percent Eutrophic Diatoms	59.1%	45.0%	20.0%
Percent Acidiphilic Diatoms	0.0%	0.0%	0.0%
Percent Alkaliphilic Diatoms	45.5%	35.0%	40.0%
Percent Nitrogen Heterotrophs	18.2%	20.0%	10.0%
Percent High Oxygen Diatoms	27.3%	30.0%	40.0%
Percent Motile Diatoms	72.7%	60.0%	40.0%
Percent Saprobic Diatoms	9.1%	15.0%	10.0%

4.4.10.2 Historic Data

The periphyton community metrics for Site FC-1-BIO have been variable from 2006 to 2020. Pennate diatoms have been the dominant group in all years with green and golden algae present in small numbers in some years. The richness metric, Number of Periphyton Divisions, significantly increased since 2006 and Number of Taxa and Diatom Taxa were both greater in 2020 than other years (previous maximums for both metrics of 20 in both 2013 and 2019; Table 4-34; Figure 4-52; Appendix E). In addition, Bahls Similarity Index, Percent Tolerant Diatoms, and Percent Saprobic Diatoms all significantly worsened over time. No metrics from 2006 to 2020 were significantly different ($p > 0.05$) between Site FC-1-BIO ($n = 15$) and the refence site ($n = 4$). While Site FC-1-BIO may experience some organic enrichment and siltation, the data indicate that the site has supported a more diverse assemblage and is similar to the refence site.

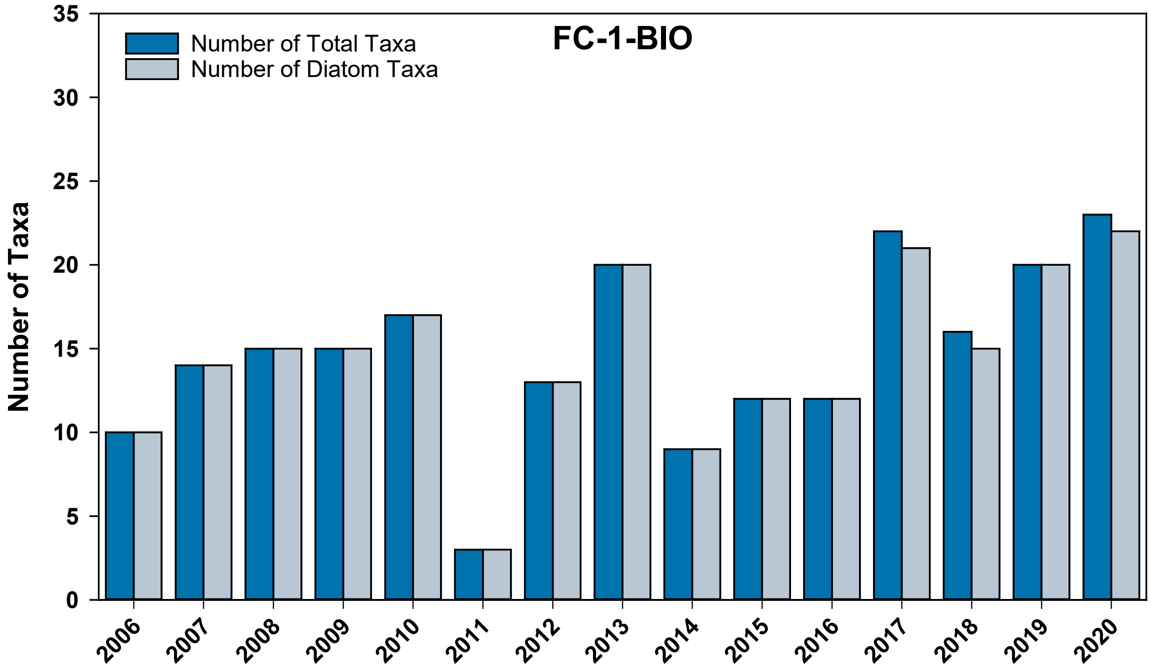

Figure 4-52: Periphyton taxa richness metrics at Site FC-1-BIO on Fantail Creek, 2006 – 2020.

4.4.11 Nevada Gulch

4.4.11.1 2020 Data

In August 2020, the periphyton assemblage at Site NG-2-BIO consisted of 99% pennate diatoms and 1% green algae (Table 4-35; Appendix D). The Diatom Diversity value was well above the 2.5 threshold, indicating a balanced community (Table 4-36). The Autotrophic Index was the lowest of any site indicating lower organic pollution. Pollution tolerant species were present in low numbers, and the Pollution Index indicated that a relatively larger proportion of the periphyton community was comprised of sensitive diatoms, and no organic enrichment influenced the site.

In 2020, periphyton richness, composition, tolerance, and trophic habit metric values at Site NG-2-BIO were comparable to those at the reference site, Site RC-1-BIO. Density was much greater at Site NG-2-BIO while the other richness metrics were similar between the two sites. Composition metrics indicated that Diversity was better at Site NG-2-BIO but good at both sites. Tolerance and trophic habit metrics were also similar between the two sites. Overall, both sites appeared to have healthy periphyton communities in 2020.

4.4.11.2 Historic Data

The periphyton community metrics for Site NG-2-BIO have been variable over the years. Pennate diatoms have been the dominant group in all years with green algae and cyanobacteria present in small numbers in some years. No significant trends for periphyton metric were observed from 2006 to 2020 except for a significant decrease in the Number of Periphyton Genera. This metric and Percent Alkaliphilic Diatom Taxa were lower in 2020 than in other years of the study (previous minimum of 10 in 2015 and 40.0% in 2007, respectively; Table 4-34; Figure 4-53; Appendix E). Data in 2020 revealed few changes, with many of the metric values being similar to those observed in the past few years. In 2020, this site continued to support a diverse periphyton assemblage.

When Site NG-2-BIO metrics were compared to the reference Site RC-1-BIO metrics, four of the eight tests indicated significant differences between the median values. Density, Diversity, and Autotrophic Index have been significantly better (p = 0.003, p = 0.016, p = 0.004, respectively) at Site NG-2-BIO (n = 15), while the Pollution Index has been significantly worse (p = 0.012) at Site NG-2-BIO than at the reference site (n = 4). While differences exist, periphyton communities at both sites have shown good diversity with few differences between the assemblages.

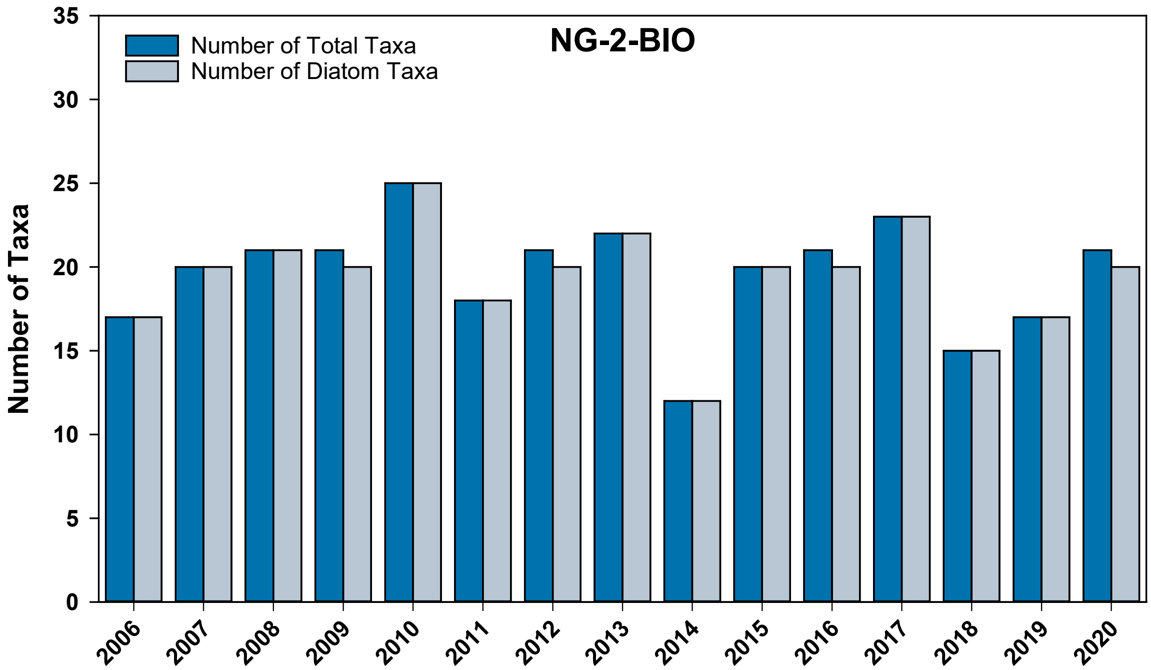

Figure 4-53: Periphyton taxa richness metrics at Site NG-2-BIO on Nevada Gulch, 2006 – 2020.

4.4.12 Stewart Gulch

4.4.12.1 2020 Data

The periphyton assemblage at Site SG-1-BIO in August 2020 consisted of all pennate diatoms (Table 4-35; Appendix D); however, the diatom Diversity value was less than the 2.5 threshold, indicating an unbalance assemblage (Table 4-36). The Autotrophic Index indicated that the stream was enriched with nutrients and shows a potential for increased periphyton growth, although both the AFDM and chlorophyll-a content were relatively low for this site. The pollution tolerant and motile diatoms were present in low numbers, and the Pollution Index value indicated that a relatively larger proportion of the periphyton community was comprised of sensitive diatoms and that no organic enrichment influenced the site. This site continues to be influenced by the flow and its higher nitrogen content from the small spring immediately upstream; the growth and expanse of the watercress was considerably less in 2020 than observed in recent years.

In 2020, periphyton richness, composition, tolerance, and trophic habit metric values at Site SG-1-BIO were comparable to those at the reference site, Site LB-4-BIO. Density was greater at Site SG-1-BIO, but all other richness metric values were similar to or greater at the reference site than at SG-1-BIO. Composition metrics indicated that Diversity was better at the reference site, and the Pollution Index metric was better at Site LB-4-BIO. However, trophic habit metrics tended to be more favorable at Site SG-1-BIO. These differences between the sites resulted in a Bahls Similarity Index of a "Somewhat Similar" community between Site SG-1-BIO and the reference site. Overall, Site SG-1-BIO in 2020 appeared to have a less robust periphyton community when compared to the reference site.

4.4.12.2 Historic Data

The periphyton community metrics for Site SG-1-BIO have been highly variable over the years with no significant trends being observed for 2006 to 2020. Pennate diatoms have been the dominant group in all years while green algae and cyanobacteria were present in small numbers in some years. All 2020 metrics were within the range of those previously observed for this site (Table 4-36; Figure 4-54; Appendix E) except for Percent Eutrophic Diatom Taxa which was less in 2020 than other years (previous minimum of 27.3% in 2006). The 2020 data revealed small changes compared to the recent years data and continues to support a limited diatom assemblage that is influenced by the emergent vegetation that covers the margins of the stream yet allows for an open thalweg as evidenced in Photo 4-6.

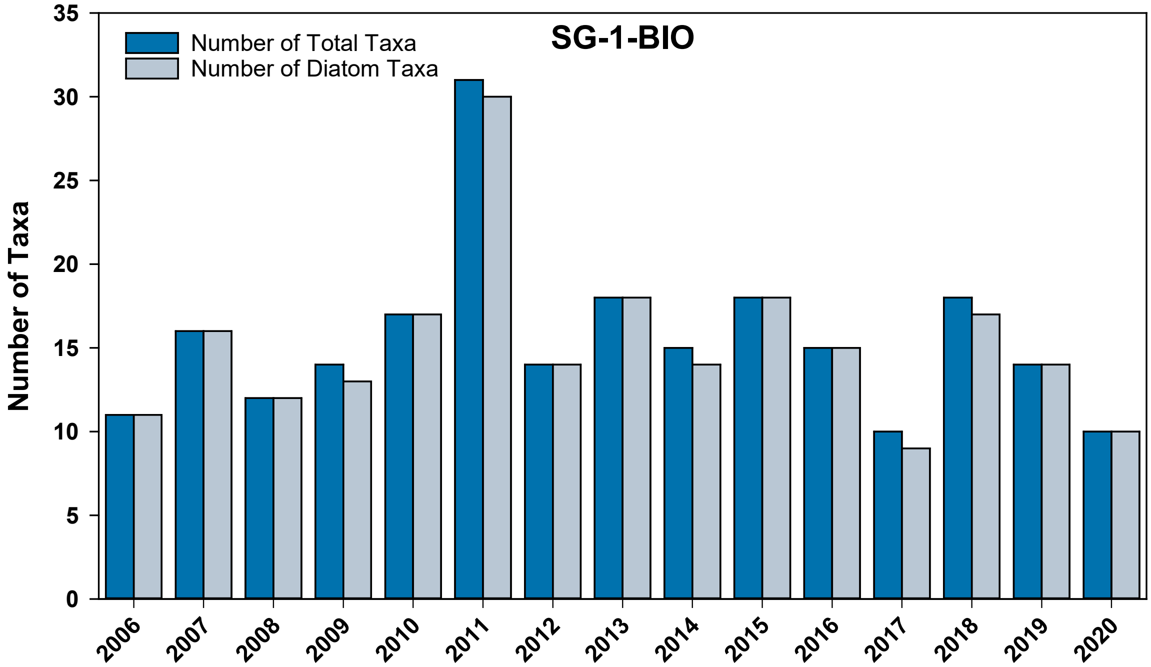

Figure 4-54: Periphyton taxa richness metrics at Site SG-1-BIO on Stewart Gulch, 2006 - 2020.

When Site SG-1-BIO metrics were compared to the reference Site LB-4-BIO metrics, five of the eight tests indicated significant differences between the sites. Density values have been significantly greater ($p = 0.014$) at Site SG-1-BIO ($n = 15$), while the Number of Taxa and Diatom Taxa, Diversity, and Pollution Index have all been significantly less ($p = 0.005$, $p = 0.013$, $p = 0.001$, and $p = 0.049$, respectively) at Site SG-1-BIO when compared to the reference site ($n = 15$; Table 4-34). Despite the differences in richness, composition, and tolerance metrics, Site SG-1-BIO continues to support an assemblage with sensitive diatoms with trophic habits.

4.5 Water Quality

Water quality samples were collected, and results obtained for sites LB-4-BIO, RC-1-BIO, AC-3-BIO, LC-1-BIO, DC-2-BIO, EFB-1-BIO, WFB-1-BIO, FC-1-BIO, and SG-1-BIO.

Total recoverable concentrations for cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), silver (Ag), and zinc (Zn), including weak acid dissociable cyanide (CN WAD) were less than their respective detection limits at all of the biological monitoring sites, while nickel (Ni) and selenium (Se) concentrations were less than their respective detection limits at most sites (Appendix F). Measurable concentrations for arsenic (As) and iron (Fe) were observed for most biological monitoring sites, although the magnitude of concentrations was similar to the reference sites, and in the case of As, concentrations were considerably less than the continuous criterion concentration (CCC) for aquatic life use (ARSD 2019 §74:51:01). Measurable concentrations of nickel were only observed at sites in Deadwood Creek, East and West False Bottom Creek, and Stewart Gulch, but concentrations were considerably less than the CCC for aquatic life use. Measurable concentrations of calcium (Ca) and magnesium (Mg) were also observed at all biomonitoring sites.

Nutrient analyses indicated that nitrate (NO_3) was less than the detection limit only at sites DC-2-BIO and WFB-1-BIO (Appendix F). However, the concentrations of nitrate were similar to that at the reference sites except for sites AC-3-BIO, EFB-1-BIO, and SG-1-BIO which were greater. The nitrogen-rich groundwater flowing into Stewart Gulch (7.5 mg/L) could be influenced by the historic Golden Reward mine, but the source of the groundwater is difficult to trace. Explosives containing nitrate are often used to break up bedrock during mining operations, and remnants of these charges can leach into groundwater. Similar concentrations of nitrate-nitrogen were observed in Annie Creek (8.8 mg/L) and East Fork False Bottom Creek (5.8 mg/L), but all concentrations were less than the numerical ground water standard of 10 mg/L (ARSD 2019 §74:54:01:04).

In addition, dissolved phosphorous (P) was below the detection limit at most sites, except for LC-1-BIO, AC-2-BIO and AC-3-BIO. Measurable concentrations of phosphorus originate in Lost Camp Gulch and influence the downstream waters. Overall, the data indicate no patterns in water chemistry relative to Wharf Mine outfalls and few localized patterns such as the phosphorus in the Annie Creek basin and nickel in the Deadwood Creek, East and West False Bottom Creek, and Stewart Gulch.

5. Conclusions

Fish, benthic macroinvertebrate, and periphyton populations were sampled and habitat was evaluated at sites near the Wharf Mine area on Labrador Gulch, Reno Creek, Annie Creek, Ross Valley, Lost Camp Gulch, Deadwood Creek, False Bottom Creek, Fantail Creek, Nevada Gulch, and Stewart Gulch in August 2020. Cleopatra Creek and McKinley Gulch remained dry. Data from these sites were analyzed to evaluate current conditions of aquatic biological populations in the streams and compared to reference site conditions. In addition, these data were compared to data from previous years and to reference sites to evaluate relationships between the aquatic populations and mining activities over time. The site on Labrador Gulch (LB-4-BIO) was used as the reference site for the sites of AC-2-BIO, DC-2-BIO, EFB-1-BIO, WFB-1-BIO, and SG-1-BIO which either support or have historically supported the biological target of fish, benthic macroinvertebrates, and periphyton. In most years, Site LB-4-BIO is also the reference site for Site AC-3-BIO but this site on lower Annie Creek was not sampled in 2020 due to the extensive deadfalls resulting from the July 8, 2020 tornado activity. The site on Reno Creek (RC-1-BIO) was used as the reference site for the sites of AC-1-BIO, RV-2-BIO, LC-1-BIO, CC-1A-BIO, FC-1-BIO, and NG-2-BIO which have supported the biological target of benthic macroinvertebrates and periphyton. These reference sites were selected based on their similar characteristics to the mining activity sites with respect to stream size and order, flow regime, ecoregion, elevation, geology, and biological populations and represent a comparative system influenced by local climatic conditions rather than mining related influences.

5.1 Habitat

Site LB-4-BIO is a high-gradient site that flows through a steep, bedrock canyon while Site RC-1-BIO is lower gradient stream, in a more vegetated and forested valley, with ample sources of fine sediments. The majority of both sites were comprised of fast water habitat, but each site also contained ample slow-water pool habitat. Substrate compositions varied at both sites, with Site LB-4-BIO being dominated by rubble, boulders, and bedrock, and substrate being mainly comprised of gravel and rubble at Site RC-1-BIO. Evidence existed at Site RC-1-BIO of a recent scouring event resulting from the July storm event.

The two sites on Annie Creek and Sites RV-2-BIO and LC-1-BIO sampled in 2020 had a diversity of habitat types, with abundant riffles and pools. Boulders and rubble were most common substrate size at sites AC-1-BIO and LC-1-BIO while fine sediment was the most abundant at sites AC-2-BIO and RV-2-BIO. Surface fines were also higher at sites AC-2-BIO and RV-2-BIO than at sites AC-1-BIO and LC-1-BIO. The high abundance of fine sediments at Site AC-2-BIO in recent years appears to be due to localized watershed runoff in Lost Camp Gulch. The recreational use and attempted road maintenance likely contributed to the fine-grained sediment inputs. Habitat characteristics in 2020 were similar to those in previous years for many metrics, and a diverse range of habitat types was found at all three sites.

EFB-1-BIO and WFB-1-BIO were dominated by riffle habitat in 2020, as in previous years, while Site DC-2-BIO was dominated by pools. All sites included at least one pool and coarse sediments, gravel, and/or rubble were the most common substrates. The general increase in stream flows due to wet-year type conditions reduced surface fine percentages from 2018 to 2019. Site DC-2-BIO had a small amount of eroding bank and Site WFB-1-BIO had several sections. Habitat conditions in 2020 were generally comparable to past years. Fine iron oxide precipitates were again observed at Site WFB-1-BIO, and the data indicate that this condition is negatively affecting the benthic macroinvertebrate and periphyton communities.

Sites FC-1-BIO, NG-2-BIO, and SG-1-BIO were predominantly composed of riffle habitat, but all sites also contained some pool habitat. Stream widths and average water depths were greatest in Stewart Gulch, while the remaining stream sites were generally narrower and shallower. Abundant macrophyte growth continued to be present in Stewart Gulch, although less than observed in recent years. A shift in groundwater patterns upstream of the Stewart Gulch site continues to provide nitrogen-rich groundwater that promotes the growth of watercress in Stewart Gulch and Whitetail Creek. Surface fines were slightly greater at Fantail Creek, which may be from nearby adjacent road activities. The upstream location of the Fantail Gulch site may limit the occurrence of high flow events which would scour fine sediments from the site. All sites contained a variety of substrate sizes. Unlike in 2019 when no erosion was observed, a small percentage or eroding banks were observed at Site FC-1-BIO and several sections of eroding bank were observed at Site NG-2-BIO.

In general, habitat characteristics at most sites have shown some variability over time, but no substantial, long term patterns have been observed. The study sites contained a diverse range of habitats in most years of sampling. Flows in 2018 and 2019, and to a lesser extent in 2020, were higher than during the previous two years due to increased precipitation in the Black Hills. Due to these increased flows, fine sediment percentages have decreased at some sites in 2018 through 2020. Most sites did not differ greatly from their respective reference sites.

5.2 Fish

Site LB-4-BIO contained a small population of Brook Trout that included YOY and second year-plus age class individuals. First year age class have been collected in previous years indicating that this site supports all life stages of Brook Trout. The mean length and weight for trout were greater at Site LB-4-BIO than the comparative mining activity sites. However, the mean condition factor and relative weight values were lower than the optimal ranges for trout at Site LB-4-BIO. In fact, the relative weight of Brook Trout has significantly decreased over time at the reference site. These fish may be stressed due to natural factors such as lower stream flow and higher water temperature in recent years.

The reference site on Reno Creek contained more than twice as many Brook Trout in 2020 than collected in previous years and no Brown Trout were collected. Site RC-1-BIO is likely near the upstream extent of suitable fish habitat that provides spawning habitat for trout. Brook Trout have been the dominant fish observed in Reno Creek in all years, except for 2019 when Brown Trout were dominant. Fish usage of this site may be seasonal or variable depending on flows within the drainage, and trout may be expanding their spawning habitat up from Whitewood Creek into Reno Creek. With only four years of data, future sampling at this site will illustrate trends within this fish population over time.

Two of the three Annie Creek biomonitoring sites were surveyed for fish in 2020. The extensive habitat disturbance in the lower portion of the basin precluded sampling at Site AC-3-BIO. No fish were collected in the upper portion of the basin at either AC-1-BIO or AC-2-BIO. Historically, Mountain Suckers, were common at Site AC-2-BIO but have been absent at this site since 2011. This absence is attributed to the water quality disturbances in 2007. There are no upstream sources of fish, and the movement of fish into this site from downstream is prevented by Annie Creek Falls. Based on the data collected, Mountain Suckers are now absent from Annie Creek upstream of Annie Creek Falls.

Despite not sampling Site AC-3-BIO in 2020, past data show that the Brook Trout population, specifically YOY and first year age class fish, has been trending downwards in recent years and that the Brown Trout population has been increasing. This shift in species dominance has been a common occurrence in many Rocky Mountain streams where the transition of colder to cool water habitat has shifted downstream due to increasing ambient air temperature and water temperature. In these streams, Brown Trout populations are expanding upstream into habitat typically dominated by Brook Trout and are beginning to competitively exclude Brook Trout from their traditional habitat. The larger numbers of second year-plus age class of Brown Trout began showing up in 2014, and 2019 is the first year when a larger number of YOY and first year age class Brown Trout were observed for this site. Overall, both Brook Trout and Brown Trout have historically maintained resident populations of all age classes at this site, and the data do not indicate that mining activities upstream of the compliance points in the Annie Creek basin have adversely affected the fish assemblage at Site AC-3-BIO.

Site DC-2-BIO maintains perennial flows and supports a naturally reproducing Brook Trout population, with multiple size classes present during most years. The density and biomass of Brook Trout in 2020 were both within the range of historical conditions. Over the years, fewer second year-plus age class sized fish have been observed compared to YOY and first year age class fish at this site, indicating this section of stream may serve primarily as a spawning and rearing area. Deep water habitat is also minimal at this site, limiting suitable habitat for larger, second year-plus age class trout.

Each site on the East Fork and West Fork False Bottom Creek has contained a Brook Trout population during the years sampled. The 2020 trout population at Site EFB-1-BIO was comprised mainly of YOY age class Brook Trout, indicating that spawning was taking place.

The population at Site WFB-1-BIO consisted of YOY and first year age class Brook Trout. Abundance, density, and biomass values at Site WFB-1-BIO have been relatively lower when compared to Site EFB-1-BIO over time, but the sampling frequency has varied at these sites. The smaller population, density, and biomass at Site WFB-1-BIO is likely related to low flows and the poorer water quality conditions. Iron oxide precipitates have been present at this site in recent years which have reduced its habitat suitability. Deep water habitat at this site, in the form of pools, is also very limited, likely decreasing usage by second year-plus age class fish in some years, particularly when flows are low. Brook Trout density and biomass estimates for both the East Fork and West Fork were similar to the values observed for the reference site on Labrador Gulch. Overall, the data show that the East Fork supports multiple age classes of fish and is suitable for spawning and rearing habitat, whereas as the West Fork supports a limited population, predominantly of YOY and first year age class fish.

The Brook Trout population in Stewart Gulch revealed density and biomass estimates greater than the long-term median conditions for Site SG-1-BIO. The presence of a high nutrient content spring immediately upstream of Site SG-1-BIO facilitates plant growth and provides habitat for benthic macroinvertebrates and YOY Brook Trout. The presence of stable Brook Trout populations including all age classes in Stewart Gulch over the monitoring period indicates that habitat and water quality conditions have been suitable to sustain a naturally reproducing population of Brook Trout. Historically, few Brown Trout have been observed in Stewart Gulch.

No fish have been collected from sites AC-1-BIO, RV-2-BIO, LC-1-BIO, and CC-1A-BIO since monitoring at these sites began. These stream reaches are small and narrow, and the sites are in the headwaters, upstream of natural fish barriers and suitable fish habitat. Because no fish have been found upstream of Annie Creek Falls since 2010, the movement of fish into the upper reaches of Annie Creek, Lost Camp Gulch, and Ross Valley are unlikely. In addition, no fish have been present at sites sampled on Nevada Gulch and Fantail Creek since 1998.

5.3 Benthic Macroinvertebrates

In 2020, the reference sites LB-4-BIO and RC-1-BIO both supported a rich and diverse benthic macroinvertebrate community including numerous sensitive species and a variety of feeding types. In fact, these sites had two of the highest diversity values of all sites. In addition, Site LB-4-BIO contained a higher percentage of Plecoptera than any other Wharf site. Site RC-1-BIO contained a moderately high percentage of *Baetis sp*. and consisted of relatively short-lived taxa. Overall, data in 2020 showed negligible differences with metric values being similar to those in previous years, indicating the macroinvertebrate community has changed little over time. Both sites exhibit a healthy macroinvertebrate community, with little to no influence from anthropogenic sources.

The Annie Creek sites, AC-1-BIO and AC-2-BIO, supported a rich and diverse benthic macroinvertebrate community in 2020, including numerous sensitive species, and both sites were comparable to the community sampled at their respective reference site. While these Annie Creek sites were dominated by *Baetis sp.* mayflies, each site contained a relative healthy macroinvertebrate community. Thirteen of the twenty-five macroinvertebrate metrics for Site AC-1-BIO significantly improved from 2006 to 2020 showing complete recovery from the water quality disturbances in 2007. Site AC-2-BIO was much less affected by this disturbance with very few trending metrics. This site has historically been impacted by poorer sediment conditions caused by the recreational use of the dirt trail adjacent to Lost Camp Gulch. Even though Site AC-3-BIO was not sampled in 2020, seven metrics have significantly trended in the direction of their expected change following a disturbance, indicating that some metric values have become poorer over time (2006 to 2019).

Each site on Ross Valley, Site RV-2-BIO, and Deadwood Creek, Site DC-2-BIO, support rich and diverse benthic macroinvertebrate communities, including numerous sensitive species, and were comparable to the communities at their respective reference sites. At Site RV-2-BIO, only two macroinvertebrate metrics significantly trended over time while both improving and declining metrics were revealed at Site DC-2-BIO; however, overall, the communities at both sites have been relatively stable over the years.

The site on Lost Camp Gulch supported few sensitive EPT taxa in 2020; although it scored well for diversity and tolerance metrics. When compared to the reference site on Reno Creek, the metrics for Lost Camp generally indicated a poorer community but still moderately healthy. Five of the twenty-five metrics, mostly EPT related metrics, significantly declined over time. The combination of low flows and the influence of poorer sediment conditions have negatively affected the macroinvertebrate community at Site LC-1-BIO.

The East Fork and West Fork False Bottom sites continued to show a disparity in many 2020 macroinvertebrate metrics. Site EFB-1-BIO supported a rich and diverse benthic macroinvertebrate community, including numerous intolerant species, with many metrics comparable to the metrics for Labrador Gulch. Site WFB-1-BIO supported a limited community that scored poorly when compared to the reference site conditions on Labrador Gulch. On the West Fork, six of the twenty-five metrics significantly trended with a majority of the metrics indicating a decline over time. When compared to the reference site conditions, each selected metric was significantly worse at Site WFB-1-BIO. The iron oxide and poorer flow conditions in the West Fork has decreased habitat suitability and negatively affected the macroinvertebrate assemblage in recent years.

Sites on Fantail Creek, Nevada Gulch, and Stewart Gulch all supported a taxonomically rich and diverse macroinvertebrate community, including intolerant species and were relatively comparable to their respective reference site condition. Sites FC-1-BIO and NG-2-BIO both revealed significant trends, three and five, respectively, with all but one of the trends revealing declining conditions over time. Many of the declining metrics were related to community composition. Both of these sites are influenced by nearby road conditions and typically receive a greater amount of sediment that decreases habitat suitability. In contrast, the Stewart Gulch site showed improvement for two of the twenty-five metrics, indicating that the macroinvertebrate community has remained stable, if not slightly improved over the years. The higher productivity at Site SG-1-BIO likely benefits the macroinvertebrate community.

Overall, the macroinvertebrate community has changed at multiple sites from 2006 to 2020. Historic metric data at Site AC-1-BIO indicate an increased community quality since 2006, and this site has become more similar to the reference site. The community was particularly poor at Site AC-1-BIO in 2007 following multiple disturbances but appears to have since been recolonized by macroinvertebrates. Conversely, the quality of the macroinvertebrate community at sites AC-3-BIO, LC-1-BIO, and WFB-1-BIO have slightly worsened over time and long term data at Site WFB-1-BIO were significantly poorer when compared to the Labrador Gulch reference site. Periodic low flows and sedimentation from adjacent roads likely caused these changes on Annie Creek and Lost Camp Gulch while iron oxide and flow conditions likely lead to the poor conditions on the West Fork False Bottom Creek.

5.4 Periphyton

In 2020, reference sites LB-4-BIO and RC-1-BIO both supported healthy periphyton communities. The Autotrophic Index at both sites was greater than any site for which they were a reference. However, the Pollution Indexes indicated no organic enrichment and the Autotrophic Indexes were likely influenced by allochthonous material. Overall, data in 2020 showed negligible change for these two sites, the metric values were similar to those in previous years, and the periphyton communities have changed little since 2006. Only five and one of the eighteen metrics significantly trended for Labrador Gulch and Reno Creek, respectively, with a mixture of improving and declining periphyton metrics over time.

The Annie Creek sites, AC-1-BIO and AC-2-BIO each exhibited variable periphyton conditions in 2020. However, both sites exhibited a moderate Autotrophic Index and Diversity above the 2.5 threshold indicating that balanced diatom assemblages were present. Both sites also revealed minimal significant trends over time. When compared to their respective reference sites, all three Annie Creek sites revealed few differences, indicating that the periphyton communities were relatively stable and healthy at these sites.

The sites on Ross Valley, RV-2-BIO, Lost Camp Gulch, LC-1-BIO, and Deadwood Creek, DC-2-BIO contained a diverse diatom community that exhibited similar periphyton metrics with their respective reference sites in 2020. However, the Autotrophic Index was relatively poor at Site RV-2-BIO. Also, the Percent Tolerant Diatoms was poor at Site LC-1-BIO indicating that siltation from adjacent dirt roadway was affecting the assemblage. Few periphyton metrics trended over time at all sites.

The East Fork and West Fork False Bottom sites continued to show a disparity in the periphyton communities in 2020. Site EFB-1-BIO contained a diverse diatom community, with many motile diatoms, and exhibited similar periphyton metrics with its reference site that mostly have not trended over time. The macroinvertebrate community at Site WFB-1-BIO is poorer than at its reference site due to the community being dominated by acidiphilic and high oxygen diatoms. As a result, diversity and other metrics were poor. Site WFB-1-BIO revealed seven significant trends over time with many metrics showing a negative trend for the autecological metrics which are largely tied to the decrease in taxa. This site continued to be influenced by iron oxide deposition which continues to negatively affect the periphyton community.

The sites on Fantail Creek, Nevada Gulch, and Stewart Gulch supported a taxonomically rich and diverse diatom community in 2020. However, when compared to their respective reference sites, many of the periphyton metrics revealed slightly poorer values. Only one periphyton metric trended over time for Site NG-2-BIO, while four of the eighteen periphyton metrics revealed significant trends for Site FC-1-BIO. At Site SG-1-BIO, many of the periphyton metrics have been highly variable over the years with no significant trends observed over time. The extensive macrophyte growth at this site has somewhat limited the periphyton community in recent years.

5.5 Overview

Aquatic biological data collected in 2020 largely indicated the presence of abundant and healthy communities of aquatic organisms near the Wharf mine, while the long-term data indicated maintenance of healthy communities over time. The sites on Labrador Gulch and Reno Creek revealed quality habitat and contained healthy fish, macroinvertebrate, and periphyton populations. These sites continue to be appropriate reference sites that show little to no influence by anthropogenic activity.

The benthic macroinvertebrate population in upper Annie Creek has fully recovered from the water quality disturbances and the disturbance caused by removal of excess biomass at Site AC-1-BIO. Mountain Suckers continue to be absent from the Site AC-2-BIO, and likely no longer inhabit any portion of the stream upstream of the falls. The macroinvertebrate community at Site AC-2-BIO did appear to be affected by fine sediments and increased siltation observed in recent years. In lower Annie Creek, healthy trout populations have historically been present, although 2019 represented the first year when Brown Trout dominated the fish assemblage. Site AC-3-BIO was not sampled in 2020 due to the tornado activity on July 8, 2020. Overall, the sites on Annie Creek contained quality habitat and healthy fish (where present), and the macroinvertebrate and periphyton populations do not appear to be affected by mining activity.

Healthy trout populations were also present in Deadwood Creek, East Fork False Bottom Creek, and Stewart Gulch. These sites also supported a rich and diverse macroinvertebrate and periphyton communities that were comparable to the reference site on Labrador Gulch; except for Stewart Gulch where periphyton assemblages was slightly limited. Trout inhabit West Fork False Bottom Creek as well, but successful recruitment is limited due to the low flow and poorer water quality conditions. Macroinvertebrate and periphyton communities are also limited at this site.

The macroinvertebrate and periphyton assemblages on Ross Valley, Lost Camp Gulch, Fantail Creek, and Nevada Gulch were slightly limited by periods of low or no flow, siltation, or organic matter deposition that resulted in minor changes from 2006 to 2020. Although many of the macroinvertebrate and periphyton metrics indicated that these sites were similar to, or in some respects, slightly better than their respective reference site on Reno Creek.

The majority of the biological metrics and habitat measurements do not indicate direct impacts from active mining in 2020. However, past mining activities may indirectly affect Stewart Gulch in terms of increasing productivity and biomass due to nitrogen inputs, while the iron oxide deposition in West Fork False Bottom is affecting the overall health of the biological assemblages. The lack of perennial or low flows in Cleopatra Creek and Lost Camp Gulch, respectively, affect the overall health of the periphyton and macroinvertebrate assemblages over the long-term, and influence the sediment conditions in Lost Camp Gulch and Annie Creek.

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Appendix A 2020 Fish Data

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/27/2020
SITE: **LABRADOR GULCH, LB-4-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	186	64	0.99	71.8	89.1
1	BRK	174	47	0.89	58.4	80.5
1	BRK	173	47	0.91	57.4	81.9
1	BRK	169	46	0.95	53.3	86.2
1	BRK	164	47	1.07	48.6	96.7
1	BRK	148	29	0.89	35.3	82.0
1	BRK	97	8.2	0.90		
1	BRK	84	5.1	0.86		
1	BRK	73	2.9	0.75		
2	BRK	177	54	0.97	61.6	87.7
2	BRK	77	3.8	0.83		
3	BRK	182	66	1.09	67.1	98.3
3	BRK	180	61	1.05	64.9	94.0
3	BRK	160	37	0.90	45.0	82.2
3	BRK	154	32	0.88	40.0	80.0
4	BRK	181	61	1.03	66.0	92.4
4	BRK	78	3.9	0.82		

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	17	17	17	12
	MIN:	73	2.9	0.75	80.0
	MAX:	186	66	1.09	98.3
	MEAN:	144.5	36.2	0.93	87.6

	1st Pass	2nd Pass	3rd Pass	4th Pass	Pop Est	95 CI	Site Area (acre)	Density (#/acre)	95 CI	Biomass (lbs/acre)
BRK	9	2	4	2	18	± 5	0.047	383	± 106	30.57

	1st Pass	2nd Pass	3rd Pass	4th Pass	Pop Est	95 CI	Site Area (ha)	Density (#/ha)	95 CI	Biomass (kg/ha)
BRK	9	2	4	2	18	± 5	0.019	947	± 263	34.28

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/25/2020
SITE: **RENO CREEK, RC-1-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	179	53	0.92	63.8	83.1
1	BRK	100	9.8	0.98		
1	BRK	99	10	1.03		
1	BRK	97	8.7	0.95		
1	BRK	97	7.1	0.78		
1	BRK	96	8.2	0.93		
1	BRK	95	8.6	1.00		
1	BRK	95	7.6	0.89		
1	BRK	95	7.4	0.86		
1	BRK	94	7.7	0.93		
1	BRK	93	7.7	0.96		
1	BRK	92	6.9	0.89		
1	BRK	91	7.2	0.96		
1	BRK	91	6.7	0.89		
1	BRK	90	6.0	0.82		
1	BRK	89	6.1	0.87		
1	BRK	87	6.5	0.99		
1	BRK	87	5.5	0.84		
1	BRK	86	6.3	0.99		
1	BRK	86	6.0	0.94		
1	BRK	86	5.5	0.86		
1	BRK	85	5.0	0.81		
1	BRK	84	5.3	0.89		
1	BRK	82	4.5	0.82		
1	BRK	82	4.4	0.80		
1	BRK	82	4.2	0.76		
1	BRK	80	5.0	0.98		
1	BRK	80	4.8	0.94		
1	BRK	79	5.7	1.16		
1	BRK	78	4.0	0.84		
1	BRK	75	4.0	0.95		
2	BRK	90	5.9	0.81		
2	BRK	88	5.8	0.85		
2	BRK	82	5.6	1.02		
2	BRK	80	4.6	0.90		
3	BRK	91	6.4	0.85		
3	BRK	89	5.5	0.78		

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	37	37	37	1
	MIN:	75	4.0	0.76	83.1
	MAX:	179	53	1.16	83.1
	MEAN:	90.6	7.5	0.90	83.1

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (acre)	Density (#/acre)		95 CI	Biomass (lbs/acre)
BRK	31	4	2	37	±	1	0.029	1276	±	34	21.10

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (ha)	Density (#/ha)		95 CI	Biomass (kg/ha)
BRK	31	4	2	37	±	1	0.012	3083	±	83	23.12

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/26/2020
SITE: **ANNIE CREEK, AC-1-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	NO FISH					

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/26/2020
SITE: **ANNIE CREEK, AC-2-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	NO FISH					

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/26/2020
SITE: **ROSS VALLEY CREEK, RV-2-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	NO FISH					

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/26/2020
SITE: **LOST CAMP GULCH, LC-1-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	NO FISH					

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/27/2020
SITE: **DEADWOOD CREEK, DC-2-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	182	55	0.91	67.1	81.9
1	BRK	180	44	0.75	64.9	67.8
1	BRK	169	42	0.87	53.3	78.7
1	BRK	169	33	0.68	53.3	61.9
1	BRK	160	39	0.95	45.0	86.6
1	BRK	159	38	0.95	44.2	86.1
1	BRK	155	33	0.89	40.8	80.9
1	BRK	153	31	0.87	39.2	79.1
1	BRK	138	23	0.88	28.4	80.9
1	BRK	136	22	0.87	27.2	80.9
1	BRK	130	22	1.00	23.6	93.1
1	BRK	130	18	0.82	23.6	76.2
1	BRK	125	25	1.28	20.9	119.5
1	BRK	125	19	0.97	20.9	90.8
1	BRK	125	17	0.87	20.9	81.2
1	BRK	122	17	0.94	19.4	87.6
1	BRK	122	14	0.77	19.4	72.1
1	BRK	121	15	0.85	18.9	79.3
1	BRK	114	13	0.88		
1	BRK	113	13	0.90		
1	BRK	111	11	0.80		
1	BRK	110	12	0.90		
1	BRK	110	11	0.83		
1	BRK	110	11	0.83		
1	BRK	107	10	0.82		
1	BRK	107	10	0.82		
1	BRK	107	10	0.82		
1	BRK	98	8.6	0.91		
1	BRK	96	8.2	0.93		
1	BRK	85	5.9	0.96		
1	BRK	81	4.4	0.83		
1	BRK	80	4.9	0.96		
1	BRK	79	5.0	1.01		
1	BRK	79	4.5	0.91		
1	BRK	78	4.6	0.97		
1	BRK	77	4.3	0.94		
1	BRK	76	3.9	0.89		
1	BRK	76	3.7	0.84		
1	BRK	76	3.5	0.80		
1	BRK	74	4.3	1.06		
1	BRK	74	4.2	1.04		
1	BRK	74	3.6	0.89		
1	BRK	74	3.5	0.86		
1	BRK	73	4.0	1.03		
1	BRK	73	3.8	0.98		
1	BRK	73	3.7	0.95		
1	BRK	73	3.2	0.82		
1	BRK	72	4.6	1.23		
1	BRK	72	3.6	0.96		
1	BRK	72	3.5	0.94		
1	BRK	72	3.4	0.91		
1	BRK	72	3.3	0.88		

1	BRK	70	3.6	1.05		
1	BRK	70	3.3	0.96		
1	BRK	69	2.8	0.85		
1	BRK	68	3.1	0.99		
1	BRK	68	2.3	0.73		
1	BRK	68	1.6	0.51		
1	BRK	67	2.9	0.96		
1	BRK	67	2.8	0.93		
1	BRK	67	2.6	0.86		
1	BRK	67	2.6	0.86		
1	BRK	66	2.8	0.97		
1	BRK	66	2.8	0.97		
1	BRK	66	2.4	0.83		
1	BRK	65	2.7	0.98		
1	BRK	65	2.4	0.87		
1	BRK	65	2.2	0.80		
1	BRK	65	2.2	0.80		
1	BRK	64	2.8	1.07		
1	BRK	64	2.2	0.84		
1	BRK	63	2.5	1.00		
1	BRK	63	2.3	0.92		
1	BRK	62	2.3	0.97		
1	BRK	62	2.3	0.97		
1	BRK	62	2.2	0.92		
1	BRK	62	2.1	0.88		
1	BRK	62	1.7	0.71		
1	BRK	61	2.5	1.10		
1	BRK	61	2.5	1.10		
1	BRK	61	2.2	0.97		
1	BRK	60	1.9	0.88		
1	BRK	60	1.8	0.83		
1	BRK	60	1.7	0.79		
1	BRK	59	1.8	0.88		
1	BRK	59	1.7	0.83		
1	BRK	58	1.7	0.87		
1	BRK	57	1.8	0.97		
1	BRK	57	1.7	0.92		
1	BRK	56	1.8	1.02		
1	BRK	56	1.7	0.97		
1	BRK	50	1.2	0.96		
2	BRK	151	31	0.90	37.6	82.4
2	BRK	126	19	0.95	21.5	88.6
2	BRK	126	15	0.75	21.5	69.9
2	BRK	124	17	0.89	20.4	83.3
2	BRK	123	17	0.91	19.9	85.4
2	BRK	121	15	0.85	18.9	79.3
2	BRK	120	15	0.87	18.4	81.4
2	BRK	119	14	0.83		
2	BRK	118	13	0.79		
2	BRK	117	15	0.94		
2	BRK	114	14	0.94		
2	BRK	111	12	0.88		
2	BRK	111	12	0.88		
2	BRK	108	12	0.95		
2	BRK	108	11	0.87		
2	BRK	106	11	0.92		
2	BRK	77	3.8	0.83		
2	BRK	76	4.4	1.00		
2	BRK	74	3.4	0.84		

2	BRK	73	3.4	0.87		
2	BRK	73	3.4	0.87		
2	BRK	72	4.2	1.13		
2	BRK	69	3.1	0.94		
2	BRK	68	2.9	0.92		
2	BRK	64	2.3	0.88		
2	BRK	64	2.3	0.88		
2	BRK	62	2.3	0.97		
2	BRK	62	2.0	0.84		
2	BRK	61	2.3	1.01		
2	BRK	61	1.9	0.84		
2	BRK	60	2.3	1.06		
2	BRK	60	1.9	0.88		
2	BRK	59	1.8	0.88		
2	BRK	58	1.9	0.97		
2	BRK	58	1.8	0.92		
2	BRK	57	1.8	0.97		
2	BRK	57	1.7	0.92		
2	BRK	55	1.7	1.02		
2	BRK	55	1.4	0.84		
2	BRK	54	1.6	1.02		
3	BRK	131	23	1.02	24.2	95.0
3	BRK	128	20	0.95	22.5	88.8
3	BRK	108	11	0.87		
3	BRK	108	11	0.87		
3	BRK	107	11	0.90		
3	BRK	105	10	0.86		
3	BRK	76	3.9	0.89		
3	BRK	75	3.8	0.90		
3	BRK	74	3.6	0.89		
3	BRK	73	3.0	0.77		
3	BRK	72	3.1	0.83		
3	BRK	69	3.3	1.00		
3	BRK	66	2.4	0.83		
3	BRK	65	2.3	0.84		
3	BRK	63	2.5	1.00		
3	BRK	62	2.5	1.05		
3	BRK	62	2.3	0.97		
3	BRK	61	2.4	1.06		
3	BRK	61	2.3	1.01		
3	BRK	59	1.8	0.88		
3	BRK	59	1.7	0.83		
3	BRK	52	1.2	0.85		

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	154	154	154	27
	MIN:	50	1.2	0.51	61.9
	MAX:	182	55	1.28	119.5
	MEAN:	85.7	8.1	0.91	82.9

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (acre)	Density (#/acre)		95 CI	Biomass (lbs/acre)
BRK	92	40	22	171	±	16	0.040	4275	±	400	76.34

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (ha)	Density (#/ha)		95 CI	Biomass (kg/ha)
BRK	92	40	22	171	±	16	0.016	10688	±	1000	86.57

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/24/2020
SITE: **EAST FORK FALSE BOTTOM CREEK, EFB-1-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	194	65	0.89	81.9	79.4
1	BRK	171	51	1.02	55.3	92.2
1	BRK	154	34	0.93	40.0	85.0
1	BRK	130	21	0.96	23.6	88.8
1	BRK	128	15	0.72	22.5	66.6
1	BRK	123	17	0.91	19.9	85.4
1	BRK	122	17	0.94	19.4	87.6
1	BRK	118	15	0.91		
1	BRK	116	15	0.96		
1	BRK	113	15	1.04		
1	BRK	109	12	0.93		
1	BRK	108	11	0.87		
1	BRK	83	5.0	0.87		
1	BRK	80	4.5	0.88		
1	BRK	80	4.0	0.78		
1	BRK	77	4.0	0.88		
1	BRK	77	4.0	0.88		
1	BRK	76	4.1	0.93		
1	BRK	75	3.6	0.85		
1	BRK	75	3.4	0.81		
1	BRK	73	3.5	0.90		
1	BRK	73	3.4	0.87		
1	BRK	73	3.4	0.87		
1	BRK	72	3.2	0.86		
1	BRK	71	3.1	0.87		
1	BRK	71	3.0	0.84		
1	BRK	70	3.0	0.87		
1	BRK	70	2.6	0.76		
1	BRK	69	3.3	1.00		
1	BRK	69	2.8	0.85		
1	BRK	68	3.1	0.99		
1	BRK	68	3.1	0.99		
1	BRK	68	2.9	0.92		
1	BRK	68	2.9	0.92		
1	BRK	68	2.6	0.83		
1	BRK	68	2.5	0.80		
1	BRK	68	2.5	0.80		
1	BRK	68	2.2	0.70		
1	BRK	67	2.8	0.93		
1	BRK	66	2.6	0.90		
1	BRK	66	2.5	0.87		
1	BRK	65	2.6	0.95		
1	BRK	65	2.6	0.95		
1	BRK	65	2.4	0.87		
1	BRK	64	2.4	0.92		
1	BRK	64	2.3	0.88		
1	BRK	63	2.1	0.84		
1	BRK	63	1.9	0.76		
1	BRK	62	2.3	0.97		
1	BRK	62	2.3	0.97		
1	BRK	62	2.2	0.92		
1	BRK	62	2.1	0.88		

1	BRK	62	2.1	0.88		
1	BRK	62	2.0	0.84		
1	BRK	62	1.9	0.80		
1	BRK	61	1.7	0.75		
1	BRK	60	1.7	0.79		
1	BRK	58	1.7	0.87		
1	BRK	57	1.5	0.81		
1	BRK	55	1.6	0.96		
2	BRK	122	16	0.88	19.4	82.4
2	BRK	115	11	0.72		
2	BRK	113	13	0.90		
2	BRK	79	4.1	0.83		
2	BRK	78	3.6	0.76		
2	BRK	75	3.6	0.85		
2	BRK	72	3.5	0.94		
2	BRK	70	3.2	0.93		
2	BRK	70	2.9	0.85		
2	BRK	68	3.2	1.02		
2	BRK	64	2.2	0.84		
2	BRK	62	2.0	0.84		
2	BRK	60	1.7	0.79		
2	BRK	55	1.4	0.84		
3	BRK	138	23	0.88	28.4	80.9
3	BRK	134	24	1.00	26.0	92.4
3	BRK	122	18	0.99	19.4	92.7
3	BRK	71	3.3	0.92		
3	BRK	69	2.6	0.79		
3	BRK	58	1.8	0.92		

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	80	80	80	5
	MIN:	55	1.4	0.70	66.6
	MAX:	194	65	1.04	92.7
	MEAN:	81.7	7.1	0.88	84.9

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (acre)	Density (#/acre)		95 CI	Biomass (lbs/acre)
BRK	60	14	6	81	±	3	0.025	3240	±	120	50.71

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (ha)	Density (#/ha)		95 CI	Biomass (kg/ha)
BRK	60	14	6	81	±	3	0.010	8100	±	300	57.51

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/24/2020
SITE: **WEST FORK FALSE BOTTOM CREEK, WFB-1-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	145	32	1.05	33.2	96.5
1	BRK	137	22	0.86	27.8	79.1
1	BRK	131	20	0.89	24.2	82.6
1	BRK	127	21	1.03	22.0	95.5
1	BRK	123	16	0.86	19.9	80.4
1	BRK	110	12	0.90		
1	BRK	84	5.8	0.98		
1	BRK	79	4.6	0.93		
1	BRK	79	4.5	0.91		
1	BRK	79	4.2	0.85		
1	BRK	79	3.9	0.79		
1	BRK	78	4.9	1.03		
1	BRK	76	4.2	0.96		
1	BRK	76	4.1	0.93		
1	BRK	76	3.9	0.89		
1	BRK	75	4.2	1.00		
1	BRK	73	3.2	0.82		
1	BRK	72	3.5	0.94		
1	BRK	72	3.3	0.88		
1	BRK	72	3.3	0.88		
1	BRK	70	3.2	0.93		
1	BRK	70	2.9	0.85		
1	BRK	69	3.2	0.97		
1	BRK	69	3.0	0.91		
1	BRK	68	3.2	1.02		
1	BRK	66	2.8	0.97		
1	BRK	64	2.7	1.03		
1	BRK	62	2.3	0.97		
2	BRK	135	22	0.89	26.6	82.8
2	BRK	118	12	0.73		
2	BRK	113	12	0.83		
2	BRK	79	4.5	0.91		
2	BRK	77	4.3	0.94		
2	BRK	76	3.7	0.84		
2	BRK	75	3.8	0.90		
2	BRK	70	3.3	0.96		
3	BRK	81	4.2	0.79		
3	BRK	73	3.4	0.87		

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	38	38	38	6
	MIN:	62	2.3	0.73	79.1
	MAX:	145	32	1.05	96.5
	MEAN:	86.3	7.3	0.91	86.2

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (acre)	Density (#/acre)		95 CI	Biomass (lbs/acre)
BRK	28	8	2	38	±	2	0.027	1407	±	74	22.64

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (ha)	Density (#/ha)		95 CI	Biomass (kg/ha)
BRK	28	8	2	38	±	2	0.011	3455	±	182	25.22

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/25/2020
SITE: **FANTAIL CREEK, FC-1-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	NO FISH					

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/25/2020
SITE: **NEVADA GULCH, NG-2-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	NO FISH					

DATA: FISH
CLIENT: WHARF
SAMPLED: 08/27/2020
SITE: **STEWART GULCH, SG-1-BIO**

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	237	118	0.89	152.4	77.5
1	BRK	235	136	1.05	148.4	91.6
1	BRK	231	118	0.96	140.7	83.9
1	BRK	213	98	1.01	109.4	89.6
1	BRK	207	93	1.05	100.1	92.9
1	BRK	190	74	1.08	76.7	96.4
1	BRK	189	65	0.96	75.5	86.1
1	BRK	188	67	1.01	74.3	90.2
1	BRK	186	59	0.92	71.8	82.1
1	BRK	183	66	1.08	68.3	96.6
1	BRK	178	65	1.15	62.7	103.7
1	BRK	177	53	0.96	61.6	86.1
1	BRK	176	54	0.99	60.5	89.2
1	BRK	176	53	0.97	60.5	87.6
1	BRK	175	53	0.99	59.4	89.2
1	BRK	171	49	0.98	55.3	88.6
1	BRK	170	48	0.98	54.3	88.3
1	BRK	170	48	0.98	54.3	88.3
1	BRK	169	48	0.99	53.3	90.0
1	BRK	168	44	0.93	52.4	84.0
1	BRK	166	48	1.05	50.5	95.1
1	BRK	166	45	0.98	50.5	89.2
1	BRK	165	45	1.00	49.5	90.9
1	BRK	164	43	0.97	48.6	88.5
1	BRK	163	23	0.53	47.7	48.2
1	BRK	158	34	0.86	43.3	78.5
1	BRK	156	40	1.05	41.6	96.1
1	BRK	155	38	1.02	40.8	93.2
1	BRK	155	37	0.99	40.8	90.7
1	BRK	153	35	0.98	39.2	89.3
1	BRK	152	34	0.97	38.4	88.6
1	BRK	151	34	0.99	37.6	90.4
1	BRK	151	31	0.90	37.6	82.4
1	BRK	150	32	0.95	36.8	86.8
1	BRK	149	30	0.91	36.1	83.1
1	BRK	147	31	0.98	34.6	89.6
1	BRK	147	29	0.91	34.6	83.8
1	BRK	147	29	0.91	34.6	83.8
1	BRK	145	32	1.05	33.2	96.5
1	BRK	145	27	0.89	33.2	81.4
1	BRK	144	30	1.00	32.5	92.4
1	BRK	140	29	1.06	29.7	97.5
1	BRK	140	28	1.02	29.7	94.1
1	BRK	140	27	0.98	29.7	90.8
1	BRK	136	25	0.99	27.2	92.0
1	BRK	135	24	0.98	26.6	90.3
1	BRK	131	21	0.93	24.2	86.8
1	BRK	130	21	0.96	23.6	88.8
1	BRK	130	20	0.91	23.6	84.6
1	BRK	127	19	0.93	22.0	86.4
1	BRK	124	18	0.94	20.4	88.2
1	BRK	123	20	1.07	19.9	100.5

1	BRK	123	18	0.97	19.9	90.4
1	BRK	122	16	0.88	19.4	82.4
1	BRK	121	17	0.96	18.9	89.9
1	BRK	118	16	0.97		
1	BRK	116	16	1.03		
1	BRK	116	14	0.90		
1	BRK	115	19	1.25		
1	BRK	115	16	1.05		
1	BRK	115	13	0.85		
1	BRK	112	14	1.00		
1	BRK	112	14	1.00		
1	BRK	111	13	0.95		
1	BRK	108	14	1.11		
1	BRK	98	8.2	0.87		
1	BRK	93	7.5	0.93		
1	BRK	90	6.9	0.95		
1	BRK	90	6.6	0.91		
1	BRK	89	5.7	0.81		
1	BRK	88	8.8	1.29		
1	BRK	87	5.9	0.90		
1	BRK	87	5.6	0.85		
1	BRK	87	5.6	0.85		
1	BRK	87	5.5	0.84		
1	BRK	87	5.4	0.82		
1	BRK	86	5.9	0.93		
1	BRK	86	5.5	0.86		
1	BRK	86	5.4	0.85		
1	BRK	86	5.3	0.83		
1	BRK	85	5.7	0.93		
1	BRK	85	5.0	0.81		
1	BRK	84	5.5	0.93		
1	BRK	84	4.5	0.76		
1	BRK	83	5.6	0.98		
1	BRK	82	4.7	0.85		
1	BRK	82	4.4	0.80		
1	BRK	82	4.4	0.80		
1	BRK	81	5.1	0.96		
1	BRK	80	4.8	0.94		
1	BRK	80	4.6	0.90		
1	BRK	80	4.5	0.88		
1	BRK	80	4.5	0.88		
1	BRK	77	3.7	0.81		
1	BRK	73	3.5	0.90		
1	BRK	73	2.9	0.75		
1	BRK	72	3.5	0.94		
1	BRK	71	3.0	0.84		
1	BRK	70	3.1	0.90		
1	BRK	70	3.0	0.87		
1	BRK	70	2.9	0.85		
1	BRK	67	2.7	0.90		
1	BRK	66	2.6	0.90		
1	BRK	66	2.5	0.87		
1	BRK	66	2.3	0.80		
2	BRK	161	41	0.98	45.9	89.3
2	BRK	144	30	1.00	32.5	92.4
2	BRK	142	28	0.98	31.1	90.1
2	BRK	139	28	1.04	29.1	96.2
2	BRK	135	24	0.98	26.6	90.3
2	BRK	127	18	0.88	22.0	81.9

2	BRK	124	18	0.94	20.4	88.2
2	BRK	96	8.4	0.95		
2	BRK	96	7.9	0.89		
2	BRK	94	7.4	0.89		
2	BRK	91	6.3	0.84		
2	BRK	90	7.3	1.00		
2	BRK	87	6.0	0.91		
2	BRK	83	4.6	0.80		
2	BRK	82	4.9	0.89		
2	BRK	81	5.1	0.96		
2	BRK	81	4.9	0.92		
2	BRK	80	4.5	0.88		
2	BRK	80	4.5	0.88		
2	BRK	80	4.0	0.78		
2	BRK	78	4.6	0.97		
2	BRK	78	4.4	0.93		
2	BRK	77	4.3	0.94		
2	BRK	74	3.9	0.96		
2	BRK	74	3.4	0.84		
2	BRK	74	3.4	0.84		
2	BRK	71	3.3	0.92		
3	BRK	153	39	1.09	39.2	99.5
3	BRK	131	19	0.85	24.2	78.5
3	BRK	121	17	0.96	18.9	89.9
3	BRK	97	9.3	1.02		
3	BRK	94	7.4	0.89		
3	BRK	89	6.3	0.89		
3	BRK	85	5.5	0.90		
3	BRK	82	6.0	1.09		
3	BRK	81	4.1	0.77		
3	BRK	76	3.4	0.77		
3	BRK	74	3.4	0.84		
3	BRK	66	2.2	0.77		

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	144	144	144	65
	MIN:	66	2.2	0.53	48.2
	MAX:	237	136	1.29	103.7
	MEAN:	117.9	22.2	0.93	88.6

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (acre)	Density (#/acre)		95 CI	Biomass (lbs/acre)
BRK	105	27	12	147	±	5	0.051	2882	±	98	141.05

	1st Pass	2nd Pass	3rd Pass	Pop Est		95 CI	Site Area (ha)	Density (#/ha)		95 CI	Biomass (kg/ha)
BRK	105	27	12	147	±	5	0.021	7000	±	238	155.40

Appendix B 2020 Benthic Macroinvertebrate Data

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/27/2020
Site: LABRADOR GULCH, LB-4-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
EPHEMEROPTERA	**995**	
Ameletus sp.	5	0.2
Baetis tricaudatus cx.	635	19.9
Diphetor hageni	225	7.1
Neoleptophlebia sp.	100	3.1
Paraleptophlebia sp.	30	0.9
PLECOPTERA	**555**	
Amphinemura sp.	25	0.8
Hesperoperla pacifica	50	1.6
Skwala americana	15	0.5
Sweltsa sp.	50	1.6
Zapada cinctipes	415	13.0
MEGALOPTERA	**40**	
Sialis sp.	40	1.3
COLEOPTERA	**50**	
Heterlimnius corpulentus	35	1.1
Optioservus sp.	15	0.5
TRICHOPTERA	**850**	
Cheumatopsyche sp.	10	0.3
Hesperophylax sp.	10	0.3
Hydropsyche sp.	25	0.8
Micrasema bactro	665	20.9
Oligophlebodes minutus	60	1.9
Rhyacophila brunnea/vao	80	2.5
DIPTERA	**605**	
Antocha monticola	45	1.4
Conchapelopia/Thienemannimyia gr.	30	0.9
Corynoneura sp.	15	0.5
Cricotopus (Nostococladius) nostocicola	115	3.6
Diamesa sp.	30	0.9
Dicranomyia sp.	10	0.3
Dicranota sp.	10	0.3
Hybomitra sp.	5	0.2
Micropsectra sp.	15	0.5
Orthocladius (Symposiocladius) lignicola	15	0.5
Orthocladius/Cricotopus gr.	30	0.9

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/27/2020
Site: LABRADOR GULCH, LB-4-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
DIPTERA (cont.)		
Pagastia sp.	65	2.0
Parorthocladius sp.	15	0.5
Phaenopsectra sp.	15	0.5
Polypedilum sp.	30	0.9
Prodiamesa sp.	30	0.9
Ptychoptera sp.	15	0.5
Radotanypus sp.	15	0.5
Rheocricotopus sp.	65	2.0
Simulium sp.	35	1.1
HYDRACARINA	**35**	
Lebertia sp.	5	0.2
Protzia sp.	30	0.9
ANNELIDA		
OLIGOCHAETA	**55**	
Eiseniella tetraedra	20	0.6
Limnodrilus sp.	5	0.2
Unid. Immature Tubificidae w/o Capilliform Chaetae	30	0.9
TOTAL (#/sample)	3,185	
NUMBER OF TAXA	44	
SHANNON-WEAVER (H’)	4.04	
TOTAL EPT TAXA	16	
EPT INDEX (of Total Taxa)	36	
EPHEMEROPTERA ABUNDANCE (of Total Number)	31	

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/25/2020
Site: RENO CREEK, RC-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
COLLEMBOLA	**10**	
Unid. Collembola	10	0.3
EPHEMEROPTERA	**835**	
Baetis tricaudatus cx.	245	7.2
Diphetor hageni	260	7.6
Neoleptophlebia sp.	270	7.9
Paraleptophlebia sp.	60	1.8
PLECOPTERA	**715**	
Amphinemura sp.	15	0.4
Hesperoperla pacifica	100	2.9
Sweltsa sp.	145	4.3
Zapada cinctipes	455	13.3
MEGALOPTERA	**15**	
Sialis sp.	15	0.4
COLEOPTERA	**190**	
Heterlimnius corpulentus	95	2.8
Optioservus sp.	90	2.6
Sanfilippodytes vilis	5	0.1
TRICHOPTERA	**225**	
Hesperophylax sp.	5	0.1
Hydropsychidae	5	0.1
Lepidostoma sp.	160	4.7
Micrasema bactro	15	0.4
Oligophlebodes minutus	15	0.4
Rhyacophila brunnea/vao	15	0.4
Rhyacophila sp.	10	0.3
DIPTERA	**690**	
Brillia sp.	35	1.0
Ceratopogoninae	10	0.3
Conchapelopia/Thienemannimyia gr.	55	1.6
Corynoneura sp.	165	4.8
Dicranomyia sp.	5	0.1
Dicranota sp.	15	0.4
Dixa sp.	40	1.2
Eukiefferiella sp.	110	3.2
Heterotrissocladius sp.	15	0.4
Meringodixa sp.	35	1.0
Micropsectra sp.	35	1.0
Orthocladius/Cricotopus gr.	15	0.4

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/25/2020
Site: RENO CREEK, RC-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
DIPTERA (cont.)		
Pagastia sp.	15	0.4
Parametriocnemus sp.	15	0.4
Paraphaenocladius sp.	15	0.4
Ptychoptera sp.	5	0.1
Rheocricotopus sp.	55	1.6
Simulium sp.	15	0.4
Tvetenia sp.	35	1.0
HYDRACARINA	**5**	
Todothyas sp.	5	0.1
CRUSTACEA		
AMPHIPODA	**700**	
Gammarus sp.	700	20.5
TURBELLARIA	**5**	
Polycelis coronata	5	0.1
ANNELIDA		
OLIGOCHAETA	**20**	
Eiseniella tetraedra	10	0.3
Tubifex sp.	5	0.1
Unid. Immature Tubificidae w/o Capilliform Chaetae	5	0.1

TOTAL (#/sample)	3,410
NUMBER OF TAXA	45
SHANNON-WEAVER (H')	4.18
TOTAL EPT TAXA	15
EPT INDEX (of Total Taxa)	33
EPHEMEROPTERA ABUNDANCE (of Total Number)	24

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/26/2020
Site: ANNIE CREEK, AC-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
COLLEMBOLA	**5**	
Unid. Collembola	5	0.1
EPHEMEROPTERA	**455**	
Baetis tricaudatus cx.	340	8.4
Diphetor hageni	105	2.6
Siphlonurus sp.	10	0.2
PLECOPTERA	**820**	
Hesperoperla pacifica	285	7.1
Sweltsa sp.	55	1.4
Zapada cinctipes	480	11.9
COLEOPTERA	**215**	
Heterlimnius corpulentus	160	4.0
Optioservus divergens	55	1.4
TRICHOPTERA	**625**	
Glossosoma sp.	5	0.1
Hesperophylax sp.	135	3.3
Lepidostoma sp.	315	7.8
Micrasema bactro	75	1.9
Oligophlebodes minutus	15	0.4
Rhyacophila brunnea/vao	75	1.9
Rhyacophila sp.	5	0.1
DIPTERA	**845**	
Chelifera/Metachela sp.	5	0.1
Diamesa sp.	160	4.0
Dicranota sp.	40	1.0
Eloeophila sp.	10	0.2
Hydrobaenus sp.	70	1.7
Meringodixa sp.	10	0.2
Metriocnemus sp.	45	1.1
Micropsectra sp.	45	1.1
Muscidae	10	0.2
Odontomesa sp.	25	0.6
Orthocladius/Cricotopus gr.	25	0.6

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/26/2020
Site: ANNIE CREEK, AC-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
DIPTERA (cont.)		
Pagastia sp.	25	0.6
Pericoma sp.	50	1.2
Phaenopsectra sp.	25	0.6
Polypedilum sp.	25	0.6
Prodiamesa sp.	25	0.6
Pseudodiamesa sp.	160	4.0
Radotanypus sp.	45	1.1
Rheocricotopus sp.	25	0.6
Tipula sp.	20	0.5
HYDRACARINA	**35**	
Lebertia sp.	5	0.1
Panisopsis sp.	20	0.5
Protzia sp.	5	0.1
Sperchon sp.	5	0.1
TURBELLARIA	**935**	
Polycelis coronata	935	23.1
ANNELIDA		
OLIGOCHAETA	**80**	
Unid. Immature Tubificidae w/ Capilliform Chaetae	75	1.9
Unid. Immature Tubificidae w/o Capilliform Chaetae	5	0.1
MOLLUSCA		
PELECYPODA	**25**	
Pisidium sp.	25	0.6

TOTAL (#/sample)	4,040	
NUMBER OF TAXA	44	
SHANNON-WEAVER (H')	4.17	
TOTAL EPT TAXA	13	
EPT INDEX (of Total Taxa)	30	
EPHEMEROPTERA ABUNDANCE (of Total Number)	11	

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/26/2020
Site: ANNIE CREEK, AC-2-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
EPHEMEROPTERA	**710**	
Ameletus sp.	10	0.5
Baetis tricaudatus cx.	585	31.2
Diphetor hageni	110	5.9
Leptophlebiidae	5	0.3
PLECOPTERA	**185**	
Hesperoperla pacifica	25	1.3
Sweltsa sp.	60	3.2
Zapada cinctipes	100	5.3
COLEOPTERA	**405**	
Heterlimnius corpulentus	160	8.5
Narpus concolor	15	0.8
Optioservus divergens	210	11.2
Zaitzevia parvula	20	1.1
TRICHOPTERA	**300**	
Glossosoma sp.	5	0.3
Hesperophylax sp.	70	3.7
Lepidostoma sp.	70	3.7
Micrasema bactro	5	0.3
Neothremma alicia	5	0.3
Oligophlebodes minutus	135	7.2
Rhyacophila brunnea/vao	5	0.3
Rhyacophila sp.	5	0.3
DIPTERA	**160**	
Brillia sp.	5	0.3
Conchapelopia/Thienemannimyia gr.	10	0.5
Corynoneura sp.	5	0.3
Diamesa sp.	5	0.3
Dicranota sp.	5	0.3
Dixa sp.	10	0.5
Eukiefferiella sp.	5	0.3
Heleniella sp.	10	0.5
Meringodixa sp.	5	0.3
Micropsectra sp.	5	0.3
Muscidae	5	0.3
Pedicia sp.	5	0.3
Phaenopsectra sp.	35	1.9
Polypedilum sp.	20	1.1
Prodiamesa sp.	5	0.3
Radotanypus sp.	10	0.5
Rheocricotopus sp.	5	0.3
Simulium sp.	5	0.3
Tipula sp.	5	0.3

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/26/2020
Site: ANNIE CREEK, AC-2-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
HYDRACARINA	**60**	
Atractides sp.	5	0.3
Lebertia sp.	35	1.9
Protzia sp.	5	0.3
Sperchon sp.	15	0.8
NEMATODA	**5**	
Unid. Nematoda	5	0.3
ANNELIDA		
OLIGOCHAETA	**30**	
Eiseniella tetraedra	15	0.8
Unid. Immature Tubificidae w/ Capilliform Chaetae	5	0.3
Unid. Immature Tubificidae w/o Capilliform Chaetae	10	0.5
MOLLUSCA		
GASTROPODA	**5**	
Physa sp.	5	0.3
PELECYPODA	**15**	
Pisidium sp.	15	0.8

TOTAL (#/sample)	1,875
NUMBER OF TAXA	48
SHANNON-WEAVER (H')	3.88
TOTAL EPT TAXA	15
EPT INDEX (of Total Taxa)	31
EPHEMEROPTERA ABUNDANCE (of Total Number)	38

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/26/2020
Site: ROSS VALLEY, RV-2-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
EPHEMEROPTERA	**380**	
Baetis tricaudatus cx.	207	15.5
Diphetor hageni	173	12.9
PLECOPTERA	**243**	
Amphinemura sp.	3	0.2
Chloroperlidae	7	0.5
Hesperoperla pacifica	13	1.0
Zapada cinctipes	220	16.5
COLEOPTERA	**33**	
Optioservus divergens	33	2.5
TRICHOPTERA	**33**	
Hesperophylax sp.	10	0.7
Lepidostoma sp.	13	1.0
Micrasema bactro	7	0.5
Oligophlebodes minutus	3	0.2
DIPTERA	**192**	
Conchapelopia/Thienemannimyia gr.	3	0.2
Diamesa sp.	7	0.5
Dicranota sp.	7	0.5
Eukiefferiella sp.	3	0.2
Meringodixa sp.	53	4.0
Pagastia sp.	3	0.2
Pericoma sp.	90	6.7
Simulium sp.	3	0.2
Stempellinella sp.	10	0.7
Tipula sp.	13	1.0
HYDRACARINA	**3**	
Arrenurus sp.	3	0.2
CRUSTACEA		
AMPHIPODA	**13**	
Gammarus sp.	13	1.0
TURBELLARIA	**433**	
Polycelis coronata	433	32.4

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/26/2020
Site: ROSS VALLEY, RV-2-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
ANNELIDA		
OLIGOCHAETA	**3**	
Unid. Immature Tubificidae w/o Capilliform Chaetae	3	0.2
MOLLUSCA		
PELECYPODA	**3**	
Sphaeriidae	3	0.2
TOTAL (#/sample)	1,336	
NUMBER OF TAXA	26	
SHANNON-WEAVER (H’)	3.04	
TOTAL EPT TAXA	10	
EPT INDEX (of Total Taxa)	38	
EPHEMEROPTERA ABUNDANCE (of Total Number)	28	

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/26/2020
Site: LOST CAMP GULCH, LC-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
EPHEMEROPTERA	**1,310**	
Baetis tricaudatus cx.	1,145	52.0
Diphetor hageni	5	0.2
Paraleptophlebia sp.	90	4.1
Siphlonurus sp.	70	3.2
PLECOPTERA	**10**	
Zapada cinctipes	10	0.5
COLEOPTERA	**205**	
Agabus cx.	5	0.2
Heterlimnius corpulentus	95	4.3
Narpus concolor	10	0.5
Optioservus castanipennis	40	1.8
Optioservus divergens	55	2.5
TRICHOPTERA	**170**	
Hesperophylax sp.	155	7.0
Lepidostoma sp.	5	0.2
Psychoglypha sp.	10	0.5
DIPTERA	**470**	
Corynoneura sp.	15	0.7
Dicranota sp.	20	0.9
Dixa sp.	10	0.5
Hydrobaenus sp.	15	0.7
Polypedilum sp.	255	11.6
Prodiamesa sp.	40	1.8
Radotanypus sp.	55	2.5
Simulium sp.	10	0.5
Synorthocladius sp.	15	0.7
Tipulidae	5	0.2
Zavrelimyia (Zavrelimyia)	30	1.4
HYDRACARINA	**5**	
Hygrobates sp.	5	0.2
ANNELIDA		
OLIGOCHAETA	**15**	
Eiseniella tetraedra	15	0.7

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/26/2020
Site: LOST CAMP GULCH, LC-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
MOLLUSCA		
PELECYPODA	**15**	
Pisidium sp.	15	0.7
TOTAL (#/sample)	2,200	
NUMBER OF TAXA	27	
SHANNON-WEAVER (H’)	2.81	
TOTAL EPT TAXA	8	
EPT INDEX (of Total Taxa)	30	
EPHEMEROPTERA ABUNDANCE (of Total Number)	60	

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/27/2020
Site: DEADWOOD CREEK, DC-2-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
COLLEMBOLA	**10**	
Unid. Collembola	10	0.2
EPHEMEROPTERA	**165**	
Baetis tricaudatus cx.	30	0.7
Diphetor hageni	110	2.6
Paraleptophlebia sp.	25	0.6
PLECOPTERA	**310**	
Hesperoperla pacifica	45	1.1
Sweltsa sp.	30	0.7
Zapada cinctipes	235	5.6
MEGALOPTERA	**180**	
Sialis sp.	180	4.3
COLEOPTERA	**50**	
Heterlimnius corpulentus	10	0.2
Narpus concolor	25	0.6
Optioservus sp.	15	0.4
TRICHOPTERA	**75**	
Hydropsyche sp.	5	0.1
Lepidostoma sp.	40	0.9
Limnephilidae	5	0.1
Micrasema bactro	15	0.4
Rhyacophila brunnea/vao	10	0.2
DIPTERA	**3,390**	
Bilyjomyia algens	495	11.7
Ceratopogoninae	10	0.2
Conchapelopia/Thienemannimyia gr.	495	11.7
Dicranomyia sp.	5	0.1
Dicranota sp.	10	0.2
Heterotrissocladius sp.	100	2.4
Meringodixa sp.	15	0.4
Micropsectra sp.	50	1.2
Orthocladius/Cricotopus gr.	100	2.4
Pagastia sp.	295	7.0
Parametriocnemus sp.	50	1.2
Pericoma sp.	5	0.1
Pseudodiamesa sp.	50	1.2
Rheocricotopus sp.	50	1.2
Trissopelopia sp.	1,660	39.4

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/27/2020
Site: DEADWOOD CREEK, DC-2-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
ANNELIDA		
OLIGOCHAETA	**5**	
Unid. Immature Tubificidae w/ Capilliform Chaetae	5	0.1
MOLLUSCA		
PELECYPODA	**30**	
Pisidium sp.	30	0.7
TOTAL (#/sample)	4,215	
NUMBER OF TAXA	33	
SHANNON-WEAVER (H')	3.27	
TOTAL EPT TAXA	11	
EPT INDEX (of Total Taxa)	33	
EPHEMEROPTERA ABUNDANCE (of Total Number)	4	

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/24/2020
Site: FALSE BOTTOM CREEK, EFB-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
EPHEMEROPTERA	**570**	
Baetis tricaudatus cx.	430	21.8
Diphetor hageni	130	6.6
Leptophlebiidae	10	0.5
PLECOPTERA	**745**	
Perlidae	15	0.8
Skwala americana	10	0.5
Sweltsa sp.	80	4.1
Zapada cinctipes	640	32.4
COLEOPTERA	**155**	
Heterlimnius corpulentus	85	4.3
Narpus concolor	60	3.0
Optioservus divergens	5	0.3
Zaitzevia parvula	5	0.3
TRICHOPTERA	**160**	
Dolophilodes sp.	10	0.5
Glossosoma sp.	10	0.5
Rhyacophila brunnea/vao	105	5.3
Rhyacophila sp.	35	1.8
DIPTERA	**255**	
Clinocera sp.	5	0.3
Corynoneura sp.	5	0.3
Dicranota sp.	70	3.5
Heleniella sp.	5	0.3
Meringodixa sp.	10	0.5
Metriocnemus sp.	5	0.3
Oreogeton sp.	35	1.8
Pagastia sp.	30	1.5
Phaenopsectra sp.	5	0.3
Polypedilum sp.	10	0.5
Simulium sp.	45	2.3
Tvetenia sp.	25	1.3
Zavrelimyia (Zavrelimyia)	5	0.3
HYDRACARINA	**5**	
Lebertia sp.	5	0.3

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/24/2020
Site: FALSE BOTTOM CREEK, EFB-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
ANNELIDA		
OLIGOCHAETA	**85**	
Eiseniella tetraedra	75	3.8
Enchytraeidae	10	0.5
TOTAL (#/sample)	1,975	
NUMBER OF TAXA	31	
SHANNON-WEAVER (H')	3.40	
TOTAL EPT TAXA	11	
EPT INDEX (of Total Taxa)	35	
EPHEMEROPTERA ABUNDANCE (of Total Number)	29	

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/24/2020
Site: FALSE BOTTOM CREEK, WFB-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
COLLEMBOLA	**1**	
Unid. Collembola	1	0.4
PLECOPTERA	**20**	
Zapada cinctipes	20	7.0
MEGALOPTERA	**4**	
Sialis sp.	4	1.4
COLEOPTERA	**7**	
Optioservus divergens	4	1.4
Sanfilippodytes vilis	2	0.7
Zaitzevia parvula	1	0.4
TRICHOPTERA	**48**	
Cernotina/Polycentropus sp.	26	9.2
Hesperophylax sp.	13	4.6
Lepidostoma sp.	3	1.1
Rhyacophila brunnea/vao	4	1.4
Rhyacophila sp.	2	0.7
DIPTERA	**191**	
Brillia sp.	11	3.9
Ceratopogoninae	18	6.3
Conchapelopia/Thienemannimyia gr.	33	11.6
Dicranota sp.	1	0.4
Heterotrissocladius sp.	33	11.6
Hybomitra sp.	1	0.4
Meringodixa sp.	1	0.4
Pagastia sp.	5	1.8
Phaenopsectra sp.	5	1.8
Polypedilum sp.	73	25.7
Pseudodiamesa sp.	5	1.8
Simulium sp.	5	1.8
ANNELIDA		
OLIGOCHAETA	**9**	
Eiseniella tetraedra	2	0.7
Enchytraeidae	2	0.7
Unid. Immature Tubificidae w/ Capilliform Chaetae	5	1.8

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/24/2020
Site: FALSE BOTTOM CREEK, WFB-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
MOLLUSCA		
PELECYPODA	**4**	
Pisidium sp.	4	1.4
TOTAL (#/sample)	284	
NUMBER OF TAXA	27	
SHANNON-WEAVER (H’)	3.72	
TOTAL EPT TAXA	6	
EPT INDEX (of Total Taxa)	22	
EPHEMEROPTERA ABUNDANCE (of Total Number)	0	

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/25/2020
Site: FANTAIL CREEK, FC-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
COLLEMBOLA	**5**	
Unid. Collembola	5	0.1
EPHEMEROPTERA	**1,310**	
Baetis tricaudatus cx.	1,300	32.9
Diphetor hageni	5	0.1
Paraleptophlebia sp.	5	0.1
PLECOPTERA	**980**	
Amphinemura sp.	40	1.0
Sweltsa sp.	25	0.6
Zapada cinctipes	915	23.2
COLEOPTERA	**235**	
Narpus concolor	5	0.1
Optioservus castanipennis	80	2.0
Optioservus divergens	135	3.4
Sanfilippodytes vilis	15	0.4
TRICHOPTERA	**155**	
Hesperophylax sp.	15	0.4
Lepidostoma sp.	85	2.2
Oligophlebodes minutus	35	0.9
Rhyacophila brunnea/vao	20	0.5
DIPTERA	**410**	
Brillia sp.	5	0.1
Corynoneura sp.	5	0.1
Dicranota sp.	15	0.4
Dixa sp.	20	0.5
Hexatoma sp.	10	0.3
Meringodixa sp.	35	0.9
Micropsectra sp.	5	0.1
Muscidae	5	0.1
Odontomesa sp.	15	0.4
Orthocladius/Cricotopus gr.	55	1.4
Pagastia sp.	5	0.1
Pericoma sp.	5	0.1
Polypedilum sp.	5	0.1
Prodiamesa sp.	10	0.3
Radotanypus sp.	45	1.1
Simulium sp.	85	2.2
Tipula sp.	75	1.9
Tvetenia sp.	10	0.3

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/25/2020
Site: FANTAIL CREEK, FC-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
TURBELLARIA	**835**	
Polycelis coronata	835	21.1
ANNELIDA		
OLIGOCHAETA	**20**	
Eiseniella tetraedra	10	0.3
Unid. Immature Tubificidae w/ Capilliform Chaetae	5	0.1
Unid. Immature Tubificidae w/o Capilliform Chaetae	5	0.1
TOTAL (#/sample)	3,950	
NUMBER OF TAXA	37	
SHANNON-WEAVER (H’)	2.96	
TOTAL EPT TAXA	10	
EPT INDEX (of Total Taxa)	27	
EPHEMEROPTERA ABUNDANCE (of Total Number)	33	

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/24/2020
Site: NEVADA GULCH, NG-2-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
COLLEMBOLA	**2**	
Unid. Collembola	2	0.6
EPHEMEROPTERA	**6**	
Baetis tricaudatus cx.	5	1.4
Diphetor hageni	1	0.3
PLECOPTERA	**47**	
Amphinemura sp.	3	0.8
Perlidae	1	0.3
Sweltsa sp.	41	11.5
Zapada cinctipes	2	0.6
COLEOPTERA	**265**	
Optioservus castanipennis	100	28.2
Optioservus divergens	162	45.6
Sanfilippodytes vilis	1	0.3
Zaitzevia parvula	2	0.6
TRICHOPTERA	**3**	
Glossosoma sp.	2	0.6
Limnephilidae	1	0.3
DIPTERA	**10**	
Dicranota sp.	1	0.3
Limnophyes sp.	1	0.3
Odontomesa sp.	1	0.3
Rheocricotopus sp.	1	0.3
Simulium sp.	1	0.3
Tipula (Sinotipula)	4	1.1
Zavrelimyia (Zavrelimyia)	1	0.3
HYDRACARINA	**5**	
Atractides sp.	2	0.6
Lebertia sp.	2	0.6
Sperchon sp.	1	0.3
TURBELLARIA	**3**	
Polycelis coronata	3	0.8
ANNELIDA		

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/24/2020
Site: NEVADA GULCH, NG-2-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
OLIGOCHAETA	**14**	
Eiseniella tetraedra	14	3.9
TOTAL (#/sample)	355	
NUMBER OF TAXA	25	
SHANNON-WEAVER (H')	2.37	
TOTAL EPT TAXA	8	
EPT INDEX (of Total Taxa)	32	
EPHEMEROPTERA ABUNDANCE (of Total Number)	2	

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/27/2020
Site: STEWART GULCH, SG-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
INSECTA		
COLLEMBOLA	**5**	
Unid. Collembola	5	0.1
EPHEMEROPTERA	**1,020**	
Baetis tricaudatus cx.	990	15.6
Diphetor hageni	30	0.5
PLECOPTERA	**2,275**	
Capniidae	15	0.2
Hesperoperla pacifica	190	3.0
Sweltsa sp.	140	2.2
Zapada cinctipes	1,930	30.3
COLEOPTERA	**1,190**	
Heterlimnius corpulentus	1,085	17.0
Narpus concolor	70	1.1
Optioservus castanipennis	15	0.2
Optioservus divergens	20	0.3
TRICHOPTERA	**810**	
Glossosoma sp.	35	0.5
Lepidostoma sp.	10	0.2
Micrasema bactro	365	5.7
Oligophlebodes minutus	330	5.2
Rhyacophila brunnea/vao	20	0.3
Rhyacophila sp.	50	0.8
DIPTERA	**900**	
Chaetocladius sp.	25	0.4
Clinocera sp.	5	0.1
Diamesa sp.	25	0.4
Dicranota sp.	25	0.4
Dixa sp.	5	0.1
Eukiefferiella sp.	420	6.6
Meringodixa sp.	5	0.1
Micropsectra sp.	25	0.4
Neoplasta sp.	5	0.1
Oreogeton sp.	20	0.3
Orthocladius/Cricotopus gr.	55	0.9
Pagastia sp.	80	1.3
Parorthocladius sp.	135	2.1
Pericoma sp.	5	0.1
Pseudodiamesa sp.	25	0.4
Simulium sp.	15	0.2
Tvetenia sp.	25	0.4

DATA: MACROINVERTEBRATE DENSITY
Client: WHARF
Sampled: 8/27/2020
Site: STEWART GULCH, SG-1-BIO

TAXA	REACH WIDE COMPOSITE (#/SAMPLE)	% OF TOTAL
HYDRACARINA	**120**	
Atractides sp.	5	0.1
Lebertia sp.	15	0.2
Protzia sp.	95	1.5
Testudacarus sp.	5	0.1
TURBELLARIA	**15**	
Polycelis coronata	15	0.2
ANNELIDA		
OLIGOCHAETA	**30**	
Eiseniella tetraedra	15	0.2
Enchytraeidae	5	0.1
Nais sp.	10	0.2
TOTAL (#/sample)	6,365	
NUMBER OF TAXA	42	
SHANNON-WEAVER (H')	3.41	
TOTAL EPT TAXA	12	
EPT INDEX (of Total Taxa)	29	
EPHEMEROPTERA ABUNDANCE (of Total Number)	16	

Appendix C Historical Benthic Macroinvertebrate Data

Table C-1: Select benthic macroinvertebrate population metrics for Site LB-4-BIO, South Dakota, 1995 - 2005. Quantitative sampling methods (i.e., Surber or Hess) were performed in these years. Data is shown for only years in which the site was sampled. NC = not calculated.

Site LB-4-BIO	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005
Total Density	572	1,155	877	1,037	1,256	1,323	1,000	1,415	2,760	994
Number of Taxa	15	32	31	24	29	32	32	33	36	34
Shannon-Weaver Diversity (H')	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Number of EPT Taxa	NC	NC	NC	14	16	16	21	18	NC	16

Table C-2: Benthic macroinvertebrate population metrics for Site LB-4-BIO, South Dakota, 2006 - 2020. Semiquantitative sampling methods (Kick) were performed in these years.

Site LB-4-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Total Density	3,210	891	2,210	2,680	1,424	3,745	729	4,051	3,390	3,722	7,760	4,788	4,245	6,640	3,185
Number of Taxa	45	30	46	34	36	34	24	42	38	40	37	44	39	55	44
Number of EPT Taxa	17	11	16	13	12	11	12	13	14	15	15	14	14	16	16
COMPOSITION METRICS															
Shannon-Weaver Diversity Index (H’)	4.40	3.88	3.67	3.91	4.09	3.65	3.62	4.06	3.61	4.03	3.67	4.19	4.07	4.01	4.04
Percent Sensitive EPT Taxa	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
EPT Index (%)	0.4	0.4	0.3	0.4	0.3	0.3	0.5	0.3	0.4	0.4	0.4	0.3	0.4	0.3	0.4
Percent *Baetis sp.*	0.5	0.2	0.9	0.8	0.8	0.8	0.9	0.7	0.9	0.7	0.8	0.5	0.5	0.5	0.6
Number of non-*Baetis* Ephemeroptera	400	107	135	180	100	301	23	480	150	380	220	590	960	760	360
Percent Chironomidae	13.7	13.8	12.0	14.9	26.7	14.2	17.4	16.8	11.8	12.6	56.4	33.3	29.2	61.1	15.2
Number of Plecoptera Taxa	5	4	5	4	3	4	3	5	5	4	4	4	4	6	5
Percent Abundance of Oligochaetes and Hirudinea	2.2	0.0	0.9	1.5	2.0	2.5	1.8	3.0	3.8	1.6	1.0	1.3	0.5	0.5	1.7
Percent Dominant Taxon	21.5	18.7	34.2	25.4	19.7	28.6	26.5	23.9	32.4	22.3	32.9	16.9	22.1	22.6	20.9
TOLERANCE METRICS															
Hilsenhoff Biotic Index (HBI)	3.41	2.50	3.84	3.55	4.09	3.85	3.15	3.91	3.86	3.77	5.00	4.24	4.24	5.65	3.39
Percent Tolerant Taxa	20.0	16.7	23.9	26.5	22.2	20.6	16.7	19.0	18.4	22.5	21.6	20.5	20.5	25.5	27.3
Percent Intolerant Taxa	46.7	56.7	54.3	44.1	50.0	47.1	54.2	47.6	42.1	45.0	48.6	47.7	46.2	49.1	43.2
Number of Intolerant Taxa	21	17	25	15	18	16	13	20	16	18	18	21	18	27	19
TROPHIC HABIT METRICS															
Number of Predator Taxa	10	6	10	6	7	11	5	11	10	9	9	10	12	17	11
Percent Collector-Gatherers	37.6	26.9	52.4	37.9	49.9	54.3	43.6	56.3	60.5	47.6	43.0	40.2	58.5	45.3	43.6
Number of Shredder Taxa	8	6	9	6	4	4	5	5	6	9	6	7	7	9	8
LIFE HISTORY METRICS															
Number of Univoltine Taxa	22	15	19	13	16	17	8	21	15	16	17	21	19	26	20
Number of Merovoltine Taxa	3	0	1	1	3	0	1	3	1	3	2	2	1	6	3
Number of Semivoltine Taxa	1	1	1	1	0	1	0	1	1	1	0	1	1	1	1
Percent Semivoltine taxa	2.2	3.3	2.2	2.9	0.0	2.9	0.0	2.4	2.6	2.5	0.0	2.3	2.6	1.8	2.3

Table C-3: Benthic macroinvertebrate population metrics for Site RC-1-BIO, South Dakota, 2017 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. Data is shown for only years in which the site was sampled.

Site RC-1-BIO	2017	2018	2019	2020
RICHNESS METRICS				
Total Density	3,001	3,821	3,855	3,410
Number of Taxa	29	38	42	45
Number of EPT Taxa	7	12	14	15
COMPOSITION METRICS				
Shannon-Weaver Diversity Index (H’)	3.59	3.61	3.78	4.18
Percent Sensitive EPT Taxa	0.2	0.2	0.3	0.3
EPT Index (%)	0.2	0.3	0.3	0.3
Percent *Baetis sp.*	0.0	0.3	0.7	0.3
Number of non-*Baetis* Ephemeroptera	180	1,380	395	590
Percent Chironomidae	64.3	11.6	9.5	16.6
Number of Plecoptera Taxa	4	3	5	4
Percent Abundance of Oligochaetes and Hirudinea	0.3	1.2	1.6	0.6
Percent Dominant Taxon	34.0	32.6	28.7	20.5
TOLERANCE METRICS				
Hilsenhoff Biotic Index (HBI)	5.64	4.24	3.79	3.65
Percent Tolerant Taxa	31.0	15.8	23.8	20.0
Percent Intolerant Taxa	51.7	44.7	40.5	48.9
Number of Intolerant Taxa	15	17	17	22
TROPHIC HABIT METRICS				
Number of Predator Taxa	10	11	13	10
Percent Collector-Gatherers	60.6	63.2	45.3	44.1
Number of Shredder Taxa	3	4	6	8
LIFE HISTORY METRICS				
Number of Univoltine Taxa	16	17	19	23
Number of Merovoltine Taxa	0	0	1	1
Number of Semivoltine Taxa	0	0	1	0
Percent Semivoltine taxa	0.0	0.0	2.4	0.0

Table C-4: Select benthic macroinvertebrate population metrics for Site AC-1-BIO, South Dakota, 1992 - 2005. Quantitative sampling methods (i.e., Surber or Hess) were performed in these years. Data is shown for only years in which the site was sampled.

Site AC-1-BIO	1992[a]	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
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
Number of Taxa	33	28	27	24	26	19	29	34	21	27	29	29
Shannon-Weaver Diversity (H’)	3.71	3.2	3.16	3.11	3.17	3.09	3.84	3.18	2.49	3.18	3.03	2.93
Number of EPT Taxa	12	12	9	7	10	7	9	10	3	3	4	9

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

Table C-5: Benthic macroinvertebrate population metrics for Site AC-1-BIO, South Dakota, 2006 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. N/A = no reference site established.

Site AC-1-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Total Density	2,026	4,243	3,311	1,960	3,216	2,429	1,247	2,093	6,820	9,473	3,881	14,054	5,150	2,360	4,040
Number of Taxa	24	11	40	29	25	29	28	31	30	33	37	44	41	39	44
Number of EPT Taxa	6	1	12	6	6	7	11	8	11	10	13	16	14	11	13
COMPOSITION METRICS															
Shannon-Weaver Diversity Index (H')	2.52	1.75	3.99	4.08	3.36	3.85	2.39	3.87	3.83	3.82	4.31	3.80	3.83	3.97	4.17
Percent Sensitive EPT Taxa	0.2	0.1	0.3	0.1	0.1	0.2	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2
EPT Index (%)	0.3	0.1	0.3	0.2	0.2	0.2	0.4	0.3	0.4	0.3	0.4	0.4	0.3	0.3	0.3
Percent *Baetis sp.*	1.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.4	0.8	1.0	0.7
Number of non-*Baetis* Ephemeroptera	0	0	1	0	0	0	0	0	0	0	210	571	350	5	115
Percent Chironomidae	4.9	99.0	23.6	27.6	27.1	38.2	6.7	58.5	59.5	60.9	41.0	35.3	9.2	12.9	17.3
Number of Plecoptera Taxa	3	0	3	3	2	4	4	2	4	3	3	5	4	3	3
Percent Abundance of Oligochaetes & Hirudinea	0.2	0.5	0.7	34.2	1.6	3.0	0.0	0.0	0.1	0.3	2.1	2.6	3.0	0.6	2.0
Percent Dominant Taxon	54.3	60.3	22.0	15.3	28.3	25.5	58.0	23.7	20.4	19.8	17.0	18.4	23.0	21.6	23.1
Number of Common Taxa	3	1	21	10	7	16	11	11	10	N/A	N/A	24	17	20	21
Community Loss Index	1.2	3.4	0.6	0.9	0.7	0.7	0.8	0.5	0.7	N/A	N/A	0.3	0.4	0.5	0.6
TOLERANCE METRICS															
Hilsenhoff Biotic Index (HBI)	3.22	6.35	3.69	6.54	4.33	4.21	2.68	4.33	5.22	5.20	4.23	4.94	3.33	3.50	3.07
Percent Tolerant Taxa	25.0	36.4	15.0	31.0	24.0	24.1	14.3	12.9	23.3	18.2	24.3	22.7	24.4	23.1	31.8
Percent Intolerant Taxa	41.7	18.2	50.0	37.9	36.0	34.5	53.6	51.6	43.3	48.5	45.9	43.2	46.3	46.2	45.5
Number of Intolerant Taxa	10	2	20	11	9	10	15	16	13	16	17	19	19	18	20
TROPHIC HABIT METRICS															
Number of Predator Taxa	5	2	9	5	3	7	7	8	7	8	8	11	10	9	12
Percent Collector-Gatherers	25.9	36.7	56.8	58.6	59.0	46.8	23.3	46.8	53.8	44.4	38.4	23.1	44.1	44.5	31.6
Number of Shredder Taxa	4	3	6	6	4	6	7	8	8	7	9	11	7	8	7
LIFE HISTORY METRICS															
Number of Univoltine Taxa	11	4	23	12	12	14	14	14	15	20	14	22	22	21	19
Number of Merovoltine Taxa	0	1	1	2	1	1	0	3	1	1	3	2	1	2	4
Number of Semivoltine Taxa	0	0	0	1	0	0	0	0	0	0	0	1	1	0	1
Percent Semivoltine taxa	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.4	0.0	2.3

Table C-6: Select benthic macroinvertebrate population metrics for Site AC-2-BIO, South Dakota, 1992 - 2005. Quantitative sampling methods (i.e., Surber or Hess) were performed in these years. Data is shown for only years in which the site was sampled.

Site AC-2-BIO	1992	1995 [a]	1996 [a]	1997 [a]	1998 [a]	1999 [a]	2000	2001	2002	2003	2004	2005
Total Density	10,840	1,333	4,586	3,597	992	5,215	2,119	10,097	4,607	2,046	1,025	2,708
Number of Taxa	37	30	29	32	17	31	34	34	42	48	30	35
Shannon-Weaver Diversity (H')	2.82	3.8	2.11	3.13	2.32	3.2	3.89	2.65	3.94	4.31	3.74	3.67
Number of EPT Taxa	17	9	14	16	6	9	13	8	12	11	10	10

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

Table C-7: Benthic macroinvertebrate population metrics for Site AC-2-BIO, South Dakota, 2006 - 2020. Semiquantitative sampling methods (Kick) were performed in these years.

Site AC-2-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Total Density	950	493	4,937	1,580	896	2,491	1,632	2,497	4,463	3,873	939	4,021	2,411	2,783	1,875
Number of Taxa	25	30	67	36	28	24	42	34	40	42	32	44	49	41	48
Number of EPT Taxa	4	8	24	11	7	8	13	12	10	9	12	16	11	9	15
COMPOSITION METRICS															
Shannon-Weaver Diversity Index (H')	3.54	3.84	3.30	4.05	3.84	3.49	4.28	3.44	3.61	3.91	3.81	4.21	3.32	3.08	3.88
Percent Sensitive EPT Taxa	0.1	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.3	0.2	0.2	0.1	0.3
EPT Index (%)	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.3	0.2	0.4	0.4	0.2	0.2	0.3
Percent *Baetis sp.*	1.0	1.0	0.8	0.8	1.0	1.0	0.8	0.9	1.0	1.0	0.6	0.4	0.9	1.0	0.8
Number of non-*Baetis* Ephemeroptera	0	0	442	45	0	0	70	20	10	0	7	180	100	70	125
Percent Chironomidae	5.8	72.6	8.1	22.2	60.7	52.7	36.8	69.9	30.7	22.7	42.2	50.2	11.0	11.3	6.4
Number of Plecoptera Taxa	3	2	7	5	3	3	3	3	3	3	3	4	3	2	3
Percent Abundance of Oligochaetes & Hirudinea	21.1	0.0	1.0	3.2	5.4	0.4	1.8	0.4	1.6	3.4	1.4	2.0	2.5	1.6	1.6
Percent Dominant Taxon	22.1	28.8	35.5	30.4	26.5	30.0	12.6	37.8	31.6	33.3	29.5	31.6	49.4	49.4	31.2
Number of Common Taxa	12	13	23	17	13	12	16	22	17	0	2	9	16	9	26
Community Loss Index	0.7	0.9	0.5	0.6	0.9	0.9	0.5	0.4	0.5	0.8	1.2	0.5	0.4	0.7	0.4
TOLERANCE METRICS															
Hilsenhoff Biotic Index (HBI)	4.77	5.20	4.73	3.57	5.43	4.81	3.97	5.36	4.74	4.59	4.30	5.04	4.92	4.97	4.13
Percent Tolerant Taxa	40.0	3.3	22.4	19.4	25.0	8.3	23.8	26.5	32.5	26.2	21.9	15.9	34.7	31.7	27.1
Percent Intolerant Taxa	36.0	43.3	43.3	50.0	42.9	62.5	52.4	44.1	32.5	45.2	50.0	50.0	38.8	43.9	43.8
Number of Intolerant Taxa	9	13	29	18	12	15	22	15	13	19	16	22	19	18	21
TROPHIC HABIT METRICS															
Number of Predator Taxa	6	5	14	8	7	3	10	8	8	10	7	8	10	9	13
Percent Collector-Gatherers	50.0	69.8	43.9	39.6	40.3	65.8	49.6	59.1	57.6	48.0	18.0	55.5	64.7	67.4	52.3
Number of Shredder Taxa	2	6	10	7	4	6	4	7	9	10	8	10	9	8	7
LIFE HISTORY METRICS															
Number of Univoltine Taxa	8	19	34	15	15	11	21	15	20	19	18	25	24	19	19
Number of Merovoltine Taxa	1	2	2	3	1	2	3	2	2	3	1	2	2	2	5
Number of Semivoltine Taxa	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0
Percent Semivoltine taxa	0.0	0.0	0.0	2.8	0.0	4.2	0.0	0.0	2.5	0.0	0.0	2.3	0.0	0.0	0.0

Table C-8: Select benthic macroinvertebrate population metrics for Site AC-3-BIO, South Dakota, 1992 - 2005. Quantitative sampling methods (i.e., Surber or Hess) were performed in these years. Data is shown for only years in which the site was sampled.

Site AC-3-BIO	1992 [a]	1995 [b]	1996 [b]	1997 [b]	1998 [b]	1999 [b]	2000	2001	2002	2003	2004	2005
Total Density	10,840	1,333	4,586	3,597	992	5,215	2,119	10,097	4,607	2,046	1,025	2,708
Number of Taxa	37	30	29	32	17	31	34	34	42	48	30	35
Shannon-Weaver Diversity (H’)	2.82	3.8	2.11	3.13	2.32	3.2	3.89	2.65	3.94	4.31	3.74	3.67
Number of EPT Taxa	17	9	14	16	6	9	13	8	12	11	10	10

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

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

Table C-9: Benthic macroinvertebrate population metrics for Site AC-3-BIO, South Dakota, 2006 - 2019. Semiquantitative sampling methods (Kick) were performed in these years. Data is shown for only years in which the site was sampled.

Site AC-3-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
RICHNESS METRICS														
Total Density	1,875	3,505	3,424	2,697	4,170	6,335	2,551	3,181	5,620	8,783	3,570	4,862	2,755	6,436
Number of Taxa	33	37	39	38	39	31	31	38	35	33	30	49	35	46
Number of EPT Taxa	14	14	17	14	15	11	12	13	10	8	7	15	10	12
COMPOSITION METRICS														
Shannon-Weaver Diversity Index (H')	3.92	3.64	4.12	4.21	4.22	2.94	3.64	4.37	3.85	2.89	3.40	4.19	3.77	3.56
Percent Sensitive EPT Taxa	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.2	0.2	0.2
EPT Index (%)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.3	0.3	0.3
Percent *Baetis sp.*	0.5	0.4	0.7	0.8	0.9	0.7	0.1	0.4	1.0	1.0	1.0	0.6	0.9	1.0
Number of non-*Baetis* Ephemeroptera	94	190	120	100	80	320	40	360	20	0	0	190	120	5
Percent Chironomidae	31.5	14.6	21.0	15.2	35.0	15.5	76.6	28.3	36.1	20.2	66.7	24.9	11.1	18.2
Number of Plecoptera Taxa	5	4	5	5	5	4	5	3	4	3	3	5	2	3
Percent Abundance of Oligochaetes & Hirudinea	1.1	0.0	1.2	0.7	1.0	0.4	0.0	0.0	0.4	0.3	2.2	1.9	4.5	1.4
Percent Dominant Taxon	23.1	34.5	21.4	16.7	18.6	51.3	25.1	23.3	18.7	47.9	24.4	24.7	31.6	34.6
Number of Common Taxa	13	16	27	22	22	19	20	20	16	17	15	13	15	20
Community Loss Index	0.5	0.7	0.4	0.4	0.4	0.5	0.5	0.4	0.6	0.5	0.8	0.4	0.6	0.6
TOLERANCE METRICS														
Hilsenhoff Biotic Index (HBI)	4.18	2.78	3.38	3.04	4.12	3.17	5.73	3.31	4.58	4.72	5.49	4.02	4.60	5.02
Percent Tolerant Taxa	21.2	13.5	20.5	15.8	12.8	22.6	16.1	18.4	17.1	21.2	30.0	20.4	31.4	28.3
Percent Intolerant Taxa	57.6	62.2	51.3	47.4	53.8	51.6	61.3	55.3	45.7	39.4	36.7	53.1	42.9	45.7
Number of Intolerant Taxa	19	23	20	18	21	16	19	21	16	13	11	26	15	21
TROPHIC HABIT METRICS														
Number of Predator Taxa	10	8	8	9	12	7	10	8	7	9	8	14	7	10
Percent Collector-Gatherers	47.8	18.5	28.5	30.1	49.2	33.3	37.2	37.4	41.8	65.9	25.8	35.6	49.2	55.1
Number of Shredder Taxa	5	6	6	6	8	4	7	8	7	8	6	9	7	8
LIFE HISTORY METRICS														
Number of Univoltine Taxa	18	21	20	17	19	13	15	18	17	16	13	26	17	21
Number of Merovoltine Taxa	2	0	0	2	3	0	3	3	2	2	1	2	1	4
Number of Semivoltine Taxa	1	0	1	1	1	0	1	1	1	0	0	1	0	1
Percent Semivoltine taxa	3.0	0.0	2.6	2.6	2.6	0.0	3.2	2.6	2.9	0.0	0.0	2.0	0.0	2.2

Table C-10: Benthic macroinvertebrate population metrics for Site RV-2-BIO, South Dakota, 2006 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. N/A = no reference site established.

Site RV-2-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Total Density	558	714	3,094	944	1,648	652	5,671	2,640	3,060	4,792	2,100	3,292	2,605	1,500	1,336
Number of Taxa	25	38	62	26	33	37	23	27	28	33	36	39	38	39	26
Number of EPT Taxa	6	10	16	8	10	7	9	7	9	12	10	12	11	11	10
COMPOSITION METRICS															
Shannon-Weaver Diversity Index (H’)	3.48	4.11	4.44	3.75	3.97	3.91	2.91	3.73	3.10	3.33	3.86	4.08	4.09	3.91	3.04
Percent Sensitive EPT Taxa	0.2	0.1	0.2	0.2	0.2	0.1	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3
EPT Index (%)	0.2	0.3	0.3	0.3	0.3	0.2	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.4
Percent *Baetis sp.*	1.0	0.9	0.7	0.8	0.5	0.3	0.0	1.0	0.8	1.0	0.3	0.5	0.3	0.9	0.5
Number of non-*Baetis* Ephemeroptera	0	2	315	24	33	21	80	0	80	10	73	11	275	25	173
Percent Chironomidae	5.9	26.6	7.6	2.5	25.4	23.0	21.5	18.9	11.1	10.2	6.4	14.9	9.6	7.3	1.9
Number of Plecoptera Taxa	3	3	6	3	4	2	3	1	3	4	3	4	5	4	4
Percent Abundance of Oligochaetes & Hirudinea	20.3	8.8	9.2	4.7	2.7	25.3	0.0	0.4	0.3	0.4	0.0	1.8	20.3	9.0	0.2
Percent Dominant Taxon	29.2	20.2	15.8	21.2	23.8	25.3	35.4	16.3	33.0	34.4	24.1	24.9	25.0	28.0	32.4
Number of Common Taxa	6	15	13	10	11	18	10	8	12	N/A	N/A	29	19	26	18
Community Loss Index	1.0	0.6	0.6	1.0	0.4	0.5	1.0	0.6	0.7	N/A	N/A	0.4	0.5	0.5	1.0
TOLERANCE METRICS															
Hilsenhoff Biotic Index (HBI)	4.72	4.35	4.50	4.05	4.07	5.47	3.78	4.72	2.77	3.70	4.15	3.44	4.95	4.14	2.85
Percent Tolerant Taxa	28.0	21.1	19.4	19.2	24.2	18.9	21.7	18.5	17.9	27.3	36.1	25.6	28.9	30.8	15.4
Percent Intolerant Taxa	36.0	34.2	37.1	42.3	45.5	40.5	52.2	48.1	42.9	51.5	38.9	43.6	47.4	38.5	61.5
Number of Intolerant Taxa	9	13	23	11	15	15	12	13	12	17	14	17	18	15	16
TROPHIC HABIT METRICS															
Number of Predator Taxa	8	6	10	4	5	9	9	8	7	5	14	11	8	11	5
Percent Collector-Gatherers	31.9	48.2	51.1	22.5	27.2	51.5	56.6	37.5	22.5	49.5	38.1	20.1	46.3	37.7	41.1
Number of Shredder Taxa	5	8	11	5	6	8	6	4	5	7	8	8	8	9	6
LIFE HISTORY METRICS															
Number of Univoltine Taxa	14	19	28	12	14	20	11	15	15	12	16	21	18	15	10
Number of Merovoltine Taxa	0	1	2	1	2	2	1	1	0	1	1	1	1	1	2
Number of Semivoltine Taxa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percent Semivoltine taxa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-11: Benthic macroinvertebrate population metrics for Site LC-1-BIO, South Dakota, 2010 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. Data is shown for only years in which the site was sampled. N/A = no reference site established.

Site LC-1-BIO	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS											
Total Density	1,087	1,317	1,521	2,074	675	1,755	3,990	5,103	2,290	566	2,200
Number of Taxa	26	37	23	38	22	24	22	24	29	18	27
Number of EPT Taxa	11	15	5	7	6	5	5	4	5	1	8
COMPOSITION METRICS											
Shannon-Weaver Diversity Index (H')	3.87	3.73	3.51	4.17	3.09	3.29	2.03	3.27	2.81	2.60	2.81
Percent Sensitive EPT Taxa	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1
EPT Index (%)	0.4	0.4	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.3
Percent *Baetis sp.*	0.9	0.2	0.0	1.0	0.0	1.0	1.0	0.0	1.0	0.0	0.9
Number of non-*Baetis* Ephemeroptera	20	471	40	0	0	0	0	51	20	0	165
Percent Chironomidae	30.1	17.8	64.4	75.0	77.6	20.8	84.5	69.8	13.3	24.9	19.3
Number of Plecoptera Taxa	3	3	2	2	1	1	1	0	1	0	1
Percent Abundance of Oligochaetes & Hirudinea	1.3	0.6	1.0	0.2	3.0	4.0	2.0	2.0	0.9	0.0	0.7
Percent Dominant Taxon	21.7	34.7	23.0	16.9	32.3	36.5	67.7	23.3	50.0	38.5	52.0
Number of Common Taxa	11	21	8	16	10	N/A	N/A	24	23	24	12
Community Loss Index	0.5	0.4	1.0	0.2	1.0	N/A	N/A	0.8	0.8	1.8	1.2
TOLERANCE METRICS											
Hilsenhoff Biotic Index (HBI)	3.72	4.07	4.89	5.39	5.87	4.97	5.69	5.86	4.83	4.43	4.95
Percent Tolerant Taxa	15.4	18.9	30.4	28.9	36.4	25.0	31.8	37.5	27.6	27.8	29.6
Percent Intolerant Taxa	46.2	43.2	26.1	39.5	31.8	37.5	45.5	29.2	31.0	38.9	48.1
Number of Intolerant Taxa	12	16	6	15	7	9	10	7	9	7	13
TROPHIC HABIT METRICS											
Number of Predator Taxa	2	9	9	14	5	6	5	7	5	4	5
Percent Collector-Gatherers	54.1	64.3	40.8	40.5	59.9	66.1	17.3	43.9	72.5	53.4	69.1
Number of Shredder Taxa	7	6	3	6	7	4	4	3	5	2	5
LIFE HISTORY METRICS											
Number of Univoltine Taxa	13	21	13	19	14	8	10	12	11	9	16
Number of Merovoltine Taxa	1	1	1	3	2	2	3	3	1	2	1
Number of Semivoltine Taxa	0	1	0	0	0	0	0	1	0	0	1
Percent Semivoltine taxa	0.0	2.7	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	3.7

Table C-12: Select benthic macroinvertebrate population metrics for Site DC-2-BIO, South Dakota, 2000 - 2005. Quantitative sampling methods (i.e., Surber or Hess) were performed in these years. Data is shown for only years in which the site was sampled.

Site DC-2-BIO	2000	2001	2002	2003	2004	2005
Total Density	1,320	3,292	5,160	1,877	7,865	7,951
Number of Taxa	33	27	43	31	39	41
Shannon-Weaver Diversity (H')	3.5	2.83	3.68	3.41	3.81	3.91
Number of EPT Taxa	13	5	13	12	16	14

Table C-13: Benthic macroinvertebrate population metrics for Site DC-2-BIO, South Dakota, 2010 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. Data is shown for only years in which the site was sampled.

Site DC-2-BIO	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS											
Total Density	2,340	5,476	1,540	1,950	6,472	4,313	1,386	4,353	2,116	2,956	4,215
Number of Taxa	30	29	30	35	34	30	27	44	40	45	33
Number of EPT Taxa	13	10	10	15	12	11	8	14	11	11	11
COMPOSITION METRICS											
Shannon-Weaver Diversity Index (H’)	3.23	3.36	3.83	4.30	2.70	3.38	3.78	4.46	4.35	4.52	3.27
Percent Sensitive EPT Taxa	0.4	0.2	0.2	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.3
EPT Index (%)	0.4	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.3
Percent *Baetis sp.*	0.8	0.7	0.5	0.8	0.8	0.7	0.0	0.1	0.3	0.6	0.2
Number of non-*Baetis* Ephemeroptera	40	110	35	105	100	90	0	170	355	155	135
Percent Chironomidae	31.1	58.7	79.2	45.4	36.9	36.4	77.2	67.8	37.3	49.6	79.4
Number of Plecoptera Taxa	5	3	3	4	3	3	3	3	3	3	3
Percent Abundance of Oligochaetes & Hirudinea	1.1	0.2	0.0	0.0	1.1	0.0	0.0	0.5	0.2	3.0	0.1
Percent Dominant Taxon	43.0	29.4	19.2	12.8	47.9	41.5	22.7	18.8	17.5	16.1	39.4
Number of Common Taxa	18	14	17	17	19	17	19	23	20	21	19
Community Loss Index	0.7	0.7	0.6	0.5	0.5	0.5	0.8	0.6	0.5	0.7	0.8
TOLERANCE METRICS											
Hilsenhoff Biotic Index (HBI)	3.20	4.59	4.61	4.53	3.74	3.43	4.57	4.66	3.64	4.85	4.94
Percent Tolerant Taxa	13.3	20.7	23.3	11.4	14.7	16.7	7.4	18.2	22.5	31.1	15.2
Percent Intolerant Taxa	56.7	37.9	43.3	51.4	44.1	46.7	55.6	43.2	40.0	35.6	54.5
Number of Intolerant Taxa	17	11	13	18	15	14	15	19	16	16	18
TROPHIC HABIT METRICS											
Number of Predator Taxa	9	11	11	11	10	11	11	12	11	16	8
Percent Collector-Gatherers	35.1	52.0	46.4	57.4	39.4	31.8	35.7	40.7	52.9	47.5	19.7
Number of Shredder Taxa	4	3	4	5	6	7	6	8	7	7	6
LIFE HISTORY METRICS											
Number of Univoltine Taxa	16	16	16	17	20	16	20	24	18	23	19
Number of Merovoltine Taxa	1	0	0	3	1	1	1	3	3	2	1
Number of Semivoltine Taxa	0	1	0	0	0	0	0	0	0	0	0
Percent Semivoltine taxa	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-14: Select benthic macroinvertebrate population metrics for Site EFB-1-BIO, South Dakota, 1995 - 2005. Quantitative sampling methods (i.e., Surber or Hess) were performed in these years. Data is shown for only years in which the site was sampled.

Site EFB-1-BIO	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total Density	3,247	619	1,451	1,313	511	3,711	2,313	3,927	2,498	2,901	7,726
Number of Taxa	24	20	27	22	23	30	36	44	39	48	33
Shannon-Weaver Diversity (H’)	2.81	3.26	3.57	3.1	3.57	3.48	3.35	3.8	3.7	4.02	3.34
Number of EPT Taxa	8	9	12	6	11	13	10	13	13	15	12

Table C-15: Benthic macroinvertebrate population metrics for Site EFB-1-BIO, South Dakota, 2006 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. Data is shown for only years in which the site was sampled.

Site EFB-1-BIO	2006	2009	2010	2018	2019	2020
RICHNESS METRICS						
Total Density	1,255	797	1,443	9,305	3,990	1,975
Number of Taxa	32	29	28	41	40	31
Number of EPT Taxa	11	10	12	11	11	11
COMPOSITION METRICS						
Shannon-Weaver Diversity Index (H’)	3.66	3.87	3.38	2.92	3.20	3.40
Percent Sensitive EPT Taxa	0.3	0.2	0.4	0.2	0.2	0.3
EPT Index (%)	0.3	0.3	0.4	0.3	0.3	0.4
Percent *Baetis sp.*	0.9	0.9	0.9	0.9	1.0	0.8
Number of non-*Baetis* Ephemeroptera	45	8	27	40	35	140
Percent Chironomidae	12.0	33.2	16.6	27.7	13.7	4.6
Number of Plecoptera Taxa	3	3	4	4	4	4
Percent Abundance of Oligochaetes & Hirudinea	4.4	29.0	1.9	0.4	1.4	4.3
Percent Dominant Taxon	31.9	27.1	33.7	45.4	39.1	32.4
Number of Common Taxa	13	16	16	17	29	15
Community Loss Index	0.5	0.8	0.8	0.5	0.7	0.9
TOLERANCE METRICS						
Hilsenhoff Biotic Index (HBI)	3.69	4.63	3.58	3.54	3.50	3.27
Percent Tolerant Taxa	18.8	27.6	17.9	22.0	25.0	16.1
Percent Intolerant Taxa	53.1	34.5	53.6	43.9	40.0	51.6
Number of Intolerant Taxa	17	10	15	18	16	16
TROPHIC HABIT METRICS						
Number of Predator Taxa	7	8	7	13	12	10
Percent Collector-Gatherers	53.7	60.9	47.3	31.0	40.4	44.8
Number of Shredder Taxa	4	5	4	4	5	2
LIFE HISTORY METRICS						
Number of Univoltine Taxa	18	11	12	21	18	12
Number of Merovoltine Taxa	0	2	1	0	1	3
Number of Semivoltine Taxa	0	0	1	1	1	1
Percent Semivoltine taxa	0.0	0.0	3.6	2.4	2.5	3.2

Table C-16: Benthic macroinvertebrate population metrics for Site WFB-1-BIO, South Dakota, 2007 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. Data is shown for only years in which the site was sampled.

Site WFB-1-BIO	2007	2008	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS												
Total Density	459	1,238	357	926	563	751	2,131	1,068	2,935	3,365	2,410	284
Number of Taxa	31	37	23	27	24	25	22	21	20	30	29	27
Number of EPT Taxa	10	11	5	7	3	8	5	8	3	4	6	6
COMPOSITION METRICS												
Shannon-Weaver Diversity Index (H’)	4.18	4.16	3.91	3.52	3.22	3.36	3.28	3.22	2.92	3.65	3.02	3.72
Percent Sensitive EPT Taxa	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1
EPT Index (%)	0.3	0.3	0.2	0.3	0.1	0.3	0.2	0.4	0.2	0.1	0.2	0.2
Percent *Baetis sp.*	0.4	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.0
Number of non-*Baetis* Ephemeroptera	3	0	0	0	0	0	0	0	0	0	5	0
Percent Chironomidae	50.8	54.0	61.6	84.0	75.3	56.2	60.1	64.8	91.3	67.8	27.8	58.1
Number of Plecoptera Taxa	5	4	3	3	1	4	2	2	1	2	2	1
Percent Abundance of Oligochaetes & Hirudinea	2.2	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	1.2	3.2
Percent Dominant Taxon	18.5	16.2	16.2	22.9	39.4	30.4	22.2	28.1	27.3	27.2	35.3	25.7
Number of Common Taxa	9	15	8	10	7	7	7	9	13	18	26	12
Community Loss Index	1.0	0.8	1.1	0.9	1.2	1.2	1.1	1.5	2.0	1.0	1.5	1.2
TOLERANCE METRICS												
Hilsenhoff Biotic Index (HBI)	4.69	4.71	4.27	5.97	5.69	4.82	5.02	5.65	5.90	5.32	4.43	5.12
Percent Tolerant Taxa	19.4	13.5	17.4	14.8	29.2	8.0	22.7	19.0	30.0	26.7	27.6	22.2
Percent Intolerant Taxa	41.9	40.5	39.1	48.1	25.0	40.0	40.9	47.6	30.0	26.7	24.1	40.7
Number of Intolerant Taxa	13	15	9	13	6	10	9	10	6	8	7	11
TROPHIC HABIT METRICS												
Number of Predator Taxa	10	12	10	14	11	9	10	10	9	8	11	9
Percent Collector-Gatherers	20.7	34.5	34.2	47.7	28.8	11.5	37.0	14.2	49.5	32.8	17.0	19.4
Number of Shredder Taxa	8	6	3	4	4	8	3	5	2	6	4	5
LIFE HISTORY METRICS												
Number of Univoltine Taxa	20	18	16	19	15	14	12	15	12	14	13	13
Number of Merovoltine Taxa	1	1	0	1	0	1	1	1	1	1	0	3
Number of Semivoltine Taxa	0	0	0	0	0	0	0	0	0	0	0	0
Percent Semivoltine taxa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-17: Benthic macroinvertebrate population metrics for Site CC-1A-BIO, South Dakota, 2006 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. Data is shown for only years in which the site was sampled.

Site CC-1A-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2018
RICHNESS METRICS											
Total Density	1,515	1,450	4,576	5,369	2,126	2,597	1,035	3,210	6,370	6,480	8,305
Number of Taxa	11	19	22	18	19	24	21	14	21	24	33
Number of EPT Taxa	1	4	7	6	3	8	4	2	7	10	7
COMPOSITION METRICS											
Shannon-Weaver Diversity Index (H')	1.71	3.01	3.31	2.35	3.11	3.11	2.73	2.43	3.27	2.73	3.11
Percent Sensitive EPT Taxa	0.1	0.2	0.2	0.2	0.1	0.2	0.0	0.1	0.1	0.3	0.2
EPT Index (%)	0.1	0.2	0.3	0.3	0.2	0.3	0.2	0.1	0.3	0.4	0.2
Percent *Baetis sp.*	0.0	1.0	0.4	0.2	0.0	0.0	0.0	0.0	0.1	0.7	0.1
Number of non-*Baetis* Ephemeroptera	0	0	30	52	0	78	11	30	530	20	120
Percent Chironomidae	96.7	38.6	65.8	81.7	69.8	42.6	70.5	96.3	72.7	78.7	95.3
Number of Plecoptera Taxa	0	1	2	2	2	1	0	0	0	3	2
Percent Abundance of Oligochaetes & Hirudinea	2.0	9.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.3	0.2
Percent Dominant Taxon	71.0	38.6	19.4	48.3	37.3	39.5	46.4	35.5	31.7	38.6	38.4
Number of Common Taxa	2	10	10	10	7	12	7	6	6	N/A	17
Community Loss Index	2.6	1.5	1.0	1.4	0.9	1.0	1.2	1.4	1.2	N/A	0.8
TOLERANCE METRICS											
Hilsenhoff Biotic Index (HBI)	6.87	4.30	4.95	6.12	5.94	4.20	5.69	6.80	5.71	6.35	6.74
Percent Tolerant Taxa	45.5	36.8	27.3	27.8	31.6	33.3	33.3	35.7	23.8	16.7	33.3
Percent Intolerant Taxa	18.2	36.8	36.4	27.8	31.6	29.2	28.6	35.7	38.1	50.0	36.4
Number of Intolerant Taxa	2	7	8	5	6	7	6	5	8	12	12
TROPHIC HABIT METRICS											
Number of Predator Taxa	1	1	4	5	4	5	8	1	3	5	5
Percent Collector-Gatherers	89.7	41.0	41.4	66.5	27.4	35.9	68.0	52.6	61.1	32.4	78.4
Number of Shredder Taxa	1	5	8	4	3	4	3	2	4	5	6
LIFE HISTORY METRICS											
Number of Univoltine Taxa	5	6	6	8	9	12	10	6	11	12	14
Number of Merovoltine Taxa	1	1	1	1	1	1	1	0	2	2	0
Number of Semivoltine Taxa	0	0	0	0	0	1	1	0	1	1	0
Percent Semivoltine taxa	0.0	0.0	0.0	0.0	0.0	4.2	4.8	0.0	4.8	4.2	0.0

Table C-18: Select benthic macroinvertebrate population metrics for Site FC-1-BIO, South Dakota, 1995 - 2005. Quantitative sampling methods (i.e., Surber or Hess) were performed in these years. Data is shown for only years in which the site was sampled. NC = not calculated.

Site FC-1-BIO	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total Density	2,061	4,714	1,738	1,088	7,897	24,540	25,085	506	14,518	9,349	1,900[a]
Number of Taxa	38	35	27	30	40	49	40	41	57	41	34
Shannon-Weaver Diversity (H’)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Number of EPT Taxa	11	12	7	11	13	14	10	12	14	9	11

Table C-19: Benthic macroinvertebrate population metrics for Site FC-1-BIO, South Dakota, 2006 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. N/A = no reference site established.

Site FC-1-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Total Density	1,600	669	1,254	3,600	2,772	2,045	480	5,034	4,660	3,300	1,845	3,053	3,941	2,850	3,950
Number of Taxa	33	32	51	28	28	33	39	36	31	35	30	37	40	34	37
Number of EPT Taxa	13	12	14	8	10	8	9	12	6	10	6	8	8	6	10
COMPOSITION METRICS															
Shannon-Weaver Diversity Index (H’)	3.20	3.72	4.60	3.05	2.96	3.19	4.36	4.05	3.28	3.64	3.96	3.94	4.08	2.74	2.96
Percent Sensitive EPT Taxa	0.3	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.1	0.2
EPT Index (%)	0.4	0.4	0.3	0.3	0.4	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.3
Percent *Baetis sp.*	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Number of non-*Baetis* Ephemeroptera	5	3	0	0	0	10	7	52	0	0	0	1	5	0	10
Percent Chironomidae	10.6	36.3	31.4	9.4	5.8	14.4	65.0	42.7	11.6	15.5	40.1	59.6	19.0	4.7	4.1
Number of Plecoptera Taxa	3	3	4	3	4	2	3	3	3	3	2	3	3	0	3
Percent Abundance of Oligochaetes & Hirudinea	0.9	4.0	1.7	0.6	0.0	0.0	1.0	0.0	1.9	0.0	1.9	3.6	1.3	0.7	0.5
Percent Dominant Taxon	31.9	26.9	14.4	36.1	36.8	38.9	17.1	14.7	33.5	27.9	24.9	16.7	19.2	36.3	32.9
Number of Common Taxa	11	13	22	13	15	22	21	15	14	N/A	N/A	9	9	11	25
Community Loss Index	0.6	0.8	0.2	0.8	0.4	0.5	0.3	0.3	0.5	N/A	N/A	0.4	0.6	0.6	0.5
TOLERANCE METRICS															
Hilsenhoff Biotic Index (HBI)	3.77	4.83	4.56	3.58	3.72	3.71	5.38	4.56	3.88	3.86	4.36	4.78	4.52	5.04	3.20
Percent Tolerant Taxa	21.2	21.9	25.5	17.9	17.9	24.2	30.8	19.4	29.0	25.7	23.3	29.7	30.0	29.4	18.9
Percent Intolerant Taxa	42.4	53.1	43.1	46.4	50.0	48.5	48.7	44.4	32.3	40.0	50.0	51.4	37.5	35.3	54.1
Number of Intolerant Taxa	14	17	22	13	14	16	19	16	10	14	15	19	15	12	20
TROPHIC HABIT METRICS															
Number of Predator Taxa	8	8	15	5	7	6	13	12	8	9	7	11	12	9	7
Percent Collector-Gatherers	41.6	51.7	40.8	21.7	20.2	33.0	34.6	42.1	42.9	38.2	27.6	41.6	34.3	38.1	36.7
Number of Shredder Taxa	9	7	9	6	5	6	6	6	7	8	6	4	7	4	8
LIFE HISTORY METRICS															
Number of Univoltine Taxa	16	13	26	11	11	17	20	22	14	18	15	20	18	19	16
Number of Merovoltine Taxa	1	3	1	3	2	0	2	1	1	2	2	1	0	2	3
Number of Semivoltine Taxa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percent Semivoltine taxa	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-20: Select benthic macroinvertebrate population metrics for Site NG-2-BIO, South Dakota, 1995 - 2005. Quantitative sampling methods (i.e., Surber or Hess) were performed in these years. Data is shown for only years in which the site was sampled. NC = not calculated.

Site NG-2-BIO	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total Density	1,317	8,007	3,726	1,429	4,245	6,100	1,736	9,759	2,940	4,334	1,860
Number of Taxa	30	41	35	35	46	24	30	28	47	39	27
Shannon-Weaver Diversity (H’)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Number of EPT Taxa	10	15	10	11	15	6	9	4	10	10	6

Table C-21: Benthic macroinvertebrate population metrics for Site NG-2-BIO, South Dakota, 2006 - 2020. Semiquantitative sampling methods (Kick) were performed in these years. N/A = Not applicable as this was a background control site.

Site NG-2-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Total Density	1,800	1,773	2,340	1,410	2,913	1,383	1,163	843	2,365	8,014	1,435	4,033	1,115	1,535	355
Number of Taxa	31	38	33	35	25	37	32	25	31	29	27	29	37	35	25
Number of EPT Taxa	8	13	8	9	9	7	10	6	8	7	5	8	9	8	8
COMPOSITION METRICS															
Shannon-Weaver Diversity Index (H')	3.48	4.28	4.27	4.10	2.89	4.41	3.80	3.26	2.97	2.78	2.47	2.51	3.33	2.98	2.37
Percent Sensitive EPT Taxa	0.2	0.3	0.2	0.1	0.3	0.1	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
EPT Index (%)	0.3	0.3	0.2	0.3	0.4	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.3
Percent *Baetis sp.*	0.0	0.0	0.1	0.1	1.0	0.4	0.0	0.5	1.0	1.0	0.0	0.2	0.9	1.0	0.8
Number of non-*Baetis* Ephemeroptera	390	85	73	95	0	26	40	3	15	0	0	31	20	5	1
Percent Chironomidae	55.3	59.5	67.2	39.0	57.5	56.9	55.7	72.7	12.3	46.8	16.4	39.4	4.1	9.4	1.1
Number of Plecoptera Taxa	1	4	3	3	5	2	4	2	2	2	2	3	3	3	4
Percent Abundance of Oligochaetes & Hirudinea	0.6	0.8	0.6	1.8	0.0	0.7	0.1	0.0	0.8	0.0	0.3	0.2	2.3	5.9	3.9
Percent Dominant Taxon	30.1	17.1	15.5	14.9	49.8	15.4	17.9	31.8	40.2	39.3	64.8	52.1	29.6	46.3	45.6
Number of Common Taxa	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	19	28	12
Community Loss Index	N/A	N/A	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	0.6	0.6	1.3
TOLERANCE METRICS															
Hilsenhoff Biotic Index (HBI)	4.82	5.36	5.11	4.08	4.85	4.84	4.99	5.68	4.38	4.91	4.22	4.93	4.11	4.25	3.75
Percent Tolerant Taxa	32.3	34.2	27.3	28.6	16.0	21.6	28.1	28.0	32.3	24.1	29.6	31.0	27.0	28.6	24.0
Percent Intolerant Taxa	38.7	44.7	45.5	34.3	56.0	40.5	43.8	44.0	41.9	58.6	48.1	44.8	48.6	40.0	52.0
Number of Intolerant Taxa	12	17	15	12	14	15	14	11	13	17	13	13	18	14	13
TROPHIC HABIT METRICS															
Number of Predator Taxa	7	10	5	6	10	8	9	8	6	6	5	9	9	8	8
Percent Collector-Gatherers	67.1	42.4	50.4	29.4	10.1	40.9	41.7	13.8	56.9	19.5	12.5	15.6	23.5	33.2	7.6
Number of Shredder Taxa	6	8	5	7	4	6	7	5	3	6	6	5	5	7	4
LIFE HISTORY METRICS															
Number of Univoltine Taxa	16	21	14	13	9	17	14	12	10	12	13	13	15	13	9
Number of Merovoltine Taxa	3	2	2	1	1	1	3	0	1	2	3	1	1	3	1
Number of Semivoltine Taxa	1	0	0	0	1	0	1	1	1	0	0	2	0	0	0
Percent Semivoltine taxa	3.2	0.0	0.0	0.0	4.0	0.0	3.1	4.0	3.2	0.0	0.0	6.9	0.0	0.0	0.0

Table C-22: Select benthic macroinvertebrate population metrics for Site SG-1-BIO, South Dakota, 1995 - 2005. Quantitative sampling methods (i.e., Surber or Hess) were performed in these years. Data is shown for only years in which the site was sampled. NC = not calculated.

Site SG-1-BIO	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total Density	5,977	4,509	2,737	467	4,791	8,957	5,116	13,225	5,464	4,213	9,921
Number of Taxa	31	24	34	21	29	34	37	42	45	44	36
Shannon-Weaver Diversity (H’)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Number of EPT Taxa	10	13	10	9	13	12	12	12	14	13	11

Table C-23: Benthic macroinvertebrate population metrics for Site SG-1-BIO, South Dakota, 2006 - 2020. Semiquantitative sampling methods (Kick) were performed in these years.

Site SG-1-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Total Density	2,910	4,070	3,311	4,470	5,619	2,215	4,021	2,912	7,521	8,842	11,800	9,420	6,906	4,400	6,365
Number of Taxa	28	33	40	30	31	34	34	25	29	30	32	38	35	45	42
Number of EPT Taxa	11	10	12	9	15	11	12	11	10	11	13	10	12	13	12
COMPOSITION METRICS															
Shannon-Weaver Diversity Index (H’)	3.83	3.91	3.99	3.62	3.94	4.48	3.82	3.69	2.83	2.98	3.42	3.99	3.40	3.77	3.41
Percent Sensitive EPT Taxa	0.3	0.2	0.3	0.3	0.4	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.2
EPT Index (%)	0.4	0.3	0.3	0.3	0.5	0.3	0.4	0.4	0.3	0.4	0.4	0.3	0.3	0.3	0.3
Percent *Baetis sp.*	0.9	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Number of non-*Baetis* Ephemeroptera	20	0	1	0	60	10	20	0	0	20	20	0	60	25	30
Percent Chironomidae	24.7	34.6	23.6	13.6	40.8	33.2	32.8	34.0	8.0	6.8	13.6	48.8	24.1	17.6	12.8
Number of Plecoptera Taxa	3	3	3	3	6	3	4	5	3	3	3	4	4	3	4
Percent Abundance of Oligochaetes & Hirudinea	0.0	0.5	0.7	1.1	0.0	1.1	0.2	0.0	0.5	0.2	0.5	0.4	0.4	0.8	0.5
Percent Dominant Taxon	17.2	22.4	22.0	23.3	13.6	13.1	18.2	27.1	42.8	39.5	25.0	18.0	27.7	24.9	30.3
Number of Common Taxa	12	18	21	19	20	22	17	16	17	15	22	23	11	25	19
Community Loss Index	0.6	0.7	0.6	0.7	0.6	0.4	0.5	0.8	0.7	0.6	0.6	0.7	0.6	0.6	0.6
TOLERANCE METRICS															
Hilsenhoff Biotic Index (HBI)	3.66	4.27	3.69	3.24	3.78	3.94	4.11	4.14	3.72	3.64	3.88	4.71	4.24	3.90	3.41
Percent Tolerant Taxa	17.9	24.2	15.0	26.7	12.9	20.6	14.7	20.0	13.8	10.0	3.1	15.8	20.0	26.7	23.8
Percent Intolerant Taxa	42.9	39.4	50.0	46.7	54.8	44.1	50.0	44.0	48.3	56.7	56.3	47.4	40.0	35.6	47.6
Number of Intolerant Taxa	12	13	20	14	17	15	17	11	14	17	18	18	14	16	20
TROPHIC HABIT METRICS															
Number of Predator Taxa	4	8	9	7	9	8	8	7	7	5	7	11	11	12	11
Percent Collector-Gatherers	48.7	57.2	56.8	42.9	63.0	51.2	69.1	72.5	57.7	69.4	66.7	63.8	54.0	54.1	47.0
Number of Shredder Taxa	5	7	6	6	6	6	6	6	6	6	5	7	5	7	5
LIFE HISTORY METRICS															
Number of Univoltine Taxa	15	21	23	12	14	20	20	12	16	17	22	21	17	19	19
Number of Merovoltine Taxa	1	0	1	1	1	0	1	1	0	1	0	1	0	3	1
Number of Semivoltine Taxa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percent Semivoltine taxa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix D 2020 Periphyton Data

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/27/2020
Site: LABRADOR GULCH, LB-4-BIO

TOTAL CELLS/cm^2	33,888
NUMBER OF TAXA	15
SHANNON-WEAVER DIVERSITY (H')	2.60
TROPHIC STATE INDEX	65.5

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes minutissima	15,062	44.4
Amphora perpusilla	837	2.5
Caloneis ventricosa minuta	837	2.5
Cocconeis placentula	8,368	24.7
Cymbella minuta	418	1.2
Navicula cryptocephala	2,092	6.2
Navicula cryptocephala veneta	418	1.2
Navicula minima	1,255	3.7
Navicula sp.	418	1.2
Navicula tripunctata	1,674	4.9
Nitzschia acicularis	418	1.2
Nitzschia frustulum	837	2.5
Nitzschia linearis	418	1.2
Rhoicosphenia curvata	418	1.2
Synedra rumpens	418	1.2

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/25/2020
Site: RENO CREEK, RC-1-BIO

TOTAL CELLS/cm^2	115,261
NUMBER OF TAXA	24
SHANNON-WEAVER DIVERSITY (H')	3.19
TROPHIC STATE INDEX	75.8

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes lanceolata	11,122	9.6
Achnanthes linearis	3,033	2.6
Achnanthes minutissima	17,188	14.9
Achnanthes recurvata	1,011	0.9
Amphora perpusilla	2,022	1.8
Anomoeoneis vitrea	1,011	0.9
Cocconeis placentula	47,521	41.2
Cymbella sinuata	2,022	1.8
Gomphonema angustatum	2,022	1.8
Meridion circulare	1,011	0.9
Navicula cryptocephala	1,011	0.9
Navicula cryptocephala veneta	2,022	1.8
Navicula minima	7,078	6.1
Navicula tripunctata	1,011	0.9
Navicula viridula	4,044	3.5
Nitzschia acicularis	1,011	0.9
Nitzschia dissipata	1,011	0.9
Nitzschia frustulum	1,011	0.9
Nitzschia linearis	1,011	0.9
Nitzschia paleacea	2,022	1.8
Rhoicosphenia curvata	3,033	2.6
Surirella ovata	1,011	0.9
Synedra ulna	1,011	0.9
CRYPTOPHYTA		
Cryptomonas erosa	1,011	0.9

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/26/2020
Site: ANNIE CREEK, AC-1-BIO

TOTAL CELLS/cm^2	173,223
NUMBER OF TAXA	22
SHANNON-WEAVER DIVERSITY (H')	3.50
TROPHIC STATE INDEX	76.3

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes lanceolata	5,973	3.4
Achnanthes linearis	2,987	1.7
Achnanthes minutissima	64,212	37.1
Amphora perpusilla	8,960	5.2
Cocconeis placentula	5,973	3.4
Cymbella minuta	2,987	1.7
Fragilaria leptostauron	2,987	1.7
Gomphonema angustatum	8,960	5.2
Gomphonema subclavatum	1,493	0.9
Navicula cryptocephala	8,960	5.2
Navicula minima	16,426	9.5
Navicula minuscula	2,987	1.7
Navicula sp.	2,987	1.7
Navicula tripunctata	7,466	4.3
Navicula viridula	1,493	0.9
Nitzschia dissipata	1,493	0.9
Nitzschia frustulum	4,480	2.6
Nitzschia palea	1,493	0.9
Rhoicosphenia curvata	10,453	6.0
CHLOROPHYTA		
Chlamydomonas sp.	2,987	1.7
Cladophora sp.	1,493	0.9
CRYPTOPHYTA		
Cryptomonas erosa	5,973	3.4

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/26/2020
Site: ANNIE CREEK, AC-2-BIO

TOTAL CELLS/cm^2	22,535
NUMBER OF TAXA	16
SHANNON-WEAVER DIVERSITY (H')	2.82
TROPHIC STATE INDEX	64.2

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes lanceolata	1,040	4.6
Achnanthes linearis	347	1.5
Achnanthes minutissima	2,427	10.8
Amphora perpusilla	1,387	6.2
Cocconeis placentula	11,093	49.2
Cymbella minuta	347	1.5
Gomphonema subclavatum	347	1.5
Navicula cryptocephala	1,387	6.2
Navicula cryptocephala veneta	693	3.1
Navicula minima	693	3.1
Navicula minuscula	347	1.5
Navicula viridula	347	1.5
Nitzschia frustulum	693	3.1
Nitzschia linearis	347	1.5
Nitzschia palea	693	3.1
Rhoicosphenia curvata	347	1.5

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/26/2020
Site: ROSS VALLEY, RV-2-BIO

TOTAL CELLS/cm^2	52,101
NUMBER OF TAXA	19
SHANNON-WEAVER DIVERSITY (H')	3.74
TROPHIC STATE INDEX	73.5

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes lanceolata	2,141	4.1
Achnanthes linearis	714	1.4
Achnanthes minutissima	4,996	9.6
Amphora perpusilla	5,710	11.0
Caloneis ventricosa minuta	2,855	5.5
Cocconeis placentula	7,137	13.7
Diploneis oculata	714	1.4
Gomphonema angustatum	1,427	2.7
Navicula cryptocephala	2,141	4.1
Navicula cryptocephala veneta	2,141	4.1
Navicula minuscula	714	1.4
Navicula reinhartii	714	1.4
Navicula tripunctata	8,565	16.4
Navicula viridula	6,423	12.3
Nitzschia linearis	714	1.4
Rhoicosphenia curvata	714	1.4
Surirella ovata	1,427	2.7
CHLOROPHYTA		
Cladophora sp.	1,427	2.7
CYANOPHYTA		
Oscillatoria sp.	1,427	2.7

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/26/2020
Site: LOST CAMP GULCH, LC-1-BIO

TOTAL CELLS/cm^2	36,665
NUMBER OF TAXA	16
SHANNON-WEAVER DIVERSITY (H')	3.34
TROPHIC STATE INDEX	63.8

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes lanceolata	3,235	8.8
Achnanthes linearis	2,876	7.8
Achnanthes minutissima	719	2.0
Amphora perpusilla	6,111	16.7
Cocconeis placentula	7,190	19.6
Cymbella minuta	359	1.0
Cymbella sinuata	1,078	2.9
Meridion circulare	719	2.0
Navicula cascadensis	359	1.0
Navicula cryptocephala veneta	359	1.0
Navicula minima	719	2.0
Navicula minuscula	2,157	5.9
Navicula sp.	359	1.0
Nitzschia communis	6,471	17.6
Nitzschia innominata	3,235	8.8
Rhoicosphenia curvata	719	2.0

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/27/2020
Site: DEADWOOD CREEK, DC-2-BIO

TOTAL CELLS/cm^2	589,501
NUMBER OF TAXA	21
SHANNON-WEAVER DIVERSITY (H')	3.41
TROPHIC STATE INDEX	85.3

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Centrales		
Melosira varians	5,082	0.9
Order Pennales		
Achnanthes clevei	10,164	1.7
Achnanthes lanceolata	30,491	5.2
Achnanthes linearis	35,573	6.0
Achnanthes minutissima	152,457	25.9
Achnanthes recurvata	5,082	0.9
Caloneis ventricosa minuta	5,082	0.9
Cymbella minuta	45,737	7.8
Cymbella sinuata	10,164	1.7
Diatoma hiemale mesodon	10,164	1.7
Fragilaria vaucheria	35,573	6.0
Gomphonema angustatum	10,164	1.7
Meridion circulare	5,082	0.9
Navicula cryptocephala	81,310	13.8
Navicula graciloides	5,082	0.9
Navicula minima	15,246	2.6
Navicula sp.	5,082	0.9
Nitzschia linearis	5,082	0.9
Synedra rumpens	106,720	18.1
Synedra ulna	5,082	0.9
CHLOROPHYTA		
Cladophora sp.	5,082	0.9

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/24/2020
Site: EAST FORK FALSE BOTTOM CREEK, EFB-1-BIO

TOTAL CELLS/cm^2	145,259
NUMBER OF TAXA	20
SHANNON-WEAVER DIVERSITY (H')	3.60
TROPHIC STATE INDEX	78.5

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes lanceolata	5,430	3.7
Achnanthes minutissima	40,726	28.0
Amphipleura pellucida	4,073	2.8
Cocconeis placentula	13,575	9.3
Cymbella minuta	2,715	1.9
Gomphonema angustatum	4,073	2.8
Gomphonema subclavatum	1,358	0.9
Meridion circulare	2,715	1.9
Navicula minima	1,358	0.9
Nitzschia capitellata	9,503	6.5
Nitzschia dissipata	4,073	2.8
Nitzschia fonticola	1,358	0.9
Nitzschia frustulum	13,575	9.3
Nitzschia linearis	12,218	8.4
Nitzschia palea	9,503	6.5
Surirella linearis	1,358	0.9
Surirella ovata	2,715	1.9
Synedra rumpens	10,860	7.5
Synedra tenera	2,715	1.9
CHLOROPHYTA		
Cladophora sp.	1,358	0.9

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/24/2020
Site: WEST FORK FALSE BOTTOM CREEK, WFB-1-BIO

TOTAL CELLS/cm^2	38,391
NUMBER OF TAXA	11
SHANNON-WEAVER DIVERSITY (H')	1.41
TROPHIC STATE INDEX	72.6

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes linearis	431	1.1
Achnanthes minutissima	863	2.2
Amphora coffeaeformis	431	1.1
Eunotia elegans	431	1.1
Eunotia pectinalis	29,766	77.5
Gomphonema angustatum	2,157	5.6
Meridion circulare	431	1.1
Navicula graciloides	431	1.1
Pinnularia sp.	431	1.1
Synedra rumpens	2,588	6.7
Synedra tenera	431	1.1

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/25/2020
Site: FANTAIL CREEK, FC-1-BIO

TOTAL CELLS/cm^2	33,939
NUMBER OF TAXA	23
SHANNON-WEAVER DIVERSITY (H')	3.51
TROPHIC STATE INDEX	68.6

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes lanceolata	3,649	10.8
Achnanthes minutissima	11,677	34.4
Amphora perpusilla	730	2.2
Caloneis ventricosa minuta	730	2.2
Denticula elegans	365	1.1
Fragilaria vaucheria	365	1.1
Gomphonema angustatum	365	1.1
Navicula cryptocephala	1,825	5.4
Navicula sp.	365	1.1
Navicula tripunctata	2,919	8.6
Navicula viridula	365	1.1
Nitzschia capitellata	730	2.2
Nitzschia fonticola	365	1.1
Nitzschia frustulum	730	2.2
Nitzschia linearis	1,095	3.2
Nitzschia microcephala	365	1.1
Nitzschia palea	2,919	8.6
Nitzschia paleacea	365	1.1
Nitzschia sigmoidea	365	1.1
Rhoicosphenia curvata	1,095	3.2
Surirella ovata	365	1.1
Synedra ulna	1,825	5.4
CHRYSOPHYTA		
Chrysococcus rufescens	365	1.1

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/24/2020
Site: NEVADA GULCH, NG-2-BIO

TOTAL CELLS/cm^2	563,447
NUMBER OF TAXA	21
SHANNON-WEAVER DIVERSITY (H')	3.57
TROPHIC STATE INDEX	83.4

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes lanceolata	33,144	5.9
Achnanthes linearis	18,939	3.4
Achnanthes minutissima	99,432	17.6
Amphora perpusilla	47,348	8.4
Caloneis ventricosa	4,735	0.8
Cymbella minuta	4,735	0.8
Cymbella sinuata	33,144	5.9
Gomphonema angustatum	23,674	4.2
Gomphonema subclavatum	9,470	1.7
Navicula cryptocephala	18,939	3.4
Navicula minima	9,470	1.7
Navicula sp.	4,735	0.8
Navicula viridula	9,470	1.7
Nitzschia capitellata	9,470	1.7
Nitzschia communis	18,939	3.4
Nitzschia frustulum	18,939	3.4
Nitzschia innominata	14,205	2.5
Nitzschia linearis	18,939	3.4
Nitzschia microcephala	4,735	0.8
Rhoicosphenia curvata	156,250	27.7
CHLOROPHYTA		
Ankistrodesmus falcatus	4,735	0.8

DATA: PERIPHYTON ANALYSES
Client: WHARF
Sampled: 8/27/2020
Site: STEWART GULCH, SG-1-BIO

TOTAL CELLS/cm^2	192,701
NUMBER OF TAXA	10
SHANNON-WEAVER DIVERSITY (H')	2.03
TROPHIC STATE INDEX	74.1

Organisms	Cells/cm^2	Rel Conc.
BACILLARIOPHYTA		
Order Pennales		
Achnanthes lanceolata	47,105	24.4
Achnanthes linearis	8,565	4.4
Achnanthes minutissima	104,201	54.1
Amphora perpusilla	4,282	2.2
Diatoma hiemale mesodon	2,855	1.5
Gomphonema angustatum	4,282	2.2
Meridion circulare	5,710	3.0
Navicula minima	1,427	0.7
Navicula minuscula	12,847	6.7
Surirella ovata	1,427	0.7

Appendix E Historical Periphyton Data

Table E-1: Periphyton population metrics for Site LB-4-BIO, South Dakota, 2005. Data is shown for the only year in which the site was sampled prior to 2006. NC = not calculated.

Site LB-4-BIO	2005
Density (cells/cm^2)	NC
Number of Taxa	54

Table E-2: Periphyton population metrics for Site LB-4-BIO, South Dakota, 2006 - 2020.

Site LB-4-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Density (cells/cm^2)	96,692	268,422	47,162	579,611	1,030,889	85,328	107,845	38,956	44,352	43,610	180,874	261,688	229,142	200,277	33,888
Relative Density (%)	73.7	100.0	100.0	37.8	97.3	53.1	96.4	96.6	98.0	100.0	100.0	100.0	99.2	100.0	100.0
Number of Taxa (species)	20	11	14	18	18	20	21	19	22	18	23	26	23	19	15
Number of Diatom Taxa	17	11	14	17	16	18	20	18	21	18	23	26	22	19	15
Number of Periphyton Divisions	7	1	1	2	5	4	3	3	3	1	1	1	2	1	1
Number of Periphyton Genera	18	10	13	15	16	15	17	13	16	6	19	22	21	15	9
COMPOSITION METRICS															
Shannon-Weaver Diversity Index for Diatoms (H')	2.88	2.42	2.90	3.18	2.58	2.79	3.20	3.05	3.43	3.23	3.82	3.87	3.51	3.47	2.60
Autotrophic Index	195	1,061	829	407	481	531	671	749	309	292	1,354	536	653	785	1,228
TOLERANCE METRICS															
Percent Tolerant Diatoms	2.4	4.6	10.2	1.3	5.5	1.7	2.8	1.8	5.2	9.7	19.0	12.2	7.4	11.4	3.7
Lange-Bertalot Pollution Index	2.85	2.41	2.63	2.75	2.72	2.82	2.75	2.75	2.58	2.53	2.42	2.56	2.64	2.58	2.83
TROPHIC HABIT METRICS															
Percent Eutrophic Diatoms	52.9	54.5	57.1	58.8	50.0	50.0	70.0	38.9	57.1	61.1	60.9	53.8	50.0	42.1	46.7
Percent Acidiphilic Diatoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	64.7	63.6	64.3	58.8	50.0	44.4	70.0	44.4	57.1	55.6	56.5	53.8	54.5	57.9	46.7
Percent Nitrogen Heterotrophs	11.8	18.2	14.3	11.8	6.3	11.1	10.0	5.6	19.0	22.2	17.4	19.2	13.6	15.8	20.0
Percent High Oxygen Diatoms	41.2	27.3	42.9	52.9	37.5	44.4	50.0	22.2	33.3	33.3	34.8	26.9	22.7	26.3	20.0
Percent Motile Diatoms	58.8	45.5	42.9	41.2	43.8	50.0	55.0	44.4	61.9	72.2	52.2	53.8	54.5	57.9	66.7
Percent Saprobic Diatoms	11.8	18.2	21.4	11.8	12.5	16.7	10.0	5.6	19.0	16.7	17.4	15.4	4.5	15.8	13.3

Table E-3: Periphyton population metrics for Site RC-1-BIO, South Dakota, 2017 - 2020. Data is shown for only years in which the site was sampled.

Site RC-1-BIO	2017	2018	2019	2020
RICHNESS METRICS				
Density (cells/cm^2)	95,449	71,399	47,771	115,261
Relative Density (%)	100.0	100.0	100.0	99.0
Number of Taxa (species)	13	14	14	24
Number of Diatom Taxa	13	14	14	23
Number of Periphyton Divisions	1	1	1	2
Number of Periphyton Genera	11	12	11	13
COMPOSITION METRICS				
Shannon-Weaver Diversity Index for Diatoms (H’)	2.30	2.24	2.52	3.14
Autotrophic Index	3,328	621	6,488	3,443
TOLERANCE METRICS				
Percent Tolerant Diatoms	2.8	5.0	9.1	6.2
Lange-Bertalot Pollution Index	2.76	2.62	2.54	2.64
TROPHIC HABIT METRICS				
Percent Eutrophic Diatoms	38.5	50.0	28.6	47.8
Percent Acidiphilic Diatoms	0.0	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	38.5	64.3	42.9	52.2
Percent Nitrogen Heterotrophs	15.4	14.3	7.1	17.4
Percent High Oxygen Diatoms	23.1	28.6	35.7	39.1
Percent Motile Diatoms	38.5	50.0	50.0	56.5
Percent Saprobic Diatoms	23.1	7.1	7.1	8.7

Table E-4: Periphyton population metrics for Site AC-1-BIO, South Dakota, 1993 - 2005.

Site AC-1-BIO	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Density(cells/cm^2)	2,100	205,900	611,500	67,300	75,000	862,800	33,900	18,271,800	108,205,900	240,100	457,700	1,894,000	288,500
Number of Taxa	6	13	11	4	2	13	3	21	22	12	13	11	11

Table E-5: Periphyton population metrics for Site AC-1-BIO, South Dakota, 2006 - 2020. N/A = no reference site established.

Site AC-1-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Density (cells/cm^2)	168,635	1,932,352	116,238	44,016	42,707	143,406	108,653	249,253	17,896,821	397,730	952,328	60,300	448,390	156,885	173,223
Relative Density (%)	87.5	100.0	100.0	100.0	29.4	19.9	100.0	99.0	100.0	100.0	100.0	65.7	99.4	97.8	94.0
Number of Taxa (species)	29	15	21	13	10	18	26	13	25	16	16	17	13	13	22
Number of Diatom Taxa	26	15	21	13	7	16	26	12	25	16	16	13	12	10	19
Number of Periphyton Divisions	6	1	1	1	3	4	1	3	1	1	1	7	3	4	3
Number of Periphyton Genera	20	13	13	10	9	13	21	11	20	7	13	16	12	11	12
COMPOSITION METRICS															
Shannon-Weaver Diversity Index for Diatoms (H')	3.59	3.04	3.04	2.54	2.64	3.00	3.88	1.98	3.58	2.26	3.33	3.02	2.29	1.84	3.28
Bahls Similarity Index (%)	29.2	34.0	15.9	35.9	13.6	10.7	42.4	34.0	11.0	N/A	N/A	24.9	22.5	31.9	38.4
Autotrophic Index	505	541	634	374	564	282	979	264	239	434	611	1,181	335	373	236
TOLERANCE METRICS															
Percent Tolerant Diatoms	6.1	24.8	3.5	5.9	26.7	7.3	15.4	12.6	15.5	3.2	3.8	0.0	17.2	18.4	12.8
Lange-Bertalot Pollution Index	2.65	2.28	2.47	2.66	2.40	2.67	2.42	2.61	2.18	2.71	2.66	2.82	2.56	2.57	2.57
TROPHIC HABIT METRICS															
Percent Eutrophic Diatoms	61.5	60.0	61.9	61.5	42.9	50.0	38.5	50.0	44.0	50.0	56.3	46.2	41.7	40.0	52.6
Percent Acidiphilic Diatoms	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	46.2	60.0	47.6	46.2	71.4	50.0	50.0	66.7	36.0	56.3	43.8	46.2	50.0	50.0	47.4
Percent Nitrogen Heterotrophs	19.2	26.7	19.0	23.1	14.3	6.3	11.5	25.0	16.0	12.5	18.8	0.0	8.3	20.0	15.8
Percent High Oxygen Diatoms	30.8	26.7	33.3	30.8	42.9	37.5	34.6	50.0	32.0	50.0	25.0	38.5	33.3	30.0	36.8
Percent Motile Diatoms	61.5	66.7	76.2	61.5	71.4	56.3	38.5	41.7	48.0	50.0	68.8	30.8	41.7	60.0	52.6
Percent Saprobic Diatoms	19.2	13.3	19.0	23.1	14.3	12.5	7.7	16.7	12.0	12.5	18.8	0.0	8.3	10.0	10.5

Table E-6: Periphyton population metrics for Site AC-2-BIO, South Dakota, 1993 - 2005.

Site AC-2-BIO	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Density(cells/cm^2)	1,900	133,800	168,500	57,800	153,600	142,300	70,200	7,804,700	7,910,400	7,500	200,500	166,700	422,800
Number of Taxa	10	14	8	3	3	13	11	19	30	12	21	11	12

Table E-7: Periphyton population metrics for from Site AC-2-BIO, South Dakota, 2006 - 2020.

Site AC-2-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Density (cells/cm^2)	325,533	837,091	17,061	69,203	150,849	16,947	112,637	914,563	874,668	23,229	187,319	215,024	89,724	95,896	22,535
Relative Density (%)	100.0	100.0	98.8	90.5	95.0	92.4	93.7	100.0	100.0	96.3	100.0	98.4	100.0	100.0	100.0
Number of Taxa (species)	16	19	20	15	15	12	18	16	18	19	14	17	16	18	16
Number of Diatom Taxa	16	19	19	14	14	11	16	16	18	18	14	16	16	18	16
Number of Periphyton Divisions	1	1	3	3	3	3	4	1	1	2	1	3	1	1	1
Number of Periphyton Genera	13	16	20	14	12	10	17	13	16	14	12	15	13	17	8
COMPOSITION METRICS															
Shannon-Weaver Diversity Index for Diatoms (H')	2.70	3.47	3.34	2.65	2.95	2.23	2.86	3.12	3.66	3.59	2.40	2.98	3.67	3.77	2.82
Bahls Similarity Index (%)	46.0	31.2	25.2	39.7	32.5	35.4	27.6	74.5	44.7	36.0	40.6	39.2	47.4	50.7	53.3
Autotrophic Index	770	2,288	1,153	430	827	209	253	619	219	551	330	4,329	176	1,933	301
TOLERANCE METRICS															
Percent Tolerant Diatoms	0.8	28.9	25.0	1.1	5.3	1.0	3.3	12.3	10.9	3.8	1.1	2.5	22.2	8.7	7.7
Lange-Bertalot Pollution Index	2.84	2.20	2.10	2.76	2.74	2.93	2.72	2.57	2.39	2.58	2.89	2.79	2.26	2.43	2.68
TROPHIC HABIT METRICS															
Percent Eutrophic Diatoms	50.0	47.4	47.4	64.3	50.0	54.5	56.3	43.8	55.6	50.0	42.9	56.3	56.3	50.0	50.0
Percent Acidiphilic Diatoms	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.0
Percent Alkaliphilic Diatoms	62.5	57.9	52.6	50.0	57.1	45.5	50.0	50.0	55.6	50.0	50.0	50.0	56.3	50.0	43.8
Percent Nitrogen Heterotrophs	6.3	15.8	15.8	7.1	7.1	9.1	25.0	18.8	22.2	11.1	0.0	18.8	18.8	16.7	18.8
Percent High Oxygen Diatoms	31.3	31.6	26.3	42.9	35.7	54.5	18.8	18.8	38.9	38.9	35.7	31.3	31.3	33.3	25.0
Percent Motile Diatoms	50.0	47.4	52.6	57.1	50.0	54.5	31.3	50.0	50.0	38.9	35.7	50.0	62.5	55.6	56.3
Percent Saprobic Diatoms	6.3	10.5	15.8	7.1	14.3	18.2	6.3	18.8	22.2	5.6	7.1	18.8	18.8	11.1	18.8

Table E-8: Periphyton population metrics for Site AC-3-BIO, South Dakota, 2000 - 2005. Data is shown for only years in which the site was sampled.

Site AC-3-BIO	2000	2001	2002	2003	2004	2005
Density (cells/cm^2)	5,411,300	1,524,700	165,200	15,400	311,800	8,300
Number of Taxa	17	33	24	11	19	15

Table E-9: Periphyton population metrics for Site AC-3-BIO, South Dakota, 2006 - 2019. Data is shown for only years in which the site was sampled.

Site AC-3-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
RICHNESS METRICS														
Density (cells/cm^2)	173,810	1,276,416	1,183,845	517,242	217,265	57,222	2,624,784	95,914	3,025,171	81,904	680,902	343,931	393,760	138,661
Relative Density (%)	99.1	100.0	100.0	100.0	96.2	95.1	100.0	100.0	100.0	97.0	100.0	100.0	99.1	99.1
Number of Taxa (species)	11	15	21	18	19	20	14	18	18	23	17	14	17	26
Number of Diatom Taxa	10	15	21	18	18	19	14	18	18	22	17	14	16	25
Number of Periphyton Divisions	3	1	1	1	3	3	1	1	1	2	1	1	3	3
Number of Periphyton Genera	11	13	19	15	16	17	12	16	16	11	13	10	16	19
COMPOSITION METRICS														
Shannon-Weaver Diversity Index for Diatoms (H’)	1.81	3.28	3.83	3.39	3.40	3.16	2.57	2.43	2.77	3.91	2.64	3.05	3.68	3.56
Bahls Similarity Index (%)	26.2	29.2	47.9	45.3	43.9	40.4	36.7	55.5	29.9	54.7	40.7	46.9	46.1	50.1
Autotrophic Index	419	532	181	376	276	210	146	168	212	397	242	3,501	257	300
TOLERANCE METRICS														
Percent Tolerant Diatoms	0.0	14.3	27.8	1.8	5.0	0.9	3.4	2.4	0.0	16.3	2.1	8.7	31.8	7.6
Lange-Bertalot Pollution Index	2.91	2.41	2.04	2.44	2.57	2.75	2.75	2.81	2.39	2.28	2.83	2.66	2.13	2.54
TROPHIC HABIT METRICS														
Percent Eutrophic Diatoms	40.0	60.0	61.9	61.1	50.0	57.9	64.3	38.9	72.2	50.0	47.1	64.3	50.0	52.0
Percent Acidiphilic Diatoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	40.0	66.7	61.9	61.1	55.6	57.9	57.1	44.4	66.7	54.5	58.8	57.1	50.0	48.0
Percent Nitrogen Heterotrophs	0.0	20.0	19.0	11.1	16.7	10.5	21.4	16.7	5.6	13.6	17.6	21.4	18.8	16.0
Percent High Oxygen Diatoms	10.0	26.7	33.3	38.9	38.9	47.4	28.6	27.8	61.1	36.4	29.4	28.6	18.8	28.0
Percent Motile Diatoms	60.0	66.7	52.4	66.7	61.1	57.9	42.9	38.9	44.4	59.1	64.7	57.1	68.8	60.0
Percent Saprobic Diatoms	10.0	20.0	14.3	5.6	16.7	5.3	21.4	11.1	5.6	13.6	11.8	21.4	18.8	16.0

Table E-10: Periphyton population metrics for Site RV-2-BIO, South Dakota, 2006 – 2020. N/A = no reference site established.

Site RV-2-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Density (cells/cm^2)	161,738	21,860	129,924	162,131	577,133	64,890	409,829	86,781	2,557,674	340,575	579,489	509,783	971,987	491,793	52,101
Relative Density (%)	98.7	91.2	91.1	69.1	56.7	62.4	100.0	97.8	100.0	98.8	95.0	98.0	100.0	97.4	95.0
Number of Taxa (species)	19	14	18	18	24	22	14	21	19	21	15	17	15	18	19
Number of Diatom Taxa	18	13	17	17	21	20	14	20	19	20	14	15	15	17	17
Number of Periphyton Divisions	3	3	3	2	5	4	1	3	1	2	3	4	1	3	3
Number of Periphyton Genera	15	12	12	14	19	19	10	15	12	9	14	14	11	15	12
COMPOSITION METRICS															
Shannon-Weaver Diversity Index for Diatoms (H')	3.71	3.23	3.24	3.29	3.73	3.39	2.33	3.75	3.33	3.84	3.37	2.62	2.19	3.20	3.58
Bahls Similarity Index (%)	33.9	26.5	40.6	51.3	26.0	22.4	36.2	48.0	18.7	N/A	N/A	32.3	21.8	37.5	40.2
Autotrophic Index	658	3,602	964	657	942	890	787	518	374	6,428	824	680	268	329	1,284
TOLERANCE METRICS															
Percent Tolerant Diatoms	1.3	3.2	8.7	1.2	1.5	1.0	3.5	6.7	7.5	5.1	0.0	0.7	6.8	10.8	1.4
Lange-Bertalot Pollution Index	2.40	2.45	2.57	2.59	2.63	2.66	2.82	2.54	2.65	2.43	2.72	2.87	2.78	2.56	2.68
TROPHIC HABIT METRICS															
Percent Eutrophic Diatoms	61.1	38.5	52.9	64.7	47.6	60.0	50.0	50.0	42.1	55.0	50.0	66.7	53.3	47.1	35.3
Percent Acidiphilic Diatoms	0.0	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	61.1	30.8	52.9	58.8	52.4	55.0	57.1	55.0	42.1	45.0	42.9	60.0	53.3	47.1	35.3
Percent Nitrogen Heterotrophs	11.1	7.7	23.5	11.8	9.5	10.0	14.3	15.0	15.8	15.0	7.1	6.7	20.0	17.6	0.0
Percent High Oxygen Diatoms	27.8	38.5	23.5	35.3	33.3	25.0	21.4	30.0	31.6	40.0	28.6	53.3	26.7	23.5	29.4
Percent Motile Diatoms	61.1	38.5	58.8	52.9	57.1	70.0	64.3	65.0	57.9	65.0	64.3	60.0	66.7	58.8	64.7
Percent Saprobic Diatoms	11.1	7.7	23.5	11.8	9.5	10.0	14.3	15.0	21.1	15.0	7.1	13.3	13.3	11.8	5.9

Table E-11: Periphyton population metrics for Site LC-1-BIO, South Dakota, 2010 - 2020. Data is shown for only years in which the site was sampled. N/A = no reference site established.

Site LC-1-BIO	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS											
Density (cells/cm^2)	77,822	19,460	151,202	576,992	13,158,786	41,065	284,581	92,030	172,369	67,790	36,665
Relative Density (%)	97.6	100.0	100.0	100.0	100.0	98.5	100.0	99.2	100.0	98.9	100.0
Number of Taxa (species)	18	10	17	18	22	16	18	18	15	18	16
Number of Diatom Taxa	17	10	17	18	22	15	18	17	15	17	16
Number of Periphyton Divisions	3	1	1	1	1	2	1	3	1	3	1
Number of Periphyton Genera	17	9	15	16	19	12	16	16	14	15	8
COMPOSITION METRICS											
Shannon-Weaver Diversity Index for Diatoms (H')	2.99	1.84	2.74	3.62	3.91	3.28	2.45	2.41	3.62	3.14	3.34
Bahls Similarity Index (%)	26.1	18.1	36.5	43.4	32.0	N/A	N/A	23.3	33.7	33.9	40.4
Autotrophic Index	228	406	660	579	144	-9,640	367	5,050	247	488	418
TOLERANCE METRICS											
Percent Tolerant Diatoms	1.2	0.9	0.9	4.7	12.3	13.8	5.1	8.3	26.7	10.3	25.5
Lange-Bertalot Pollution Index	2.81	2.95	2.88	2.41	2.19	2.46	2.78	2.75	2.18	2.62	2.28
TROPHIC HABIT METRICS											
Percent Eutrophic Diatoms	35.3	60.0	52.9	55.6	45.5	60.0	50.0	41.2	46.7	47.1	31.3
Percent Acidiphilic Diatoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	47.1	60.0	58.8	55.6	40.9	66.7	61.1	41.2	53.3	47.1	43.8
Percent Nitrogen Heterotrophs	11.8	10.0	11.8	16.7	13.6	20.0	16.7	17.6	20.0	11.8	12.5
Percent High Oxygen Diatoms	29.4	50.0	52.9	38.9	31.8	46.7	33.3	29.4	26.7	29.4	18.8
Percent Motile Diatoms	47.1	40.0	47.1	50.0	50.0	46.7	44.4	47.1	53.3	52.9	50.0
Percent Saprobic Diatoms	5.9	10.0	5.9	16.7	18.2	20.0	11.1	11.8	13.3	11.8	18.8

Table E-12: Periphyton population metrics for Site DC-2-BIO, South Dakota, 2000 - 2005. Data is shown for only years in which the site was sampled.

Site DC-2-BIO	2000	2001	2002	2003	2004	2005
Density (cells/cm^2)	24,300,000	3,138,300	836,700	159,100	255,500	143,500
Number of Taxa	22	23	14	20	24	15

Table E-13: Periphyton population metrics for Site DC-2-BIO, South Dakota, 2011 - 2020. Data is shown for only years in which the site was sampled.

Site DC-2-BIO	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS										
Density (cells/cm^2)	161,425	1,825,935	954,051	8,851,146	1,014,763	1,469,829	3,523,436	350,055	115,714	589,501
Relative Density (%)	85.0	100.0	100.0	97.2	96.5	96.2	100.0	100.0	96.7	99.0
Number of Taxa (species)	19	17	17	16	18	18	12	20	25	21
Number of Diatom Taxa	17	17	17	15	17	17	12	20	24	20
Number of Periphyton Divisions	5	1	1	3	2	3	1	1	3	3
Number of Periphyton Genera	17	16	12	14	13	14	10	18	21	12
COMPOSITION METRICS										
Shannon-Weaver Diversity Index for Diatoms (H')	3.04	2.60	2.93	2.63	2.49	2.78	1.91	2.81	3.52	3.37
Bahls Similarity Index (%)	21.9	13.9	40.5	30.4	19.0	28.5	12.8	51.7	37.5	38.4
Autotrophic Index	549	278	802	350	1,285	1,347	16,357	1,535	1,788	411
TOLERANCE METRICS										
Percent Tolerant Diatoms	10.2	2.5	4.3	2.2	5.4	2.0	0.9	0.0	1.4	2.6
Lange-Bertalot Pollution Index	2.26	2.26	2.53	2.60	2.59	2.35	2.68	2.65	2.46	2.51
TROPHIC HABIT METRICS										
Percent Eutrophic Diatoms	47.1	23.5	52.9	46.7	47.1	47.1	41.7	30.0	25.0	35.0
Percent Acidiphilic Diatoms	5.9	11.8	0.0	0.0	5.9	5.9	8.3	5.0	12.5	0.0
Percent Alkaliphilic Diatoms	47.1	23.5	64.7	53.3	47.1	47.1	41.7	35.0	37.5	40.0
Percent Nitrogen Heterotrophs	17.6	11.8	11.8	6.7	11.8	17.6	16.7	5.0	4.2	10.0
Percent High Oxygen Diatoms	35.3	29.4	52.9	60.0	35.3	47.1	16.7	50.0	54.2	40.0
Percent Motile Diatoms	41.2	47.1	35.3	33.3	41.2	41.2	33.3	35.0	50.0	30.0
Percent Saprobic Diatoms	5.9	5.9	11.8	6.7	5.9	17.6	16.7	5.0	4.2	5.0

Table E-14 : Periphyton population metrics for Site EFB-1-BIO, South Dakota, 1995 - 2005.

Site EFB-1-BIO	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Density (cells/cm^2)	87,600	49,400	56,000	70,400	66,700	8,786,200	2,088,600	56,100	8,600	435,500	186,500
Number of Taxa	8	2	2	5	13	18	32	20	11	20	5

Table E-15: Periphyton population metrics for Site EFB-1-BIO, South Dakota, 2006 - 2020. Data is shown for only years in which the site was sampled.

Site EFB-1-BIO	2006	2009	2010	2018	2019	2020
RICHNESS METRICS						
Density (cells/cm^2)	501,365	15,135	118,510	47,427	47,387	145,259
Relative Density (%)	99.1	100.0	92.6	94.8	89.5	99.0
Number of Taxa (species)	15	18	19	17	13	20
Number of Diatom Taxa	14	18	18	16	11	19
Number of Periphyton Divisions	3	1	3	3	4	2
Number of Periphyton Genera	15	17	18	15	13	11
COMPOSITION METRICS						
Shannon-Weaver Diversity Index for Diatoms (H')	2.37	3.19	3.29	2.77	2.06	3.56
Bahls Similarity Index (%)	27.2	43.4	32.5	51.7	29.1	43.3
Autotrophic Index	6,225	1,764	656	918	2,120	1,039
TOLERANCE METRICS						
Percent Tolerant Diatoms	1.8	1.2	0.0	1.1	0.0	7.5
Lange-Bertalot Pollution Index	2.78	2.56	2.67	2.53	2.47	2.39
TROPHIC HABIT METRICS						
Percent Eutrophic Diatoms	42.9	44.4	44.4	43.8	18.2	47.4
Percent Acidiphilic Diatoms	0.0	0.0	5.6	6.3	18.2	0.0
Percent Alkaliphilic Diatoms	50.0	50.0	55.6	50.0	9.1	47.4
Percent Nitrogen Heterotrophs	7.1	11.1	0.0	6.3	0.0	15.8
Percent High Oxygen Diatoms	50.0	50.0	61.1	43.8	45.5	47.4
Percent Motile Diatoms	28.6	38.9	38.9	25.0	36.4	47.4
Percent Saprobic Diatoms	7.1	16.7	5.6	12.5	0.0	21.1

Table E-16: Periphyton population metrics for Site WFB-1-BIO, South Dakota, 2007 - 2020. Data is shown for only years in which the site was sampled.

Site WFB-1-BIO	2007	2008	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS												
Density (cells/cm^2)	360,080	44,542	36,272	98,482	113,584	1,486,017	130,377	309,968	120,204	231,781	102,572	38,391
Relative Density (%)	98.2	85.3	100.0	96.0	96.0	99.2	100.0	90.7	60.9	48.4	100.0	100.0
Number of Taxa (species)	25	16	12	8	11	7	8	14	11	11	13	11
Number of Diatom Taxa	23	15	12	7	9	6	8	13	9	10	13	11
Number of Periphyton Divisions	4	3	1	3	5	3	1	3	5	2	1	1
Number of Periphyton Genera	20	16	12	7	11	7	7	13	10	10	12	8
COMPOSITION METRICS												
Shannon-Weaver Diversity Index for Diatoms (H')	3.70	3.04	2.62	1.14	1.76	1.05	2.55	2.26	1.86	2.50	2.60	1.41
Bahls Similarity Index (%)	25.1	8.5	15.2	3.5	3.8	6.3	11.2	12.4	1.6	2.7	6.5	2.2
Autotrophic Index	2,180	2,442	1,477	455	974	507	942	1,039	18,940	451	2,176	826
TOLERANCE METRICS												
Percent Tolerant Diatoms	7.3	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
Lange-Bertalot Pollution Index	2.35	2.37	2.29	2.90	2.56	2.12	2.22	2.68	2.77	2.53	2.27	2.84
TROPHIC HABIT METRICS												
Percent Eutrophic Diatoms	65.2	33.3	41.7	14.3	22.2	16.7	25.0	30.8	22.2	10.0	30.8	18.2
Percent Acidiphilic Diatoms	0.0	20.0	16.7	28.6	33.3	16.7	12.5	23.1	22.2	20.0	23.1	27.3
Percent Alkaliphilic Diatoms	56.5	46.7	50.0	28.6	11.1	16.7	25.0	23.1	22.2	20.0	38.5	27.3
Percent Nitrogen Heterotrophs	17.4	20.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent High Oxygen Diatoms	39.1	40.0	33.3	57.1	55.6	50.0	62.5	53.8	44.4	50.0	53.8	63.6
Percent Motile Diatoms	65.2	40.0	16.7	14.3	22.2	16.7	12.5	30.8	22.2	10.0	15.4	18.2
Percent Saprobic Diatoms	17.4	13.3	0.0	0.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table E-17: Periphyton population metrics for Site CC-1A-BIO, South Dakota, 2006 - 2020. Data is shown for only years in which the site was sampled.

Site CC-1A-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2018
RICHNESS METRICS											
Density (cells/cm^2)	5,663,748	3,001,940	1,539,484	83,866	231,339	72,316	355,256	1,561,471	3,851,376	91,714	1,384,744
Relative Density (%)	100.0	100.0	100.0	100.0	83.1	100.0	100.0	100.0	100.0	89.6	99.2
Number of Taxa (species)	10	11	17	13	15	18	15	14	13	19	13
Number of Diatom Taxa	10	11	17	13	14	18	15	14	13	18	12
Number of Periphyton Divisions	1	1	1	1	3	1	1	1	1	2	2
Number of Periphyton Genera	10	10	13	13	15	14	12	12	13	10	12
COMPOSITION METRICS											
Shannon-Weaver Diversity Index for Diatoms (H')	2.03	2.90	2.78	3.22	2.82	3.04	2.28	3.10	2.32	3.58	2.99
Bahls Similarity Index (%)	41.5	42.5	24.8	27.3	32.3	46.8	33.6	25.6	8.2	N/A	28.4
Autotrophic Index	2,350	223	714	434	758	909	440	352	608	N/A	240
TOLERANCE METRICS											
Percent Tolerant Diatoms	29.3	39.4	39.4	15.1	19.4	23.6	4.9	45.9	24.3	22.1	19.4
Lange-Bertalot Pollution Index	1.89	1.87	1.83	2.13	2.05	2.10	2.54	1.70	1.91	2.10	2.19
TROPHIC HABIT METRICS											
Percent Eutrophic Diatoms	30.0	27.3	41.2	30.8	35.7	33.3	33.3	50.0	30.8	33.3	41.7
Percent Acidiphilic Diatoms	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	40.0	45.5	47.1	38.5	57.1	44.4	40.0	57.1	38.5	44.4	50.0
Percent Nitrogen Heterotrophs	10.0	18.2	11.8	23.1	21.4	16.7	20.0	35.7	23.1	16.7	33.3
Percent High Oxygen Diatoms	40.0	36.4	35.3	30.8	42.9	33.3	40.0	35.7	38.5	38.9	16.7
Percent Motile Diatoms	30.0	36.4	64.7	46.2	42.9	44.4	53.3	42.9	38.5	50.0	58.3
Percent Saprobic Diatoms	20.0	18.2	17.6	15.4	21.4	11.1	20.0	21.4	15.4	16.7	16.7

Table E-18: Periphyton population metrics for Site FC-1-BIO, South Dakota, 1993 - 2005. * = cells/sample.

Site FC-1-BIO	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Density (cells/cm^2)	194,100*	616,000	102,300	64,300	106,500	95,800	67,500	4,755,200	17,113,700	74,700	142,600	600,400	118,900
Number of Taxa	10	7	4	2	8	10	11	20	20	18	15	17	7

Table E-19: Periphyton population metrics for Site FC-1-BIO, South Dakota, 2006 - 2020. Data is shown for only years in which the site was sampled. N/A = no reference site established.

Site FC-1-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Density (cells/cm^2)	21,480	45,744	63,819	11,317	22,039	1,425	41,443	188,546	19,736	17,642	217,582	209,787	24,302	33,872	33,939
Relative Density (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.0	92.9	100.0	99.0
Number of Taxa (species)	10	14	15	15	17	3	13	20	9	12	12	22	16	20	23
Number of Diatom Taxa	10	14	15	15	17	3	13	20	9	12	12	21	15	20	22
Number of Periphyton Divisions	1	1	1	1	1	1	1	1	1	1	1	3	3	1	2
Number of Periphyton Genera	9	8	11	13	12	3	12	15	7	5	11	18	14	12	12
COMPOSITION METRICS															
Shannon-Weaver Diversity Index for Diatoms (H')	2.99	1.99	2.40	2.88	3.30	1.58	3.57	2.35	3.10	2.24	1.66	2.68	2.93	3.43	3.46
Bahls Similarity Index (%)	38.0	48.9	65.4	43.5	53.9	52.6	36.6	43.3	27.6	N/A	N/A	21.2	24.1	38.1	33.1
Autotrophic Index	802	2,035	8,817	522	1,159	3,409	2,940	529	1,102	432	909	4,018	607	1,266	446
TOLERANCE METRICS															
Percent Tolerant Diatoms	0.0	1.8	1.9	0.0	2.1	0.0	0.0	0.7	0.0	10.0	0.6	2.7	1.9	13.2	9.8
Lange-Bertalot Pollution Index	2.63	2.40	2.42	2.35	2.19	2.33	2.59	2.72	2.18	2.54	2.93	2.79	2.69	2.26	2.49
TROPHIC HABIT METRICS															
Percent Eutrophic Diatoms	70.0	50.0	53.3	40.0	58.8	66.7	38.5	40.0	55.6	50.0	58.3	57.1	46.7	50.0	59.1
Percent Acidiphilic Diatoms	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	60.0	50.0	60.0	33.3	47.1	66.7	46.2	45.0	55.6	33.3	50.0	42.9	46.7	35.0	45.5
Percent Nitrogen Heterotrophs	0.0	21.4	13.3	6.7	11.8	0.0	0.0	10.0	22.2	25.0	8.3	9.5	13.3	15.0	18.2
Percent High Oxygen Diatoms	50.0	21.4	40.0	26.7	58.8	33.3	38.5	30.0	55.6	25.0	41.7	42.9	46.7	25.0	27.3
Percent Motile Diatoms	20.0	57.1	53.3	53.3	52.9	66.7	38.5	45.0	66.7	75.0	66.7	57.1	33.3	60.0	72.7
Percent Saprobic Diatoms	0.0	14.3	6.7	6.7	5.9	0.0	0.0	10.0	11.1	16.7	16.7	14.3	6.7	20.0	9.1

Table E-20: Periphyton population metrics for Site NG-2-BIO, South Dakota, 1993 - 2005. * = cells/sample.

Site NG-2-BIO	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Density(cells/cm^2)	1,336,800*	460,900	130,800	341,000	235,600	56,500	52,500	6,206,200	6,204,700	1,062,900	255,200	1,515,100	955,600
Number of Taxa	6	11	7	3	9	2	6	29	11	11	28	11	13

Table E-21: Periphyton population metrics for Site NG-2-BIO, 2006 - 2020. Data is shown for only years in which the site was sampled. N/A = Not applicable as this was a background control site.

Site NG-2-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Density (cells/cm^2)	880,052	1,209,235	1,686,978	267,725	244,357	220,060	583,332	2,107,682	391,223	670,054	2,779,570	2,002,287	169,710	298,884	563,447
Relative Density (%)	100.0	100.0	100.0	84.1	100.0	100.0	99.1	100.0	100.0	100.0	99.2	100.0	100.0	100.0	99.0
Number of Taxa (species)	17	20	21	21	25	18	21	22	12	20	21	23	15	17	21
Number of Diatom Taxa	17	20	21	20	25	18	20	22	12	20	20	23	15	17	20
Number of Periphyton Divisions	1	1	1	3	1	1	2	1	1	1	2	1	1	1	2
Number of Periphyton Genera	15	18	16	15	20	15	18	17	9	10	16	17	11	11	9
COMPOSITION METRICS															
Shannon-Weaver Diversity Index for Diatoms (H')	3.08	3.54	3.01	3.73	4.21	3.34	3.62	3.88	2.75	3.20	3.44	3.97	2.51	3.13	3.53
Bahls Similarity Index (%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	17.3	19.2	41.2	34.7
Autotrophic Index	538	541	455	445	496	513	213	206	204	95	204	1,806	435	505	142
TOLERANCE METRICS															
Percent Tolerant Diatoms	2.9	3.7	1.9	4.7	11.7	0.7	8.1	9.6	0.0	7.5	6.4	5.8	3.9	7.8	5.9
Lange-Bertalot Pollution Index	2.48	2.43	2.59	2.42	2.23	2.30	2.45	2.25	2.24	2.01	2.34	2.40	2.75	2.52	2.61
TROPHIC HABIT METRICS															
Percent Eutrophic Diatoms	41.2	45.0	61.9	65.0	56.0	55.6	65.0	54.5	66.7	50.0	60.0	60.9	53.3	41.2	45.0
Percent Acidiphilic Diatoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	47.1	40.0	52.4	55.0	48.0	55.6	65.0	50.0	58.3	45.0	50.0	47.8	53.3	41.2	35.0
Percent Nitrogen Heterotrophs	11.8	15.0	23.8	15.0	16.0	16.7	30.0	22.7	8.3	20.0	20.0	17.4	20.0	17.6	20.0
Percent High Oxygen Diatoms	35.3	30.0	42.9	40.0	44.0	44.4	30.0	36.4	66.7	25.0	40.0	39.1	40.0	35.3	30.0
Percent Motile Diatoms	35.3	35.0	57.1	65.0	56.0	61.1	55.0	59.1	50.0	55.0	65.0	56.5	53.3	58.8	60.0
Percent Saprobic Diatoms	5.9	20.0	14.3	10.0	12.0	0.0	15.0	22.7	0.0	10.0	10.0	8.7	13.3	11.8	15.0

Table E-22 Periphyton population metrics for Site SG-1-BIO, South Dakota, 1993 - 2005. * = cells/sample.

Site SG-1-BIO	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Density(cells/cm^2)	2,939,500*	247,700	207,100	77,500	214,100	56,600	100,800	5,806,500	1,646,600	445,700	274,900	242,900	1,354,400
Number of Taxa	13	7	6	4	11	2	9	26	19	10	10	7	11

Table E-23: Periphyton population metrics for Site SG-1-BIO, South Dakota, 2006 - 2020. Data is shown for only years in which the site was sampled.

Site SG-1-BIO	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RICHNESS METRICS															
Density (cells/cm^2)	1,794,085	191,330	138,576	597,915	1,679,861	71,932	470,367	1,754,926	3,473,607	188,461	554,651	280,592	847,012	83,582	192,701
Relative Density (%)	100.0	100.0	100.0	95.2	100.0	93.7	100.0	100.0	98.9	100.0	100.0	99.3	98.8	100.0	100.0
Number of Taxa (species)	11	16	12	14	17	31	14	18	15	18	15	10	18	14	10
Number of Diatom Taxa	11	16	12	13	17	30	14	18	14	18	15	9	17	14	10
Number of Periphyton Divisions	1	1	1	3	1	3	1	1	3	1	1	3	3	1	1
Number of Periphyton Genera	10	13	11	10	13	20	13	15	10	10	10	7	14	13	7
COMPOSITION METRICS															
Shannon-Weaver Diversity Index for Diatoms (H')	2.32	2.45	2.03	2.26	3.02	3.98	2.37	2.86	1.61	2.96	2.69	1.90	2.19	2.13	2.03
Bahls Similarity Index (%)	28.2	21.5	23.8	32.8	31.9	53.9	19.1	51.5	12.1	30.2	27.5	12.6	53.3	42.1	47.4
Autotrophic Index	854	613	1,221	159	182	340	150	359	186	1,377	467	10,102	224	436	385
TOLERANCE METRICS															
Percent Tolerant Diatoms	6.8	5.4	14.8	3.3	4.2	5.0	3.1	4.4	0.6	4.5	10.8	0.7	6.6	3.2	7.4
Lange-Bertalot Pollution Index	2.56	2.31	2.56	2.44	2.52	2.47	2.66	2.55	2.76	2.50	2.48	2.84	2.59	2.52	2.58
TROPHIC HABIT METRICS															
Percent Eutrophic Diatoms	27.3	43.8	41.7	46.2	41.2	46.7	42.9	27.8	50.0	44.4	53.3	33.3	41.2	35.7	20.0
Percent Acidiphilic Diatoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.0	0.0	0.0	11.1	0.0	0.0	0.0
Percent Alkaliphilic Diatoms	45.5	50.0	41.7	46.2	41.2	50.0	50.0	38.9	42.9	38.9	46.7	33.3	47.1	42.9	40.0
Percent Nitrogen Heterotrophs	9.1	12.5	16.7	15.4	11.8	16.7	14.3	11.1	7.1	16.7	26.7	11.1	11.8	21.4	10.0
Percent High Oxygen Diatoms	54.5	43.8	33.3	46.2	52.9	40.0	42.9	38.9	35.7	33.3	33.3	55.6	29.4	42.9	40.0
Percent Motile Diatoms	36.4	43.8	58.3	61.5	47.1	56.7	50.0	50.0	42.9	55.6	66.7	11.1	41.2	50.0	40.0
Percent Saprobic Diatoms	9.1	12.5	8.3	15.4	11.8	10.0	14.3	11.1	14.3	16.7	13.3	11.1	11.8	14.3	10.0

Appendix F 2020 Water Quality Data

MIDCONTINENT
TESTING LABORATORIES, INC.

Page 1 of 2

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: NPDES005 - BIO
Sampled: 08/26/20 at 08:25 AM
by Steve Podall, Justin Thorp
Sample Matrix: Water

Lab ID#: 20200828106
Received: 08/27/20 at 01:15 PM
by Dean Aurand
Account: W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	219	mg/L	1			SM 2340 B	GAM	09/02/20
Total Dissolved Solids	220	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	08/28/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	08/28/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	08/28/20
Nitrogen, Nitrate (NO3)	1.96	mg/L	2	0.018	0.100	SM 4500-NO3 F	BLL	08/28/20
Phosphorus (P) Dissolved	0.013	mg/L	1	0.003	0.010	SM 4500-P E	SAA	08/31/20
Metals - Dissolved								
Calcium (Ca)	50.3	mg/L	2	0.197	2.00	SM 3111 B	TMS	08/28/20
Magnesium (Mg)	22.7	mg/L	1	0.099	0.500	SM 3111 B	TMS	08/28/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	08/31/20
Metals - Total Recoverable								
Arsenic (As)	0.012	mg/L	10	0.00073	0.005	EPA 200.8	TNA	08/31/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	08/31/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	08/31/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	08/31/20
Iron (Fe)	0.128	mg/L	10	0.001	0.050	EPA 200.8	TNA	08/31/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	08/31/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	08/31/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	08/31/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	08/31/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	08/31/20
Field Test								
Field Flow Rate	150	gal/min	1			Field Flow	BLL	08/27/20

Report of Analysis for: **WHARF RESOURCES(USA),INC** Sample Site: **NPDES005 - BIO**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field pH	8.35	S.U.	1			Field pH	BLL	08/27/20
Field Temperature	12.7	°C	1			Field Temp.	BLL	08/27/20

Report Approved By:

Report Approved On: 9/2/2020 1:22:14 PM

MIDCONTINENT
TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: Reno
Sampled: 09/15/20 at 01:15 PM
by Justin Thorp
Sample Matrix: Water

Lab ID#: 20200917103
Received: 09/16/20 at 12:25 PM
by Dean Aurand
Account: W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	102	mg/L	1			SM 2340 B	GAM	09/21/20
pH	7.93	S.U.	1			SM 4500-H+ B	JAM	09/17/20
Total Dissolved Solids	105	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/17/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/17/20
Nitrogen, Nitrate (NO3)	3.47	mg/L	5	0.045	0.250	SM 4500-NO3 F	BLL	09/17/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	27.2	mg/L	1	0.099	1.00	SM 3111 B	TMS	09/17/20
Magnesium (Mg)	8.23	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/17/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/17/20
Metals - Total Recoverable								
Arsenic (As)	< 0.005	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/17/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/17/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/17/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/17/20
Iron (Fe)	0.206	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/17/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/17/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/17/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/17/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/17/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/17/20

Report of Analysis for: **WHARF RESOURCES(USA),INC** Sample Site: **Reno**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field Flow Rate	75.0	gal/min	1			Field Flow	BLL	09/17/20
Field pH	8.10	S.U.	1			Field pH	BLL	09/17/20
Field Temperature	11.0	° C	1			Field Temp.	BLL	09/17/20

Report Approved By:

Report Approved On: 9/21/2020 12:57:29 PM

MIDCONTINENT TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: SG-Bio
Sampled: 09/15/20 at 01:45 PM by Justin Thorp
Sample Matrix: Water

Lab ID#: 20200917104
Received: 09/16/20 at 12:25 PM by Dean Aurand
Account: W1007 - GOLDEN REWARD MINING CO.

MATT ZIETLOW
GOLDEN REWARD MINING CO.
10928 WHARF ROAD
LEAD, SD 57754

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	313	mg/L	1			SM 2340 B	GAM	09/21/20
pH	7.85	S.U.	1			SM 4500-H+ B	JAM	09/17/20
Total Dissolved Solids	401	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/17/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/17/20
Nitrogen, Nitrate (NO3)	7.46	mg/L	10	0.090	0.500	SM 4500-NO3 F	BLL	09/17/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	94.1	mg/L	3	0.296	3.00	SM 3111 B	TMS	09/17/20
Magnesium (Mg)	19.1	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/17/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/17/20
Metals - Total Recoverable								
Arsenic (As)	0.016	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/17/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/17/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/17/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/17/20
Iron (Fe)	0.138	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/17/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/17/20
Nickel (Ni)	0.033	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/17/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/17/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/17/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/17/20

Report of Analysis for: **GOLDEN REWARD MINING CO.** Sample Site: **SG-Bio**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field Flow Rate	625	gal/min	1			Field Flow	BLL	09/17/20
Field pH	7.68	S.U.	1			Field pH	BLL	09/17/20
Field Temperature	10.1	° C	1			Field Temp.	BLL	09/17/20

Report Approved By:

Report Approved On: 9/21/2020 12:57:29 PM

MIDCONTINENT TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: Whitetail Creek Bio
Sampled: 09/15/20 at 02:00 PM by Justin Thorp
Sample Matrix: Water

Lab ID#: 20200917105
Received: 09/16/20 at 12:25 PM by Dean Aurand
Account: W1007 - GOLDEN REWARD MINING CO.

MATT ZIETLOW
GOLDEN REWARD MINING CO.
10928 WHARF ROAD
LEAD, SD 57754

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	265	mg/L	1			SM 2340 B	GAM	09/21/20
pH	7.81	S.U.	1			SM 4500-H+ B	JAM	09/17/20
Total Dissolved Solids	309	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/17/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/17/20
Nitrogen, Nitrate (NO3)	2.51	mg/L	5	0.045	0.250	SM 4500-NO3 F	BLL	09/17/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	78.8	mg/L	3	0.296	3.00	SM 3111 B	TMS	09/17/20
Magnesium (Mg)	16.7	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/17/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/17/20
Metals - Total Recoverable								
Arsenic (As)	0.022	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/17/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/17/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/17/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/17/20
Iron (Fe)	0.076	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/17/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/17/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/17/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/17/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/17/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/17/20

Report of Analysis for: **GOLDEN REWARD MINING CO. Bio** Sample Site: **Whitetail Creek**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field Flow Rate	850	gal/min	1			Field Flow	BLL	09/17/20
Field pH	7.50	S.U.	1			Field pH	BLL	09/17/20
Field Temperature	9.80	° C	1			Field Temp.	BLL	09/17/20

Report Approved By:

Report Approved On: 9/21/2020 12:57:29 PM

MIDCONTINENT TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: AC-3 Biomon
Sampled: 09/15/20 at 12:40 PM
by Justin Thorp
Sample Matrix: Water

Lab ID#: 20200917102
Received: 09/16/20 at 12:25 PM
by Dean Aurand
Account: W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	223	mg/L	1			SM 2340 B	GAM	09/21/20
pH	8.25	S.U.	1			SM 4500-H+ B	JAM	09/17/20
Total Dissolved Solids	217	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/17/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/17/20
Nitrogen, Nitrate (NO3)	8.75	mg/L	10	0.090	0.500	SM 4500-NO3 F	BLL	09/17/20
Phosphorus (P) Dissolved	0.011	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	53.8	mg/L	2	0.197	2.00	SM 3111 B	TMS	09/17/20
Magnesium (Mg)	21.5	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/17/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/17/20
Metals - Total Recoverable								
Arsenic (As)	0.013	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/17/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/17/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/17/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/17/20
Iron (Fe)	0.064	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/17/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/17/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/17/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/17/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/17/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/17/20

Report of Analysis for: **WHARF RESOURCES(USA),INC** Sample Site: **AC-3 Biomon**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field Flow Rate	222	gal/min	1			Field Flow	BLL	09/17/20
Field pH	8.56	S.U.	1			Field pH	BLL	09/17/20
Field Temperature	9.50	° C	1			Field Temp.	BLL	09/17/20

Report Approved By:

Report Approved On: 9/21/2020 12:57:29 PM

MIDCONTINENT
TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: DC-2-Bio
Sampled: 09/16/20 at 11:20 AM by Justin Thorp
Sample Matrix: Water

Lab ID#: 20200918104
Received: 09/17/20 at 10:50 AM by Bobbie Laurenz
Account: W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	114	mg/L	1			SM 2340 B	GAM	09/22/20
pH	7.62	S.U.	1			SM 4500-H+ B	JAM	09/21/20
Total Dissolved Solids	150	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/18/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/18/20
Nitrogen, Nitrate (NO3)	< 0.050	mg/L	1	0.009	0.050	SM 4500-NO3 F	BLL	09/18/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	33.6	mg/L	1	0.099	1.00	SM 3111 B	TMS	09/18/20
Magnesium (Mg)	7.26	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/18/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/18/20
Metals - Total Recoverable								
Arsenic (As)	< 0.005	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/21/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/21/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/21/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/21/20
Iron (Fe)	0.273	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/21/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/21/20
Nickel (Ni)	0.008	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/21/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/21/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/21/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/21/20

Report of Analysis for: **WHARF RESOURCES(USA),INC** Sample Site: **DC-2-Bio**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date
Field Test							
Field Flow Rate	115	gal/min	1			Field Flow	BLL 09/17/20
Field pH	7.53	S.U.	1			Field pH	BLL 09/17/20
Field Temperature	8.10	° C	1			Field Temp.	BLL 09/17/20

Report Approved By:

Report Approved On: 9/22/2020 12:53:12 PM

MIDCONTINENT
TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: EFB - Bio
Sampled: 09/16/20 at 09:40 AM
by Justin Thorp
Sample Matrix: Water

Lab ID#: 20200918103
Received: 09/17/20 at 10:50 AM
by Bobbie Laurenz
Account: W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	264	mg/L	1			SM 2340 B	GAM	09/22/20
pH	7.54	S.U.	1			SM 4500-H+ B	JAM	09/21/20
Total Dissolved Solids	387	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/18/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/18/20
Nitrogen, Nitrate (NO3)	5.82	mg/L	5	0.045	0.250	SM 4500-NO3 F	BLL	09/18/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	84.0	mg/L	3	0.296	3.00	SM 3111 B	TMS	09/18/20
Magnesium (Mg)	13.1	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/18/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/18/20
Metals - Total Recoverable								
Arsenic (As)	< 0.005	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/21/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/21/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/21/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/21/20
Iron (Fe)	0.257	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/21/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/21/20
Nickel (Ni)	0.006	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/21/20
Selenium (Se)	0.011	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/21/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/21/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/21/20

Report of Analysis for: **WHARF RESOURCES(USA),INC** Sample Site: **EFB - Bio**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field Flow Rate	125	gal/min	1			Field Flow	BLL	09/17/20
Field pH	7.57	S.U.	1			Field pH	BLL	09/17/20
Field Temperature	7.50	° C	1			Field Temp.	BLL	09/17/20

Report Approved By:

Report Approved On: 9/22/2020 12:53:12 PM

MIDCONTINENT
TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site:	WFB - Bio
Sampled:	09/16/20 at 09:30 AM by Justin Thorp
Sample Matrix:	Water
Lab ID#:	20200918102
Received:	09/17/20 at 10:50 AM by Bobbie Laurenz
Account:	W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	45.7	mg/L	1			SM 2340 B	GAM	09/22/20
pH	4.52	S.U.	1			SM 4500-H+ B	JAM	09/21/20
Total Dissolved Solids	118	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/18/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/18/20
Nitrogen, Nitrate (NO3)	< 0.050	mg/L	1	0.009	0.050	SM 4500-NO3 F	BLL	09/18/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	10.4	mg/L	1	0.099	1.00	SM 3111 B	TMS	09/18/20
Magnesium (Mg)	4.80	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/18/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/18/20
Metals - Total Recoverable								
Arsenic (As)	< 0.005	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/21/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/21/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/21/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/21/20
Iron (Fe)	0.142	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/21/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/21/20
Nickel (Ni)	0.025	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/21/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/21/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/21/20
Zinc (Zn)	0.053	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/21/20

Report of Analysis for: **WHARF RESOURCES(USA),INC** Sample Site: **WFB - Bio**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field Flow Rate	25.0	gal/min	1			Field Flow	BLL	09/17/20
Field pH	4.39	S.U.	1			Field pH	BLL	09/17/20
Field Temperature	7.80	° C	1			Field Temp.	BLL	09/17/20

Report Approved By:

Report Approved On: 9/22/2020 12:53:12 PM

MIDCONTINENT
TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: Labador Gulch Bio
Sampled: 09/16/20 at 08:35 AM by Justin Thorp
Sample Matrix: Water

Lab ID#: 20200918101
Received: 09/17/20 at 10:50 AM by Bobbie Laurenz
Account: W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Physical Properties								
Hardness	196	mg/L	1			SM 2340 B	GAM	09/22/20
pH	8.22	S.U.	1			SM 4500-H+ B	JAM	09/21/20
Total Dissolved Solids	204	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/18/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/18/20
Nitrogen, Nitrate (NO3)	0.076	mg/L	1	0.009	0.050	SM 4500-NO3 F	BLL	09/18/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	46.1	mg/L	1	0.099	1.00	SM 3111 B	TMS	09/18/20
Magnesium (Mg)	19.7	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/18/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/18/20
Metals - Total Recoverable								
Arsenic (As)	0.007	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/21/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/21/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/21/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/21/20
Iron (Fe)	0.053	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/21/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/21/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/21/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/21/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/21/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/21/20

Report of Analysis for: **WHARF RESOURCES(USA),INC Bio** Sample Site: **Labador Gulch**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date
Field Test							
Field Flow Rate	200	gal/min	1			Field Flow	BLL 09/17/20
Field pH	8.36	S.U.	1			Field pH	BLL 09/17/20
Field Temperature	7.20	° C	1			Field Temp.	BLL 09/17/20

Report Approved By:

Report Approved On: 9/22/2020 12:53:12 PM

MIDCONTINENT
TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: Lost Camp - BIO
Sampled: 08/26/20 at 08:40 AM by Steve Podall, Justin Thorp
Sample Matrix: Water

Lab ID#: 20200828107
Received: 08/27/20 at 01:15 PM by Dean Aurand
Account: W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	136	mg/L	1			SM 2340 B	GAM	09/02/20
Total Dissolved Solids	165	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	08/28/20
Total Suspended Solids	12.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	08/28/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	08/28/20
Nitrogen, Nitrate (NO3)	0.504	mg/L	1	0.009	0.050	SM 4500-NO3 F	BLL	08/28/20
Phosphorus (P) Dissolved	0.036	mg/L	1	0.003	0.010	SM 4500-P E	SAA	08/31/20
Metals - Dissolved								
Calcium (Ca)	38.3	mg/L	1	0.099	1.00	SM 3111 B	TMS	08/28/20
Magnesium (Mg)	9.88	mg/L	1	0.099	0.500	SM 3111 B	TMS	08/28/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	08/31/20
Metals - Total Recoverable								
Arsenic (As)	0.005	mg/L	10	0.00073	0.005	EPA 200.8	TNA	08/31/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	08/31/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	08/31/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	08/31/20
Iron (Fe)	0.127	mg/L	10	0.001	0.050	EPA 200.8	TNA	08/31/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	08/31/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	08/31/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	08/31/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	08/31/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	08/31/20
Field Test								
Field Flow Rate	75.0	gal/min	1			Field Flow	BLL	08/27/20

Report of Analysis for: **WHARF RESOURCES(USA),INC** Sample Site: **Lost Camp - BIO**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field pH	8.01	S.U.	1			Field pH	BLL	08/27/20
Field Temperature	13.0	°C	1			Field Temp.	BLL	08/27/20

Report Approved By:

Report Approved On: 9/2/2020 1:22:14 PM

MIDCONTINENT TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: NPDES001 - BIO
Sampled: 08/26/20 at 08:50 AM
by Steve Podall, Justin Thorp
Sample Matrix: Water

Lab ID#: 20200828108
Received: 08/27/20 at 01:15 PM
by Dean Aurand
Account: W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	243	mg/L	1			SM 2340 B	GAM	09/02/20
Total Dissolved Solids	242	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	08/28/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	08/28/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	08/28/20
Nitrogen, Nitrate (NO3)	3.09	mg/L	5	0.045	0.250	SM 4500-NO3 F	BLL	08/28/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	08/31/20
Metals - Dissolved								
Calcium (Ca)	54.1	mg/L	2	0.197	2.00	SM 3111 B	TMS	08/28/20
Magnesium (Mg)	26.2	mg/L	1	0.099	0.500	SM 3111 B	TMS	08/28/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	08/31/20
Metals - Total Recoverable								
Arsenic (As)	0.012	mg/L	10	0.00073	0.005	EPA 200.8	TNA	08/31/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	08/31/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	08/31/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	08/31/20
Iron (Fe)	< 0.050	mg/L	10	0.001	0.050	EPA 200.8	TNA	08/31/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	08/31/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	08/31/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	08/31/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	08/31/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	08/31/20
Field Test								
Field Flow Rate	0.250	gal/min	1			Field Flow	BLL	08/27/20

Report of Analysis for: **WHARF RESOURCES(USA),INC** Sample Site: **NPDES001 - BIO**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field pH	8.46	S.U.	1			Field pH	BLL	08/27/20
Field Temperature	12.2	° C	1			Field Temp.	BLL	08/27/20

Report Approved By:

Report Approved On: 9/2/2020 1:22:14 PM

MIDCONTINENT
TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: NPDES002 - BIO
Sampled: 08/26/20 at 08:55 AM
by Steve Podall, Justin Thorp
Sample Matrix: Water

Lab ID#: 20200828109
Received: 08/27/20 at 01:15 PM
by Dean Aurand
Account: W1002 - WHARF RESOURCES(USA),INC

MATT ZIETLOW
WHARF RESOURCES(USA),INC.
10928 WHARF ROAD
LEAD, SD 577549710

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	268	mg/L	1			SM 2340 B	GAM	09/02/20
Total Dissolved Solids	310	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	08/28/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	08/28/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	08/28/20
Nitrogen, Nitrate (NO3)	1.28	mg/L	1	0.009	0.050	SM 4500-NO3 F	BLL	08/28/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	08/31/20
Metals - Dissolved								
Calcium (Ca)	54.6	mg/L	2	0.197	2.00	SM 3111 B	TMS	08/28/20
Magnesium (Mg)	32.1	mg/L	1	0.099	0.500	SM 3111 B	TMS	08/28/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	08/31/20
Metals - Total Recoverable								
Arsenic (As)	0.007	mg/L	10	0.00073	0.005	EPA 200.8	TNA	08/31/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	08/31/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	08/31/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	08/31/20
Iron (Fe)	0.052	mg/L	10	0.001	0.050	EPA 200.8	TNA	08/31/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	08/31/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	08/31/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	08/31/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	08/31/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	08/31/20
Field Test								
Field Flow Rate	0.120	gal/min	1			Field Flow	BLL	08/27/20

Report of Analysis for: **WHARF RESOURCES(USA),INC** Sample Site: **NPDES002 - BIO**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field pH	8.47	S.U.	1			Field pH	BLL	08/27/20
Field Temperature	12.5	° C	1			Field Temp.	BLL	08/27/20

Report Approved By:

Report Approved On: 9/2/2020 1:22:14 PM

MIDCONTINENT
TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: NG-2-Bio
Sampled: 09/15/20 at 03:00 PM
by Justin Thorp
Sample Matrix: Water

Lab ID#: 20200917107
Received: 09/16/20 at 12:25 PM
by Dean Aurand
Account: W1007 - GOLDEN REWARD MINING CO.

MATT ZIETLOW
GOLDEN REWARD MINING CO.
10928 WHARF ROAD
LEAD, SD 57754

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst	Date
Physical Properties								
Hardness	321	mg/L	1			SM 2340 B	GAM	09/21/20
pH	8.14	S.U.	1			SM 4500-H+ B	JAM	09/17/20
Total Dissolved Solids	483	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/17/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/17/20
Nitrogen, Nitrate (NO3)	0.106	mg/L	1	0.009	0.050	SM 4500-NO3 F	BLL	09/17/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	90.3	mg/L	3	0.296	3.00	SM 3111 B	TMS	09/17/20
Magnesium (Mg)	23.2	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/17/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/17/20
Metals - Total Recoverable								
Arsenic (As)	0.006	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/17/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/17/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/17/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/17/20
Iron (Fe)	< 0.050	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/17/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/17/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/17/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/17/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/17/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/17/20

Report of Analysis for: **GOLDEN REWARD MINING CO.** Sample Site: **NG-2-Bio**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field Flow Rate	40.0	gal/min	1			Field Flow	BLL	09/17/20
Field pH	8.36	S.U.	1			Field pH	BLL	09/17/20
Field Temperature	14.2	° C	1			Field Temp.	BLL	09/17/20

Report Approved By:

Report Approved On: 9/21/2020 12:57:29 PM

MIDCONTINENT
TESTING LABORATORIES, INC.

2381 South Plaza Drive P.O. Box 3388 Rapid City, SD 57709
(605) 348-0111 -- www.thechemistrylab.com

Sample Site: FC-Bio
Sampled: 09/15/20 at 02:40 PM
by Justin Thorp
Sample Matrix: Water

Lab ID#: 20200917106
Received: 09/16/20 at 12:25 PM
by Dean Aurand
Account: W1007 - GOLDEN REWARD MINING CO.

MATT ZIETLOW
GOLDEN REWARD MINING CO.
10928 WHARF ROAD
LEAD, SD 57754

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Physical Properties								
Hardness	453	mg/L	1			SM 2340 B	GAM	09/21/20
pH	7.68	S.U.	1			SM 4500-H+ B	JAM	09/17/20
Total Dissolved Solids	562	mg/L	100ml	14.7	50.0	SM 2540 C	JNM	09/17/20
Total Suspended Solids	< 10.0	mg/L	100ml	3.49	10.0	SM 2540 D	JNM	09/17/20
Non-Metallics								
Cyanide, WAD	< 0.010	mg/L	1	0.00032	0.010	Kelada 01	TMN	09/17/20
Nitrogen, Nitrate (NO3)	3.38	mg/L	5	0.045	0.250	SM 4500-NO3 F	BLL	09/17/20
Phosphorus (P) Dissolved	< 0.010	mg/L	1	0.003	0.010	SM 4500-P E	SAA	09/21/20
Metals - Dissolved								
Calcium (Ca)	111	mg/L	3	0.296	3.00	SM 3111 B	TMS	09/17/20
Magnesium (Mg)	42.8	mg/L	1	0.099	0.500	SM 3111 B	TMS	09/17/20
Metals - Total								
Mercury (Hg)	< 0.0002	mg/L	1	0.00005	0.0002	EPA 245.1	TMS	09/17/20
Metals - Total Recoverable								
Arsenic (As)	0.010	mg/L	10	0.00073	0.005	EPA 200.8	TNA	09/17/20
Cadmium (Cd)	< 0.001	mg/L	10	0.00019	0.001	EPA 200.8	TNA	09/17/20
Chromium (Cr)	< 0.001	mg/L	10	0.000082	0.001	EPA 200.8 DRC	TNA	09/17/20
Copper (Cu)	< 0.005	mg/L	10	0.00011	0.005	EPA 200.8	TNA	09/17/20
Iron (Fe)	0.327	mg/L	10	0.001	0.050	EPA 200.8	TNA	09/17/20
Lead (Pb)	< 0.001	mg/L	10	0.000159	0.001	EPA 200.8	TNA	09/17/20
Nickel (Ni)	< 0.005	mg/L	10	0.000096	0.005	EPA 200.8	TNA	09/17/20
Selenium (Se)	< 0.005	mg/L	10	0.000845	0.005	EPA 200.8	TNA	09/17/20
Silver (Ag)	< 0.001	mg/L	10	0.000139	0.001	EPA 200.8	TNA	09/17/20
Zinc (Zn)	< 0.050	mg/L	10	0.006	0.050	EPA 200.8	TNA	09/17/20

Report of Analysis for: **GOLDEN REWARD MINING CO.** Sample Site: **FC-Bio**

Parameter	Result	Units	DF	MDL	PQL	Method	Analyst/Date	
Field Test								
Field Flow Rate	25.0	gal/min	1			Field Flow	BLL	09/17/20
Field pH	7.54	S.U.	1			Field pH	BLL	09/17/20
Field Temperature	10.9	° C	1			Field Temp.	BLL	09/17/20

Report Approved By:

Report Approved On: 9/21/2020 12:57:29 PM