Water Quality Characteristics for the Snake River, North Fork of the Snake River, Peru Creek, and Deer Creek in Summit County, Colorado: 2001 to 2002

Andrew S. Todd[1], Diane M. McKnight[1], and Sabre M. Duren[1]

[1]Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309, U.S.A.

Institute of Arctic and Alpine Research

University of Colorado, Boulder, Colorado 80309

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Disclaimer

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the U.S. Environmental Protection Agency or the National Science Foundation. We have taken appropriate measures throughout sample collection, processing, and analysis to ensure quality control over these data. The sampling and analytical error has been determined by duplicate analysis at a number of sites throughout the annual hydrograph. A copy of these data files (including additions or corrections to the data tables after publication of this report) is included as a CD with this report, and will also be made available by an e-mail request to the INSTAAR information center at instaar-info@instaar.colorado.edu.

ABSTRACT

As a result of both historic mining activity and natural biogeochemical processes, a large portion of the Snake River watershed in Summit County, Colorado has water quality that is impaired by acid rock drainage (ARD), resulting in low pH and elevated aqueous concentrations of metals, specifically Al, Cd, Cu, Mn, and Zn. This report presents chemical monitoring data collected during studies conducted from November 2001 through September 2002, a period of time which encompassed the most extreme drought that has been recorded in the region in the past 100 yr. This data set provides a description of several anthropogenic ARD sources. Further, it reveals that at most study sites, aqueous metal concentrations decreased during snowmelt in spring and were greatest in summer during the low stream flows associated with the severe drought conditions. This variability has direct implications for in-stream biota and for the design of future assessments of ecosystem potential.

INTRODUCTION

Acid rock drainage (ARD) is a common feature of watersheds in the Rocky Mountain region of the United States and Canada, and in many other regions of the world. Although natural weathering of pyrite contributes to ARD in some Rocky Mountain watersheds, pyrite weathering associated with past mining activities, called acid mine drainage (AMD), typically has a more significant impact on water quality. During the initial wave of mining and European expansion into the West, miners excavated veins of minerals and exposed sulfidic minerals (such as pyrite) to atmospheric oxygen, greatly accelerating their weathering through microbially mediated reactions. As a result of the large spatial extent of this mining legacy, AMD has been referred to as the greatest water quality problem facing the Western United States (Mineral Policy Center, 1997).

The weathering and oxidation of pyrite occurs in three steps, and the process becomes autocatalytic in nature. Weathering of pyrite increases the concentrations of trace metals through the co-weathering of other sulfidic minerals associated with pyrite, as well as of other minerals in the vicinity of the pyrite due to the acidic conditions. Water quality of streams receiving AMD is typically acidic with high concentrations of dissolved metals such as zinc, copper, cadmium, iron, and aluminum. Additionally, AMD streambeds are characterized by bright orange and white colored deposits that indicate iron hydroxide and aluminum hydroxide deposition, respectively (Theobald et al., 1963; McKnight et al., 1992). High metal ion concentrations, low pH, and hydroxide deposition limit stream biota, including microbes, algae, invertebrates, and fish, for many kilometers of streams in Colorado (McKnight and Feder, 1984; Niyogi, 1999).

This report focuses on the Snake River of Colorado and several of its primary tributaries, including Deer Creek, Peru Creek, and the North Fork of the Snake River. In April 1999, the Snake River Task Force (SRTF) was formed, bringing together multiple parties in the watershed. The mission of the Task Force is to improve water quality in the watershed, with an emphasis on identifying, evaluating, and implementing opportunities to reduce trace metal concentrations in the Snake River. Within the SRTF, primary informational needs toward developing AMD remediation strategies in the Snake River Basin were identified, including the identification of major sources of AMD and the characterization of the variation in concentration of trace metals in the stream throughout the year, with a focus on spring snowmelt. Responding to this need, this report is the product of research conducted to address these informational needs. Here we present chemical monitoring data collected during these studies, conducted from November 2001 through September 2002.

SITE DESCRIPTION

The Snake River watershed is located in central Colorado's Rocky Mountains immediately west of the Continental Divide (Fig. 1). As a result of both historic mining activity and natural biogeochemical processes, a large percentage of the basin is impacted by acid rock drainage. The Snake River and Peru Creek are identified on Colorado's 2000 303(d) list of impaired water bodies due to high concentrations of zinc, cadmium, copper, lead, and manganese. The headwaters of the Snake River receive inflow from acidic and metal-enriched tributaries and groundwater on the eastern side of the watershed, where disseminated pyrite is abundant in the country rock (Theobald et al., 1963). This headwater reach also runs through a naturally occurring bog iron ore deposit. The inflow of Deer Creek, a pristine tributary of approximately equal flow, raises the pH and causes precipitation of aluminum and iron hydroxides.

The next substantial tributary, Peru Creek, receives inflow from numerous abandoned mines. The Pennsylvania Mine, located on the Peru Creek tributary, has been found to be one of largest sources of metals and acidity within this watershed (McKnight and Bencala, 1990). As in the confluence with Deer Creek, large sections of the Snake River and Peru Creek are coated in metal hydroxides—

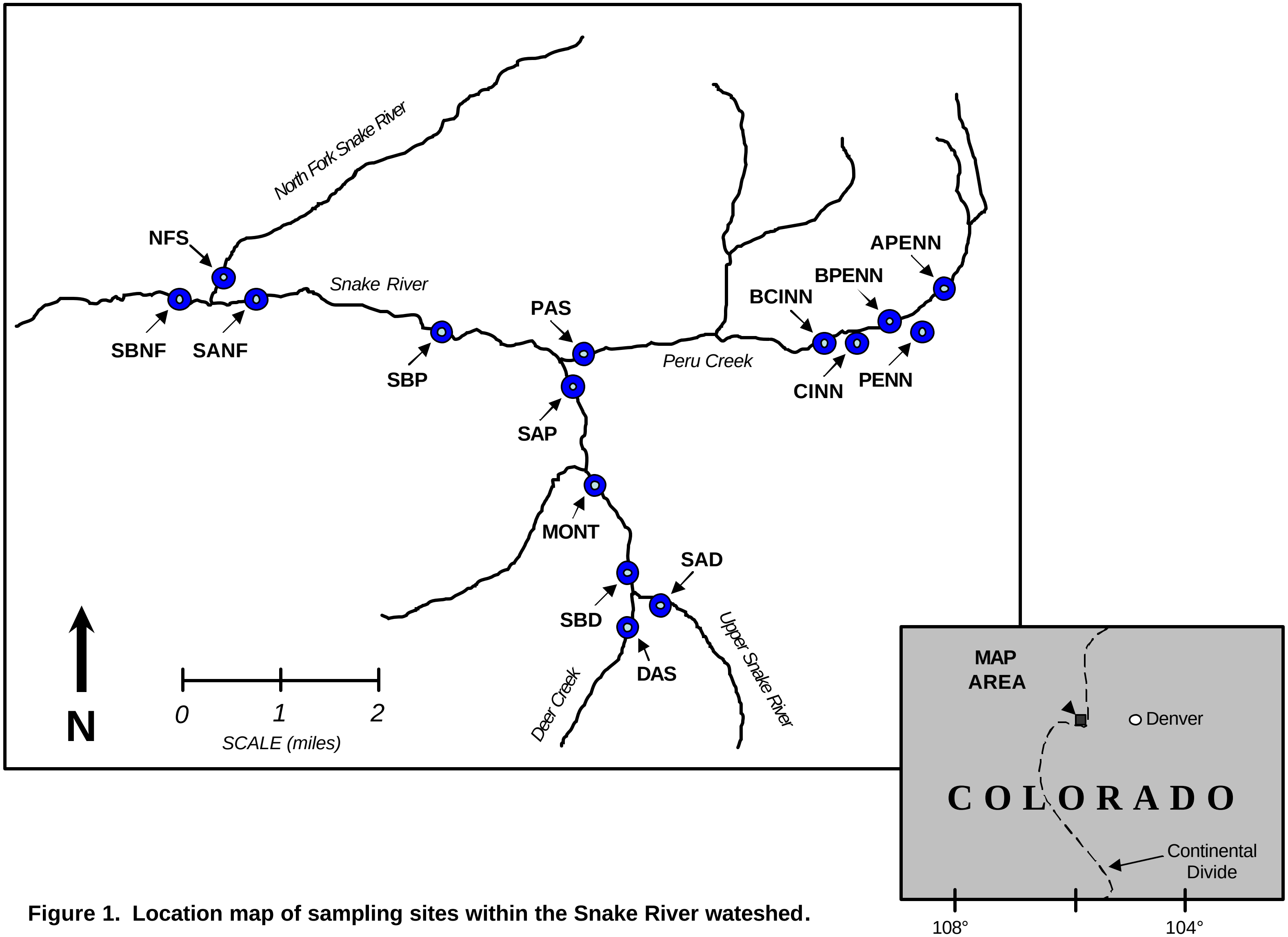


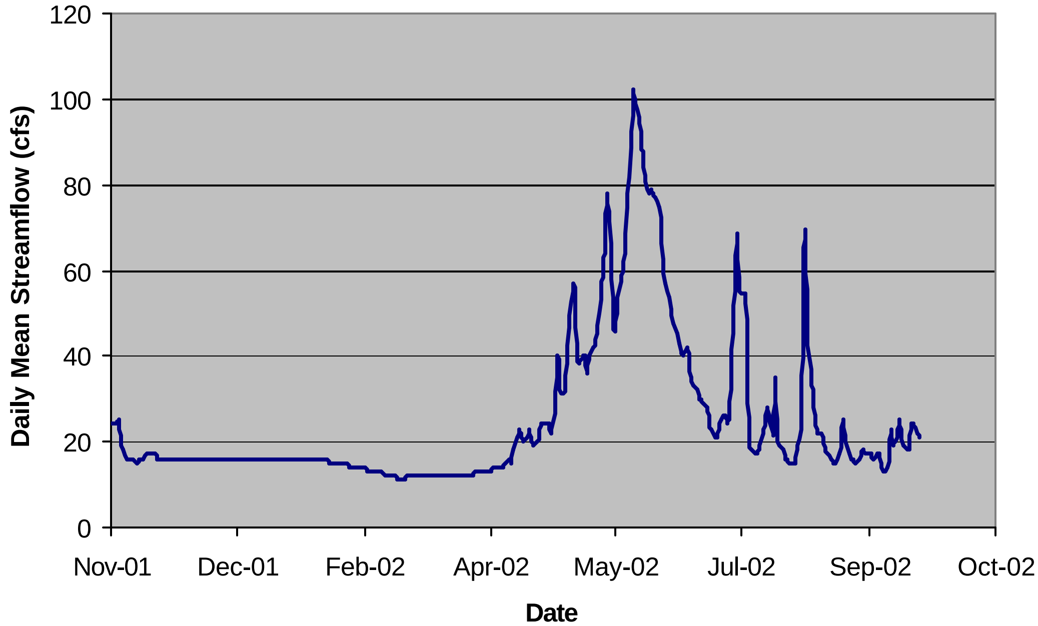
Figure 1. Location map of sampling sites within the Snake River wateshed.

primarily iron and aluminum hydroxides—which precipitate out of solution as flow from pristine tributaries raises the pH of the stream water. The Snake River, joined by the tributaries Keystone Gulch (not shown) and the North Fork of the Snake River, flows into Dillon Reservoir, which is a major water supply for the city of Denver. Keystone and A-Basin ski resorts are located within the basin and use water from these streams for snowmaking.

In order to characterize the year-round dynamics of water chemistry in the Snake River watershed, sampling sites were established at 15 locations within the Snake River and its major tributaries (Fig. 1). These sites were monitored from November 2001 to September 2002, a period which encompassed the most extreme drought that has been recorded in the region in the past 100 yr (McKee et al., 2000). During this time period, the maximum discharge recorded at the U.S. Geological Survey (USGS) gauge on the Snake River near Keystone was 102 cubic feet per second (cfs) and occurred on 31 May 2002 (Fig. 2). This peak discharge is markedly lower than in years with a typical snowpack, and maximum discharge occurred approximately 2 weeks earlier than is typical (Boyer et al., 1999).

Near the confluence of the upper Snake River and Deer Creek, a total of 4 sampling sites were established to monitor the seasonal changes in water quality at this important confluence of first-order streams. Above this confluence, the chemistry of Deer Creek (**DAS)** has been characterized as typical of a pristine, Rocky Mountain stream with circum-neutral pH and low metals concentrations (Bencala et al., 1987). In contrast, upstream of its confluence with Deer Creek, the Snake River (**SAD**) is naturally acidic due to the weathering of pyrite disseminated in the country rock, and the stream water has elevated concentrations of heavy metals (e.g., Al, Cd, Cu, Fe, Mn, and Zn) from weathering reactions. Downstream of this confluence, the other 2 sampling sites were established (**SBD** and **MONT**) to monitor changes in water quality resulting from the mixing of the low pH upper

Figure 2. Snake River Hydrograph from 4 November 2001 through 21 September 2002. Data were obtained from the USGS gauge #09047500 (Snake River near Montezuma, CO). Due to drought conditions, run-off was below normal during Water Year 2002.



Snake River and Deer Creek, as well as the effects of a small mine located between the 2 sites (SBD and MONT).

Within the upper reaches of the Peru Creek tributary, 5 sampling sites were established to monitor the influence of 2 anthropogenic AMD sources on the instream chemistry of Peru Creek. Discharge from the Pennsylvania Mine (**PENN**), a prolific producer of silver into the late 1940s, has been estimated to be one of the largest sources of aqueous metals and acidity in the catchment (McKnight and Bencala, 1990). The Cinnamon Gulch basin (**CINN**) is another potential source of AMD, with drainage entering Peru Creek downstream of the Pennsylvania Mine inputs. In order to gauge the importance of these anthropogenic inputs, sampling sites above the Pennsylvania Mine (**APENN**), between the Pennsylvania Mine and Cinnamon Gulch (**BPENN**), and below the Cinnamon Gulch inflow(**BCINN**) were established. Because of the remote location and inaccessibility of these 5 sites during winter months due to avalanche risk, frequency of sampling was limited to snow-free periods within the monitoring period.

The confluence of the Snake River and Peru Creek was monitored at 3 sampling sites, including the Snake River upstream of Peru Creek (**SAP**), Peru Creek upstream of the Snake River (**PAS**), and the Snake River downstream of this confluence (**SBP**). The downstream sampling location was sited approximately 1.6 km below this confluence to allow for complete mixing.

Finally, sampling sites were established within the North Fork of the Snake River (**NFS**), the Snake River upstream of the North Fork (**SANF**), and downstream of the confluence of these two streams (**SBNF**). All of these sites were located within close proximity of the resort town of Keystone.

METHODS

During the period from November 2001 through September 2002, water quality samples and associated measurements were taken approximately once per month during fall and winter months, and once per week thereafter.

Grab samples for inorganic analyses were collected in acid-washed 1-L plastic bottles that had been rinsed three times with stream water. pH and conductivity were measured at field sites using a YSI 63 multimeter. Samples were filtered, either on-site (weather permitting) or in the laboratory, through 0.4-µm Nucleopore filters using an Antlia pneumatic hand pump filtering apparatus. Samples were filtered into cleaned 120-mL plastic bottles. Samples for cation and dissolved metals analysis were acidified using 0.5-mL concentrated Ultrex nitric acid. Sulfate concentrations were measured using a Dionex Ion Chromatograph, and cation and metal concentrations were measured using a Jarrel-Asch Inductively Coupled Plasma (ICP) spectrometer. Detection limits for the three ICP runs are presented in Appendix A, Table A1. Detection limits for individual ICP runs vary slightly due the unique conditions of each run, and were determined using measurement of experimental blanks. Error calculated for duplicate samples in this study are presented in Table A2. Percent error was found to be consistently low (ranging from an average of 1.8% to 13%), and so the measured values are reported without adjustments for error. The error range was typically higher for trace metals measured at low concentrations (e.g., Cd, Cu, and Ni).

Dissolved organic carbon (DOC) samples were collected in the field in pre-combusted glass bottles, and were filtered through Fisherbrand pre-combusted glass-fiber filters (GF-C) into amber-colored glass bottles that had been cleaned and combusted in the laboratory prior to sampling. Following filtration, DOC samples were kept refrigerated. DOC was analyzed within 2 weeks of sample collection using a Shimadzu TOC-5050A total organic carbon analyzer.

WATER QUALITY CHARACTERISTICS

Water quality characteristics from this study in the Snake River watershed are presented as data Tables A3–A17 in Appendix A of this report. Measurements for DOC, pH, conductivity, sulfate, hardness (as mg/L calcium carbonate), and a suite of cations and trace metals (Al, Ca, Cd, Cu, Fe, Mg, Mn, Ni, and Zn) are reported.

Upper Snake River, Deer Creek and Montezuma

Tables A3–A7 include water quality data for the 5 stream sampling sites (**SAD**, **DAS**, **SBD**, and **MONT, SAP**) that describe the chemistry of the Upper Snake River/Deer Creek confluence. As demonstrated in previous studies within this watershed, reactive aqueous metals (such as Al) are soluble in highly acidic waters, and less soluble at the higher pH values characteristic of spring runoff (Brooks et al., 2001; McKnight and Bencala, 1990; Boyer et al., 1999). Precipitation of hydrous aluminum oxides is evident in the consistent differences in Al concentration between SAD and SBD. Decreases in aluminum concentration occurred during the snowmelt period of late-May through mid-June when increased pH values caused decreases in aluminum solubility (Fig. 3). In contrast, Zn, which is less reactive because its solubility does not decrease in the neutral pH range occurring below the confluence, demonstrated behavior primarily reflecting dilution by snowmelt in the spring (Fig. 4) (Filipek et al., 1987).

Pennsylvania Mine, Cinnamon Gulch and Peru Creek

Tables A8–A13 report water quality data for the 6 stream sampling sites (**APENN**, **PENN**, **BPENN**, **CINN**, **BCINN**, and **PAS**) within the Peru Creek drainage. In contrast to natural pyrite weathering in the upper Snake River basin, the Pennsylvania Mine and other abandoned mines in this drainage have been identified as the major sources of trace metals and acidity to the stream (McKnight and Bencala, 1990). The year-round influx of trace metals from the Pennsylvania Mine, and from the mine-rich Cinnamon Gulch drainage (Tables A8 and A10), plays a dominant role in determining the downstream chemistry of Peru Creek and

Figure 3. Measured dissolved aluminum concentrations at the Deer Creek/Snake River confluence.

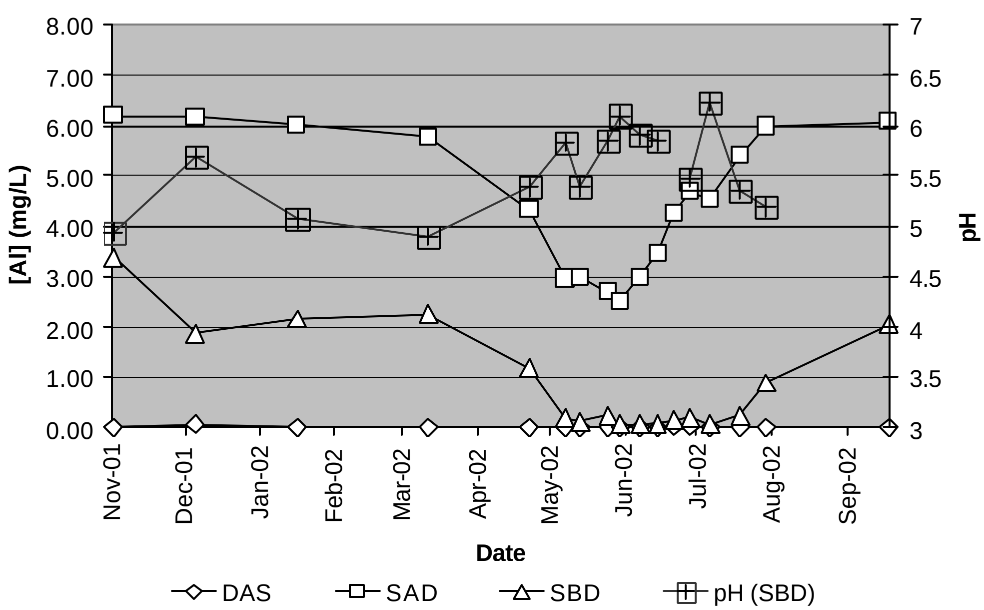
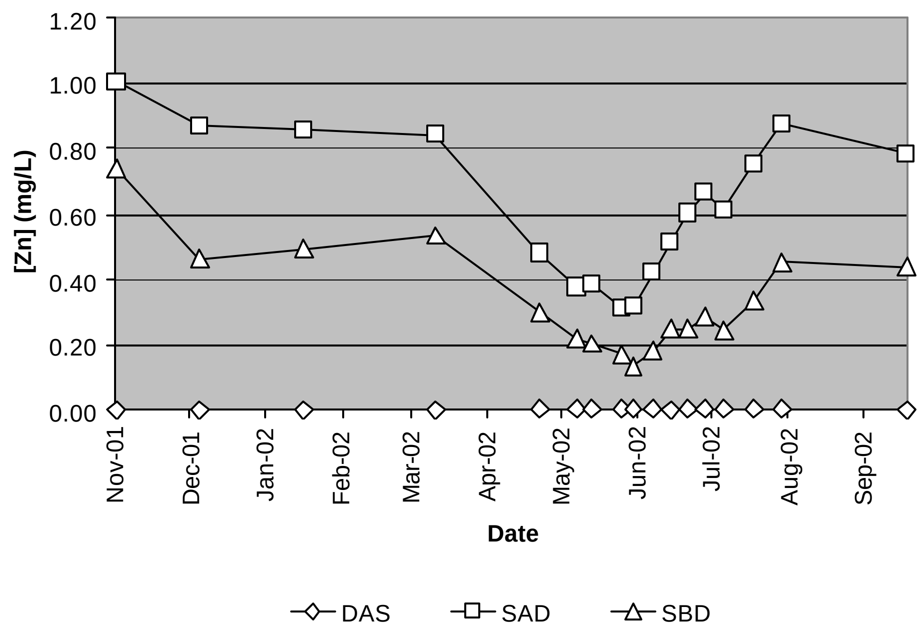


Figure 4. **Measured dissolved zinc concentrations at the Deer Creek/Snake River confluence.**



the Snake River. It is notable that Cinnamon Gulch caused increases in Zn concentrations in Peru Creek throughout the year.

Along the main stem of Peru Creek, numerous seeps and inflows, including the substantial Chihuahua Gulch inflow, raised instream pH (Tables A8 and A10) and drove the precipitation of Al and Fe, which have limited solubility at neutral pH, and caused a decrease in Al and Fe concentrations (Fig. 5). These inflows also caused the dilution of less reactive metals (Fig. 6). However, Zn concentrations remained elevated, while the concentrations of other potentially toxic trace metals (Cu, Cd, and Ni) decreased to lower concentrations. Despite the extremely low snowpack, dilution of mine inflows during snowmelt in May caused trace metal concentrations to decrease compared to concentrations during the winter and summer periods.

Beyond the Headwaters

Below its confluence with Peru Creek, the Snake River and the quality of its stream water have become issues of great concern for a diverse range of local, state, and federal interests (Todd et al., 2003). Tables A14–A17 report water quality data for the 4 stream sampling sites (**SBP**, **SANF**, **NFS**, and **SBNF**) located in and around the town of Keystone. While dilution during snowmelt, precipitation of metals, and additional processes in the headwater reaches of the Snake River yield lower year-round concentrations of reactive trace metals at these downstream sites (Figs. 5 and 7), aqueous concentrations of less reactive metals, such as Zn, remain elevated (Figs. 8 and 9). Elevated levels of Zn have been demonstrated to be acutely and/or chronically toxic to fish species (e.g., rainbow trout) commonly stocked in the region (Hansen et al., 2002).

Comparison with Previous Water Quality Measurements

Table 1 compares metals concentrations measured at the Deer Creek/Upper Snake River confluence during this study with two previous studies conducted

Figure 5. Dissolved aluminum concentrations along Peru Creek and the Snake River measured on three dates in 2002. Distance downstream increases from left to right.

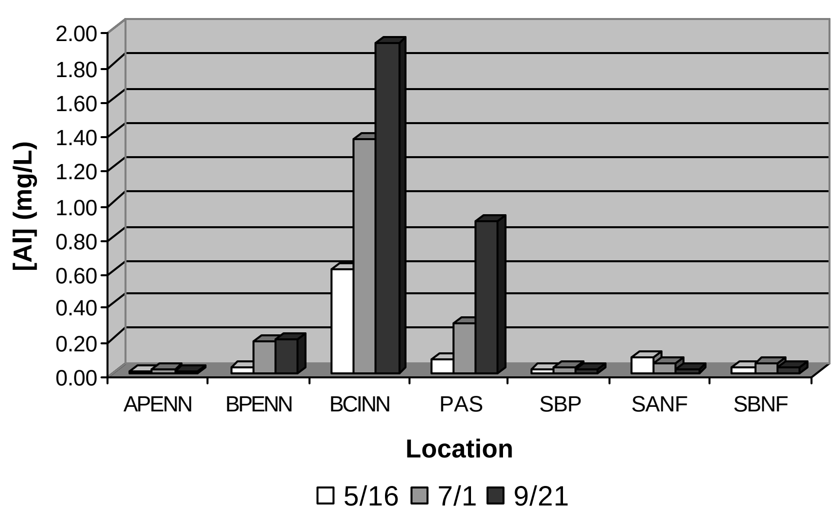


Figure 6. Dissolved zinc concentrations along Peru Creek and the Snake River measured on three dates in 2002. Distance downstream increases from left to right.

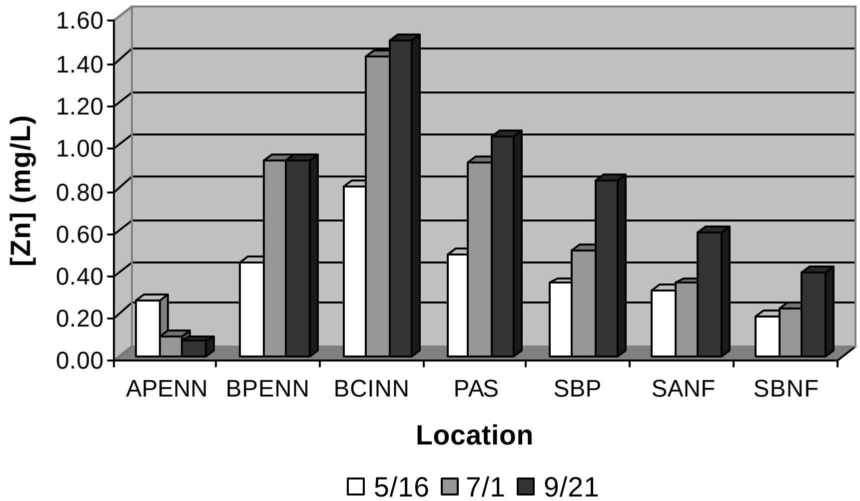
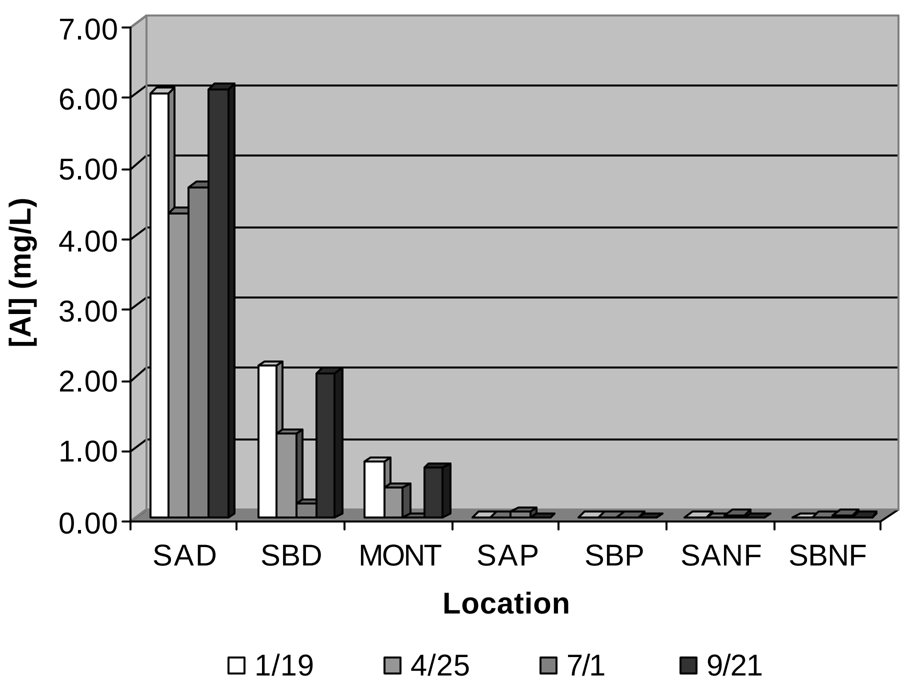


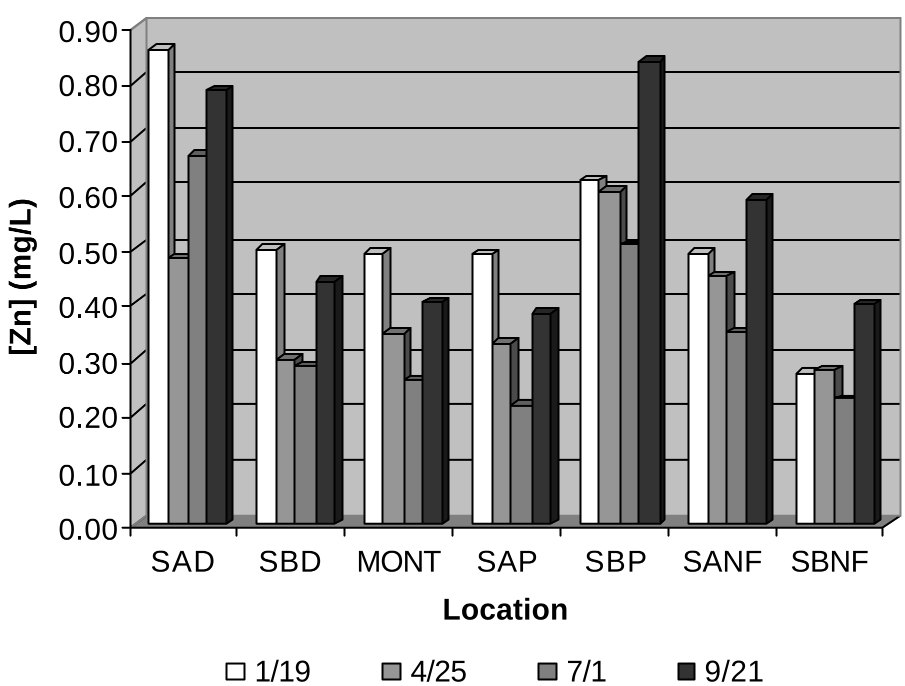
Figure 7. Dissolved aluminum concentrations along the Snake River measured on four dates in 2002. Distance downstre am increases from left to right.



within the basin. Both the Fey et al. (2002) study and our study reflect low-flow conditions in the watershed (27.5 and 21 cfs, respectively) as measured at the permanent USGS flow gauge along the Snake River in the town of Keystone. For most metals, concentrations are higher at these low-flow conditions when compared to ranges of measured values from the higher flow year (46 cfs) presented in the Boyer (1999) study.

This comparison complements earlier findings in our report which typically displayed highest metals concentrations occurring during winter months, the time of the year when flows are at their lowest. These results suggest that measurements of low-flow water chemistry may be the most important indicators of the potential for ARD-receiving streams to support year-round aquatic

Figure 8. Dissolved zinc concentrations along the Snake River measured on four dates in 2002. Distance downstream increases from left to right.



ecosystems. Further, these results illustrate the importance of implementing year-round monitoring efforts to obtain a complete picture of water chemistry for making management decisions in ARD-impacted streams.

Table 2 compares metals concentrations from the Pennsylvania Mine, as measured during this study and from the year 1984. This comparison illustrates the continuing role that this mine plays in shaping the water chemistry of Peru Creek and, ultimately, the Snake River. Table 3 presents, for the first time, original data obtained during this previous study used to calculate trace metal losses (McKnight and Bencala, 1990).

Risks to Aquatic Ecosystems

It is evident from the water quality data presented in the previous section that the streamwater in Peru Creek, the Upper Snake River, and the mainstem

Figure 9. Measured dissolved zinc concentrations at the North Fork/Snake River confluence.

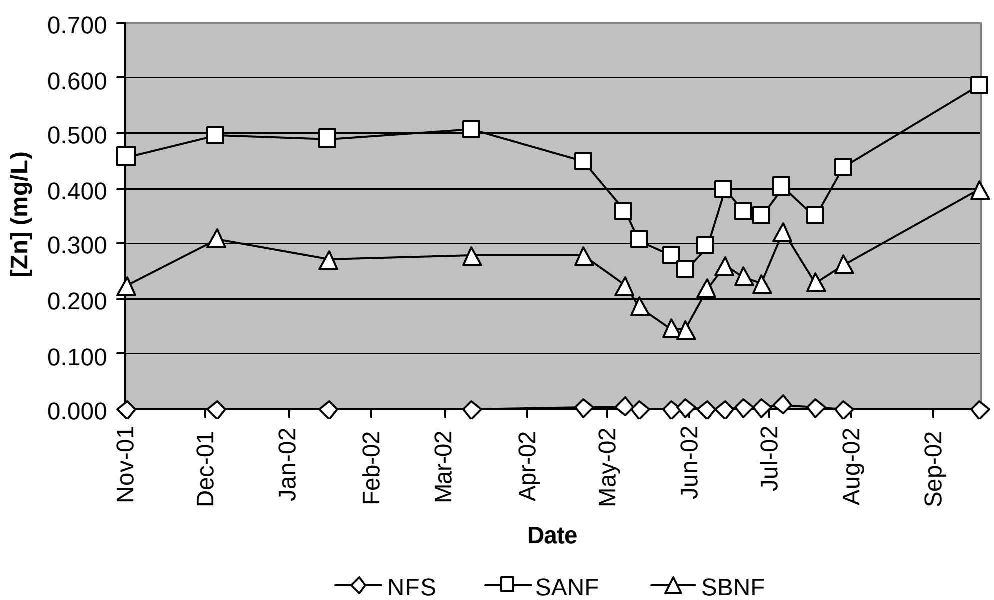


Table 1. Dissolved metal concentrations at three common points (DAS, SAD, and SBD) in the Upper Snake River watershed as measured in three unique studies conducted during three different flow conditions. Flow rates measured at the USGS gauge in Keystone were as follows: 46 cfs (10/10/82), 27.5 cfs (10/9/01), and 21 cfs (9/21/02). Ranges of concentration maxima and minima as measured from 1980 – 1990 (Boyer et al., 1999) are compared with low flow maximum and high flow (6/2/02) minimum dissolved metals concentrations measured during this study. Bold text highlights values that fall above this yearly range. "BDL" indicates below-detection limit and "n/a" indicates parameters not analyzed or missing.

Site/Study	Date	Al (µg/L)	Ca (mg/L)	Cd (µg/L)	Cu (µg/L)	Fe (µg/L)	Mg (mg/L)	Mn (µg/L)	Ni (µg/L)	Zn (µg/L)
DAS										
Fey et al.	10/9/01	4.2	13	0.04	0.50	10	2.4	11.3	0.3	5.5
Boyer et al.	10/10/82	BDL	9.36	BDL	5	122	1.57	37	n/a	23
This study	9/21/02	6	12.9	BDL	BDL	83	2.35	7	BDL	BDL
Boyer et al. Yearly Range (Min)		*0-73*	*5.55-9.36*	*0-2*	*0-1*	*10-61*	*0.586-1.51*	*0-30*	*n/a*	*0-20*
Snowmelt Minimum (This Study)		12	7.35	0	0	48	1.29	5	0	4
Boyer et al. Yearly Range (Max)		*40-987*	*13.9-16.2*	*0-16*	*0-28*	*168-400*	*2.32-7.66*	*14-143*	*n/a*	*21-204*
Low Flow Maximum (This Study)		51	14.2	0	3	161	2.59	8	1	7
SAD										
Fey et al.	10/9/01	5660	9.8	2.56	20	1010	6.3	1350	26.8	588
Boyer et al.	10/10/82	2880	6.67	1	16	798	3.17	685	13	378
This Study	9/21/02	6060	13.1	4	22	741	7.53	1290	28	782
Boyer et al. Yearly Range (Min)		*432-1840*	*3.21-6.37*	*0-1*	*0-9*	*20-296*	*1.11-2.56*	*58-393*	*n/a*	*29-271*
Snowmelt Minimum (This Study)		**2510**	**7.35**	1	**10**	**998**	**3.37**	**513**	13	**311**
Boyer et al. Yearly Range (Max)		*4130-5730*	*11.0-15.4*	*0-17*	*15-129*	*831-1640*	*5.09-10.7*	*1030-1370*	*n/a*	*512-754*
Low Flow Maximum (This Study)		**6190**	13.5	5	22	1550	7.56	**1590**	29	**1010**
SBD										
Fey et al.	10/9/01	2160	12	2.28	11.3	212	4.7	793	15.3	512
Boyer et al.	10/10/82	575	10.8	1	11	262	2.86	338	n/a	308
This Study	9/21/02	2060	12.5	2	12	270	5.11	702	15	437
Boyer et al. Yearly Range (Min)		*0-670*	*3.20-7.36*	*0-3*	*0-6*	*20-192*	*1.09-2.06*	*20-263*	*n/a*	*16-172*
Snowmelt Minimum (This Study)		45	**7.51**	1	2	**283**	**2.189**	224	5	138
Boyer et al. Yearly Range (Max)		*1470–5150*	*12.2–16.2*	*0-20*	*11-71*	*420-1500*	*4.07-9.75*	*609-1030*	*n/a*	*296-779*
Low Flow Maximum (This Study)		3380	13.7	3	14	588	6.14	**1176**	21	737

Snake River consistently have higher concentrations of aqueous metals than the reference streams in this study, the North Fork and Deer Creek. In order to assess how these metal concentrations might limit site-specific aquatic biotic communities, screening-level exposure estimates and preliminary risk calculations are employed. In brief, the highest measured site-specific metals concentrations are compared with documented water quality criteria to obtain an estimate of risk to a generic freshwater ecosystem. As this is a screening-level investigation, the risk calculations are inherently conservative and are intended to screen out metals that pose negligible risk, while retaining metals of concern (MOC) for further investigation. This study utilizes the calculation of Hazard Quotients (HQ) at each site as detailed below(EPA, 1997):

$$HQ = \text{estimated exposure/benchmark exposure}$$

The results of HQ calculations for Al, Cd, Cu, Mn, Ni, and Zn are presented in Appendix A in Tables A18–A23. Cd, Cu, Mn, and Zn were selected because of their presence on the State of Colorado's 303(d) list for the Snake River and Peru Creek. Previous investigations have indicated that Al can play a

Table 2. Dissolved metal concentrations at two common sampling points in the Peru Creek drainage as measured during two unique sampling events.

Site/Study	Date	Al (mg/L)	Ca (mg/L)	Fe (mg/L)	Mg (mg/L)	Mn (mg/L)	Zn (mg/L)
Pennsylvania Mine							
McKnight and Bencala, 1990	9/14/84	14.5	70.0	40.0	21.6	19.0	28.5
This Study	9/21/02	21.5	92.9	23.2	31.8	23.1	27.8
Below Pennsylvania Mine							
McKnight and Bencala, 1990	9/14/84	1.12	11.31	0.910	2.70	1.27	1.65
This Study	9/21/02	6.06	13.12	0.741	7.53	1.29	0.782

Table 3. Original Peru Creek (and tributaries) water chemistry data from McKnight and Bencala (1990) (mg/L). Results/Values in bold correspond with sites within this data report. Pennsylvania mine drainage (PAM) measurements correspond with this data report's PENN site. Peru Creek downstream of the Pennsylvania mine (PC15) corresponds with this data report's BPENN site. "od" indicates over-detection-limit and "nd" below-detection-limit for that analyte.**

ID	F	Cl^-	SO_4	pH*	Na	K	Mg	Ca	Al	Mn	Fe	Zn
GL1	0.00	0.13	7.41	7.90	0.49	0.44	1.28	5.43	nd	nd	0.01	nd
GL4	0.13	0.41	8.23	6.90	1.08	0.53	0.99	5.78	0.01	nd	0.03	0.03
FG1	0.08	0.25	19.32	6.33	0.81	0.47	1.37	6.69	0.08	0.06	0.05	0.15
RM1	0.15	0.14	49.30	4.81	1.10	0.60	3.17	12.54	0.27	0.42	0.02	0.20
GL6	0.11	0.18	32.90	5.46	0.95	0.53	21.7	9.34	0.16	0.21	0.04	0.17
PC3	0.11	0.22	19.72	6.52	0.79	0.58	2.00	10.69	nd	0.01	0.04	nd
PC4	0.11	0.31	27.39	6.28	0.97	0.61	2.07	9.62	nd	0.11	0.04	0.11
PC5	0.12	0.17	28.89	6.65	0.97	0.62	2.23	10.68	0.30	0.13	0.11	0.16
PMS	0.37	1.19	44.40	4.18	1.73	3.84	1.06	5.10	3.65	1.83	0.10	3.18
PC6	0.13	0.16	28.68	7.11	1.02	0.60	2.31	11.28	0.15	0.09	nd	0.10
PF1	0.21	0.20	78.90	6.14	1.10	0.43	1.35	4.58	0.42	0.10	0.93	0.06
AP1	0.03	0.02	8.89	7.33	0.98	0.64	1.56	6.59	0.22	0.01	0.07	0.02
SBT	0.91	0.29	502.00	2.93	8.05	0.94	12.22	90.90	1.14	59.18	14.63	20.68
PAM	**od**	**od**	**od**	**3.19**	**od**	**od**	**21.57**	**70.04**	**14.55**	**18.97**	**39.95**	**28.50**
PC8	0.19	0.12	42.10	6.09	1.30	0.65	2.86	11.96	0.69	1.56	1.64	1.73
PC15	**0.28**	**0.15**	**49.10**	**5.49**	**1.53**	**0.73**	**2.70**	**11.31**	**1.12**	**1.27**	**0.91**	**1.65**

** pH is dimensionless.*
***Please refer to Figure 1 of McKnight and Bencala (1990) for additional site descriptions and locations.*

limiting role in aquatic ecosystems (Niyogi, 1999). Ni was added as a metal of potential concern. Dissolved Pb was not investigated due to high detection limits associated with analytical instrumentation; however, information is available regarding dissolved Pb distribution within the watershed (Fey et al., 2001).

Because measurements are incomplete in winter at upper Peru Creek sites APENN, BPENN, and BCINN, these tables include HQ calculations for both year-round and limited data sets. The limited data set includes measurement of samples taken on 4 November 2001, and beginning again on 16 May 2002. The purpose of these calculations is to demonstrate that calculated maximum HQs at these 3 sites are likely artificially low, as winter-time aqueous metals concentrations are often higher than summertime levels.

Summary information of risk estimates to both acute and chronic aqueous metal exposure is presented in Tables 4 and 5. Each tables is divided into three sections; the first represents Upper Snake River sites, the second represents Peru Creek sites, and the third represents Lower Snake River sites downstream of the confluence with Peru Creek.

CONCLUSIONS

This occasional paper presents data collected during a year-long sampling effort in the Snake River watershed, and we have described our findings on trends in the data set. The following conclusions were made during this investigation.

Pennsylvania Mine and Cinnamon Gulch Are Major Sources of Trace Metals in Peru Creek

The data collected during our study show that drainage from both the Pennsylvania Mine and the Cinnamon Gulch catchment drastically change the downstream water chemistry of Peru Creek. There are many other mines within the Peru Creek watershed, but it is evident that these two measured inflows to Peru Creek are major anthropogenic sources of trace metals.

Instream Precipitation of Metal Oxides Is a Dominant Process

Water chemistry data from key confluences in this study illustrate the important role that precipitation of metal oxides plays in determining downstream water chemistry. Toxic levels of dissolved Al in low pH, ARD inflows are dramatically reduced on merging with higher pH receiving streams. In contrast, due to differences in pH-dependent solubility, high levels of Zn and Cd are only diluted downstream of these confluences.

Table 4. Summary table of screening-level aquatic ecosystem risk calculations in the Snake River Watershed, based on literature based acute toxicity thresholds or the EPA's Criteria Maximum Concentration (CMC).*

Site ID	Al		Cd		Cu		Mn		Ni		Zn	
	L	Y	L	Y	L	Y	L	Y	L	Y	L	Y
SAD	X	X	X	X	X	X					X	X
DAS												
SBD	X	X				X					X	X
MONT		X									X	X
SAP											X	X
APENN											X	
BPENN			X		X						X	
BCINN	X		X		X						X	
PAS	X	X	X	X	X	X					X	X
SBP			X	X							X	X
SANF			X	X							X	X
NFS												
SBNF											X	X

**L= limited data only, Y = year-round data, X indicates locations at which the calculated HQ exceeded a value of 1. Shaded cells indicate sampling sites with incomplete data to calculate this risk value.*

Low-Flow Conditions during Drought Years and Winter Months Yield High Aqueous Metals Concentrations. Snowmelt Causes Dilution of Trace Metals in Peru Creek

Elevated levels of metals measured during winter months and dry years indicate that these times may be important periods of high stress on aquatic ecosystems. It is therefore important to include winter months and dry years in assessments of ecosystem potential in streams that receive ARD.

Zn and Cd Are Primary Metals of Snake River Watershed-Wide Ecological Concern

Owing to inputs from both anthropogenic and natural sources, and to their conservative chemistry in these headwater streams, Zn and Cd exist as metals of

Table 5. Summary table of screening-level aquatic ecosystem risk calculations in the Snake River Watershed, based on literature based chronic thresholds or the EPA's Criterion Continuous Concentration (CCC).*

Site ID	Al		Cd		Cu		Mn		Ni		Zn	
	L	Y	L	Y	L	Y	L	Y	L	Y	L	Y
SAD	X	X	X	X	X	X	X	X			X	X
DAS												
SBD	X	X	X	X	X	X		X			X	X
MONT	X	X	X	X							X	X
SAP	X	X	X	X							X	X
APENN											X	
BPENN	X		X		X		X				X	
BCINN	X		X		X		X				X	
PAS	X	X	X	X	X	X	X	X			X	X
SBP			X	X	X	X					X	X
SANF	X	X	X	X							X	X
NFS			X	X								
SBNF			X	X							X	X

**L= limited data only, Y = year-round data, X indicates locations at which the calculated HQ exceeded a value of 1. Shaded cells indicate sampling sites with incomplete data to calculate this risk value.*

primary ecological concern throughout the Snake River watershed. Other dissolved metals, including Cu and Al, exceed conservative toxicity thresholds in certain regions of the watershed, but both Zn and Cd continue to exceed thresholds at the most downstream site included in our study (**SBNF**). Future studies of dissolved metal ecological impacts near the Snake River's confluence with the North Fork of the Snake River will focus on Zn and Cd, with additional consideration given to secondary metals of potential ecological concern, including Cu and Al.

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APPENDIX A: Tables

TABLE A1. Detection limits (µg/L) for three different ICP runs for water quality samples. Variability in detection limits is a function of analysis of experimental blanks included in each ICP run. Samples for Runs 1 and 2 were selected to cluster all run-off samples, while Run 3 captured low-flow periods and run-off samples (6/17/02) that had been misplaced.

	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	SiO2	Zn
Run 1	3.4	34.7	0.4	0.9	2.2	2.4	0.1	1.6	426.2	2.1
Run 2	1.5	14.5	0.3	0.8	2.4	3.5	0.1	1.1	43.7	0.7
Run 3	2.8	33.5	0.5	0.9	6.1	7.4	2.5	1.1	53.3	17.3
Run 1	4/25/02, 5/10/02, 5/16/02, 5/28/02, 6/02/02, 6/10/02 (incomplete)									
Run 2	6/24/02, 7/01/02, 7/09/02, 7/21/02, 8/01/02 (incomplete)									
Run 3	11/04/01, 12/08/01, 1/19/02, 3/14/02, 6/17/02, 9/21/02, 8/01/02 (NFS, SANF, SBNF, SBP), 6/10/02 (SANF, NFS, SBNF)									

TABLE A2. Percent error from calculated arithmetic mean of duplicate samples. Average error is reported at the bottom of the table. Site IDs are a combination of sample date and site location.

Site ID	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
110401NFS	4.4	1.6	BDL	BDL	BDL	1.1	BDL	BDL	BDL
120801SAD	2.0	2.0	4.5	2.1	2.5	2.2	2.2	2.0	1.9
011902SAD	3.9	3.8	2.4	4.0	3.9	3.5	3.6	3.0	3.2
31402PAS	2.4	2.5	1.2	1.5	2.4	2.3	2.6	4.2	2.0
42502SBNF	0.2	0.3	6.4	12	0.4	0.7	1.0	2.2	0.7
51002SAD	0.2	0.1	2.7	0.3	0.0	0.5	0.0	1.6	0.1
51602BCINN	0.4	0.4	3.8	0.1	0.2	0.6	0.5	4.2	0.3
52802SAP	0.3	0.6	6.4	1.5	2.6	0.1	0.4	11	1.3
52802SBNF	0.1	0.1	37	3.8	2.7	0.1	0.6	41	1.4
60202BCINN	3.0	2.2	3.0	3.2	2.5	2.5	2.5	8.8	2.7
61002SAP	0.4	0.3	13	17	19	0.6	0.2	2.4	0.4
61702SANF	2.9	3.9	0.7	0.2	BDL	4.0	4.0	7.4	3.8
61702SBD	3.4	4.2	7.4	3.6	4.2	3.5	3.4	0.7	3.7
62402BCINN	0.1	0.3	0.4	0.3	0.2	0.2	0.2	6.0	0.5
70102SBD	1.5	0.5	4.1	1.7	0.3	1.5	1.1	2.4	0.6
70102SBP	1.6	1.7	3.9	6.1	15	1.8	1.4	2.8	1.1
70902PENN	1.7	1.2	0.8	1.3	1.2	1.5	1.1	1.7	0.9
72102DAS	1.3	3.5	31	44	3.2	3.8	0.2	78	4.8
80102NFS	2.4	10	BDL	BDL	6.1	11	BDL	BDL	BDL
80102SAP	0.1	2.1	5.7	150	2.3	1.6	2.0	5.8	2.6
92102BPENN	4.5	3.8	3.5	4.4	5.1	3.6	3.5	5.3	3.3
Average Error	1.8	2.2	7.2	13	3.9	2.2	1.6	10.0	1.9

TABLE A3. Snake River upstream of confluence with Deer Creek (SAD) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.536	3.84	147	113	62.4	6.19	12.7	0.005	0.019	0.016	7.46	1.59	0.029	1.01
12/8/01	0.421	4.30	169	109	63.4	6.05	12.7	0.004	0.022	0.702	7.39	1.36	0.028	0.853
1/19/02		3.89	185		61.4	6.26	13.0	0.004	0.021	0.655	7.59	1.39	0.029	0.887
3/14/02	0.573	3.96	272	120	59.5	5.78	12.3	0.004	0.018	0.407	6.99	1.24	0.028	0.842
4/25/02	1.13	4.00	222	87.8	46.3	4.32	9.77	0.002	0.014	1.55	5.32	0.908	0.020	0.480
5/10/02	1.08	4.11	165	67.1	36.3	2.97	8.12	0.002	0.010	1.14	3.87	0.650	0.014	0.377
5/16/02	1.86	3.63	176	66.5	36.1	2.99	8.04	0.002	0.012	1.05	3.89	0.671	0.015	0.385
5/28/02	1.20	3.99	172	63.2	33.5	2.68	7.41	0.001	0.010	0.901	3.64	0.563	0.014	0.311
6/2/02	0.924	3.94	162	55.3	32.2	2.51	7.35	0.001	0.010	0.998	3.37	0.513	0.013	0.318
6/10/02	0.802	3.45	142	66.8	37.8	2.99	8.54	0.002	0.012	0.754	4.01	0.649	0.015	0.422
6/17/02	0.581	3.75	165	75.8	41.6	3.46	9.10	0.002	0.013	0.622	4.59	0.747	0.017	0.517
6/24/02	0.340		175	87.8	49.0	4.26	10.7	0.003	0.016	0.716	5.43	0.954	0.021	0.602
7/1/02	0.365	3.71	245	93.4	52.8	4.68	11.3	0.003	0.019	0.630	5.95	1.07	0.023	0.666
7/9/02	0.669	4.11	237	93.5	50.9	4.54	10.9	0.003	0.017	0.710	5.76	1.03	0.022	0.611
7/21/02	0.599	3.80	223		58.2	5.39	12.2	0.003	0.019	0.663	6.75	1.26	0.026	0.752
8/1/02		3.66	219	118	64.6	5.99	13.5	0.004	0.020	0.540	7.48	1.44	0.029	0.872
9/21/02					63.8	6.06	13.1	0.004	0.022	0.741	7.53	1.29	0.028	0.782
Maximum				120		6.19	13.5	0.005	0.022	1.55	7.59	1.59	0.029	1.01

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$.*

TABLE A4. Deer Creek upstream of confluence with the Snake River (DAS) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	1.13	6.21	63.6	14.8	39.2	BDL	12.1	BDL	BDL	BDL	2.20	BDL	BDL	BDL
12/8/01	0.630	7.60	61.0	14.7	39.8	0.051	12.3	BDL	BDL	0.127	2.23	0.006	BDL	0.007
1/19/02		6.02	71.4	16.4	46.1	0.008	14.2	BDL	BDL	0.046	2.59	0.004	BDL	0.007
3/14/02	0.878	7.64	106	18.1	45.2	0.004	14.0	BDL	0.001	0.030	2.50	BDL	BDL	0.005
4/25/02	4.64	7.23	81.9	11.8	38.4	0.011	12.0	BDL	0.003	0.161	2.03	0.008	BDL	0.005
5/10/02	3.46	7.33	69.3	9.73	32.5	0.009	10.3	BDL	BDL	0.097	1.65	0.005	BDL	0.004
5/16/02	3.40	7.03	71.3	8.69	30.6	0.008	9.64	BDL	0.002	0.087	1.59	0.005	BDL	0.004
5/28/02	3.20	7.77	65.5	8.52	27.9	0.011	8.74	BDL	0.001	0.059	1.47	0.004	BDL	0.003
6/2/02	2.28	7.52	54.0	6.12	23.7	0.012	7.35	BDL	BDL	0.048	1.29	0.005	BDL	0.004
6/10/02	1.70	7.80	38.2	6.76	24.0	0.008	7.45	BDL	BDL	0.042	1.32	0.004	BDL	0.003
6/17/02	1.29	7.33	51.2	7.91	26.7	0.009	8.21	BDL	BDL	0.040	1.52	0.003	BDL	BDL
6/24/02	1.78		49.1	7.56	27.7	0.027	8.55	BDL	0.002	0.056	1.54	0.004	BDL	0.006
7/1/02	1.27	7.37	64.9	8.10	29.4	0.024	9.06	BDL	0.001	0.053	1.64	0.003	BDL	0.005
7/9/02	1.43	7.53	70.3	8.42	30.5	0.008	9.43	BDL	BDL	0.074	1.69	0.003	0.001	0.003
7/21/02	2.04	7.18	66.5		37.2	0.007	11.9	BDL	BDL	0.094	2.14	0.003	BDL	0.004
8/1/02		6.98	72.5	12.7	40.9	0.006	12.6	BDL	BDL	0.067	2.27	0.002	BDL	0.003
9/21/02					41.8	0.006	12.9	BDL	BDL	0.083	2.35	0.007	BDL	BDL
Maximum				18.105		0.051	14.2	BDL	0.003	0.161	2.59	0.008	0.001	0.007

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$. BDL indicates Below Detection Limit for that analyte.*

TABLE A5. Snake River downstream of confluence with Deer Creek (SBD) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.420	4.94	139	70.7	58.5	3.38	13.3	0.003	0.014	0.245	6.14	1.18	0.021	0.737
12/8/01	0.263	5.68	84.2	65.0	49.6	1.86	11.9	0.002	0.011	0.048	4.82	0.726	0.015	0.461
1/19/02		5.08	109	71.2	52.9	2.16	12.7	0.002	0.012	0.042	5.14	0.766	0.015	0.495
3/14/02	0.466	4.89	145	75.8	56.6	2.26	13.7	0.002	0.013	0.054	5.46	0.782	0.017	0.537
4/25/02	1.16	5.38	125	56.0	43.4	1.19	10.8	0.001	0.008	0.588	3.99	0.556	0.012	0.300
5/10/02	2.58	5.83	94.8	38.6	36.2	0.192	9.60	0.001	0.005	0.392	2.98	0.376	0.009	0.216
5/16/02	1.70	5.39	99.3	36.9	34.1	0.130	9.08	0.001	0.004	0.248	2.79	0.351	0.007	0.202
5/28/02	1.07	5.85	92.5	36.3	30.9	0.232	8.08	0.001	0.004	0.343	2.60	0.305	0.007	0.171
6/2/02	0.838	6.10	77.7	27.6	27.8	0.045	7.51	0.001	0.002	0.283	2.19	0.224	0.005	0.138
6/10/02	0.698	5.90	67.7	31.2	31.1	0.057	8.30	0.001	0.003	0.195	2.53	0.281	0.007	0.183
6/17/02	0.447	5.84	80.3	36.8	37.0	0.099	9.23	0.001	0.003	0.181	3.04	0.352	0.008	0.241
6/24/02	0.360		78.6	38.1	36.6	0.144	9.54	0.001	0.004	0.129	3.10	0.390	0.009	0.248
7/1/02	0.424	5.47	109	42.5	40.2	0.206	10.4	0.001	0.006	0.139	3.56	0.458	0.010	0.289
7/9/02	0.580	6.23	106	40.8	39.7	0.070	10.3	0.001	0.004	0.095	3.37	0.411	0.009	0.245
7/21/02	0.642	5.36	110		45.7	0.251	11.6	0.002	0.007	0.160	4.04	0.558	0.012	0.333
8/1/02		5.19	121	63.9	53.8	0.890	13.4	0.002	0.010	0.174	4.97	0.741	0.015	0.452
9/21/02					52.2	2.06	12.5	0.002	0.012	0.270	5.11	0.702	0.015	0.437
Maximum				75.8		3.38	13.7	0.003	0.014	0.588	6.14	1.18	0.021	0.737

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$.*

TABLE A6. Snake River in the Town of Montezuma (MONT) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.315	5.62	71.3	57.7	53.6	0.195	13.9	0.002	0.005	0.016	4.58	0.569	0.011	0.426
12/8/01	0.355	5.93	76.0	62.3	60.8	0.586	15.6	0.002	0.008	0.075	5.28	0.610	0.013	0.474
1/19/02		5.61	110	70.1	60.0	0.791	15.3	0.002	0.009	0.072	5.27	0.618	0.014	0.490
3/14/02	1.10	5.47	152	75.1	64.3	0.793	16.7	0.002	0.008	0.086	5.47	0.604	0.014	0.518
4/25/02	1.13	5.76	122	53.1	46.8	0.429	12.1	0.001	0.006	0.412	4.00	0.477	0.011	0.347
5/10/02	1.80	6.33	95.7	41.5	37.7	0.041	10.2	BDL	0.002	0.295	2.97	0.312	0.007	0.225
5/16/02	1.80	6.06	103		36.4	0.017	9.91	0.001	0.002	0.183	2.84	0.296	0.006	0.206
5/28/02	1.11	6.74	98.5	39.0	33.6	0.022	8.97	0.001	0.001	0.195	2.72	0.280	0.006	0.187
6/2/02	0.932	6.83	81.5	29.3	29.2	0.164	7.96	0.001	0.001	0.174	2.25	0.205	0.006	0.138
6/10/02	0.800	5.86	71.9	32.8	31.9	0.021	8.65	0.001	0.001	0.071	2.49	0.241	0.007	0.170
6/17/02	0.596	6.72	84.1	38.5	37.2	0.017	9.91	0.001	0.001	0.061	3.03	0.298	0.008	0.226
6/24/02	0.422		82.8	40.0	39.5	0.016	10.6	0.001	0.002	0.026	3.17	0.334	0.008	0.235
7/1/02	0.606	6.24	115	43.9	44.2	0.020	11.7	BDL	0.001	0.039	3.62	0.377	0.008	0.260
7/9/02	0.729	6.89	111	42.1	42.1	0.035	11.4	0.001	0.002	0.008	3.35	0.336	0.008	0.221
7/21/02	2.82	5.98	105		47.7	0.017	12.7	0.001	0.001	0.043	3.91	0.424	0.010	0.294
8/1/02		5.87	122	62.9	54.8	0.040	14.5	0.001	0.003	0.087	4.53	0.516	0.011	0.381
9/21/02					55.0	0.709	14.0	0.002	0.006	0.156	4.84	0.503	0.012	0.403
Maximum				75.1		0.793	16.7	0.002	0.009	0.412	5.47	0.618	0.014	0.518

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$. BDL indicates Below Detection Limit for that analyte.*

TABLE A7. Snake River upstream of the confluence with Peru Creek (SAP) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.328	6.19	115	63.2	63.1	0.007	18.0	BDL	BDL	BDL	4.40	BDL	0.002	0.262
12/8/01	0.244	6.88	87.7	62.5	67.0	0.018	19.1	0.001	0.002	0.015	4.67	0.393	0.007	0.492
1/19/02		6.25	104	65.3	68.4	0.022	19.5	0.001	0.002	BDL	4.80	0.400	0.008	0.487
3/14/02	0.449	6.90	155	66.3	90.7	0.025	26.0	0.001	0.001	0.010	6.29	0.465	0.009	0.613
4/25/02	1.29	6.97	118	48.4	49.2	0.037	13.8	0.001	0.002	0.026	3.57	0.374	0.008	0.326
5/10/02	1.15	7.05	102	36.1	41.8	0.029	12.0	BDL	0.001	0.014	2.88	0.262	0.005	0.230
5/16/02	1.53	6.43	108	35.6	39.5	0.027	11.3	0.001	0.002	0.024	2.74	0.257	0.007	0.220
5/28/02	1.31	7.31	101	34.9	35.6	0.026	10.0	0.001	0.001	0.017	2.52	0.234	0.004	0.175
6/2/02	1.22	7.15	84.3	26.0	31.8	0.048	9.18	BDL	0.001	0.030	2.15	0.170	0.004	0.122
6/10/02	0.845	7.24	73.2	30.0	33.7	0.045	9.62	0.001	0.001	0.009	2.31	0.194	0.004	0.147
6/17/02	0.613	7.11	85.7	35.2	42.8	0.044	12.2	BDL	0.001	0.007	3.00	0.252	0.005	0.205
6/24/02	0.605		86.5	36.7	43.4	0.029	12.4	0.001	0.001	0.003	3.01	0.265	0.006	0.206
7/1/02	0.546	6.83	114	40.2	48.5	0.096	13.8	0.001	0.002	0.016	3.39	0.296	0.006	0.214
7/9/02	0.697	7.10	116	38.6	45.5	0.029	13.0	0.001	BDL	BDL	3.16	0.276	0.004	0.224
7/21/02	0.797	6.72	112		54.4	0.127	15.6	0.001	0.002	0.031	3.74	0.333	0.005	0.252
8/1/02		6.49	121	56.1	62.4	0.032	18.3	0.001	0.000	0.005	4.37	0.409	0.007	0.320
9/21/02					60.2	0.015	16.8	0.001	0.001	0.006	4.42	0.426	0.008	0.381
Maximum				66.3		0.127	26.0	0.001	0.002	0.030	6.29	0.465	0.009	0.613

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$. BDL indicates Below Detection Limit for that analyte.*

TABLE A8. Peru Creek upstream of the Pennsylvania Mine (APENN) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01		7.62	78.8	42.8	52.9	0.008	14.8	BDL	0.001	BDL	3.86	0.040	0.002	0.094
5/16/02	1.45	6.04	117	41.5	42.8	0.015	12.1	0.001	0.002	0.009	3.07	0.282	0.003	0.262
5/28/02	0.984	6.95	112	43.4	41.4	0.017	11.6	0.001	0.002	0.005	3.01	0.292	0.003	0.237
6/2/02	0.734	6.86	116	42.3	43.8	0.025	12.0	0.001	0.001	0.005	3.37	0.222	0.003	0.201
6/10/02	0.707	7.06	84.0	44.3	44.9	0.024	12.3	0.000	0.001	0.004	3.41	0.155	0.002	0.167
6/17/02	0.526	6.46	82.3	42.2	42.2	0.028	11.6	BDL	0.001	0.008	3.24	0.106	0.002	0.129
6/24/02	0.525		83.0	39.0	43.8	0.023	12.2	BDL	0.001	0.012	3.24	0.081	0.002	0.104
7/1/02	0.675	6.59	84.0	36.6	43.7	0.026	12.2	BDL	0.001	0.019	3.22	0.058	0.001	0.088
7/9/02	0.582	6.93	104	37.5	41.6	0.015	11.7	BDL	BDL	0.011	3.05	0.040	0.001	0.080
7/21/02	0.604	6.35	93.6		41.1	0.015	11.5	BDL	BDL	0.014	3.01	0.032	BDL	0.072
8/1/02		6.30	88.8	39.0	43.9	0.014	12.3	BDL	0.001	0.014	3.19	0.031	0.002	0.076
9/21/02					50.1	0.010	14.1	BDL	BDL	0.007	3.65	0.031	BDL	0.068
Maximum				44.311		0.028	14.8	0.001	0.002	0.019	3.859	0.292	0.003	0.262

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$. BDL indicates Below Detection Limit for that analyte.*

TABLE A9. Pennsylvania Mine (PENN) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
5/16/02	0.779	4.22	860	491	363	6.01	96.7	0.069	0.651	20.3	29.5	19.4	0.096	14.7
5/28/02	0.481	5.01	880	500	368	6.52	97.3	0.070	0.702	20.1	30.3	19.8	0.099	15.4
6/2/02	0.329	4.98	758	508	381	7.87	101	0.073	0.816	20.7	31.5	20.6	0.103	16.3
6/10/02	0.414	4.66	684	556	395	12.6	104	0.089	1.23	22.1	33.1	22.6	0.121	19.4
6/17/02	0.311	4.31	763	580	373	14.6	97.8	0.106	2.34	18.8	31.2	21.3	0.120	23.3
6/24/02	0.276		839	567	368	17.7	99.5	0.117	3.70	19.6	29.1	19.0	0.124	23.1
7/1/02	0.693	3.61	977	558	355	18.7	96.7	0.114	4.18	20.7	27.6	17.2	0.119	22.8
7/9/02	0.357	3.47	961	553	358	18.8	97.8	0.110	4.06	21.9	28.6	17.9	0.120	22.2
7/21/02	0.379	3.26			348	16.6	93.3	0.098	3.25	21.8	27.9	18.5	0.113	19.7
8/1/02		3.36	817	539	404	16.8	110	0.113	3.09	24.2	31.6	22.6	0.130	21.7
9/21/02					363	21.5	92.9	0.129	5.60	23.2	31.8	23.1	0.146	27.8
Maximum				580		18.7	110	0.129	5.60	24.2	33.1	23.1	0.146	27.8

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$.*

TABLE A10. Peru Creek downstream of the Pennsylvania Mine (BPENN) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.247	5.99	140	76.9	68.7	0.913	18.6	0.009	0.258	0.016	5.42	1.52	0.012	2.00
5/16/02	1.25	6.00	124	46.2	43.9	0.036	12.3	0.002	0.012	0.022	3.21	0.437	0.005	0.447
5/28/02	0.777	6.59	120	45.9	45.2	0.037	12.6	0.002	0.014	0.015	3.32	0.473	0.005	0.444
6/2/02	1.19	6.64	118	46.0	47.3	0.020	12.9	0.002	0.012	0.015	3.68	0.426	0.005	0.420
6/10/02	0.609	6.30	98.5	53.2	50.3	0.032	13.7	0.003	0.026	0.032	3.92	0.628	0.006	0.597
6/17/02	0.401	6.28	103	53.6	47.8	0.094	12.8	0.003	0.045	0.063	3.86	0.708	0.006	0.786
6/24/02	0.353		106	53.8	52.0	0.104	14.3	0.003	0.068	0.051	3.97	0.761	0.007	0.885
7/1/02	0.375	5.94	136	52.8	51.0	0.184	13.9	0.004	0.084	0.055	3.94	0.716	0.007	0.923
7/9/02	0.429	5.91	132	54.5	53.2	0.184	14.5	0.004	0.091	0.047	4.10	0.770	0.007	0.984
7/21/02	0.463	5.56	114		53.3	0.428	14.6	0.004	0.095	0.086	4.09	0.811	0.009	1.03
8/1/02		5.50	122	58.6	56.2	0.281	15.6	0.005	0.089	0.063	4.16	0.865	0.008	1.08
9/21/02					65.0	0.203	18.5	0.004	0.079	0.061	5.15	0.663	0.007	0.955
Maximum				76.9		0.913	18.6	0.009	0.258	0.086	5.42	1.52	0.012	2.00

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$.*

TABLE A11. Cinnamon Gulch (CINN) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.404	4.26	196	89.2	58.9	4.44	15.1	0.007	0.151	0.011	5.14	2.37	0.018	1.51
5/16/02	1.41	3.95	190	75.8	45.7	3.25	12.1	0.005	0.114	0.333	3.76	1.83	0.015	1.08
5/28/02	1.18	4.79	176	66.3	38.2	2.83	9.93	0.005	0.113	0.322	3.25	1.61	0.012	0.969
6/2/02	0.756	4.20	175	63.3	36.5	3.21	9.34	0.005	0.133	0.413	3.21	1.60	0.015	0.998
6/10/02	0.732	3.95	128	71.8	41.6	3.26	10.9	0.005	0.138	0.311	3.47	1.64	0.015	1.04
6/17/02	0.558	3.94	131	74.2	44.7	3.05	11.7	0.005	0.129	0.223	3.76	1.67	0.013	1.03
6/24/02	0.471		138	72.8	47.5	3.15	12.7	0.005	0.135	0.240	3.85	1.84	0.015	1.05
7/1/02	0.633	4.17	169	74.5	46.1	3.15	12.2	0.005	0.137	0.261	3.80	1.88	0.015	1.10
7/9/02	0.529	4.39	188	77.2	49.9	3.49	13.1	0.006	0.143	0.274	4.16	2.12	0.016	1.19
7/21/02	0.704	4.03	149		48.5	3.26	12.8	0.006	0.137	0.335	4.01	2.07	0.016	1.18
8/1/02		4.03	151	79.0	53.0	3.43	14.2	0.007	0.140	0.369	4.27	2.28	0.018	1.29
9/21/02					74.7	5.20	19.5	0.008	0.201	0.283	6.30	2.77	0.021	1.65
Maximum				89.2		5.20	19.5	0.008	0.201	0.413	6.30	2.77	0.021	1.65

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$.*

TABLE A12. Peru Creek downstream of Cinnamon Gulch (BCINN) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.213	5.06	148		71.7	2.25	19.0	0.010	0.274	0.024	5.90	2.10	0.017	2.36
5/16/02	1.53	4.99	138	57.4	46.6	0.615	12.9	0.004	0.062	0.074	3.56	0.900	0.008	0.805
5/28/02	0.795	5.38	141	57.5	46.8	0.879	12.8	0.004	0.073	0.085	3.60	1.03	0.010	0.850
6/2/02	0.683	5.24	141	66.8	48.3	0.948	12.6	0.004	0.080	0.115	3.82	1.01	0.009	0.870
6/10/02	0.588	4.37	120	69.7	49.8	1.16	13.3	0.004	0.102	0.104	4.01	1.21	0.010	1.10
6/17/02	0.519	4.79	124	68.0	50.3	1.19	13.2	0.005	0.115	0.112	4.18	1.33	0.010	1.26
6/24/02	0.467		125	67.6	56.6	1.36	15.2	0.006	0.139	0.108	4.53	1.50	0.013	1.37
7/1/02	0.525	4.83	130	73.5	55.9	1.37	14.8	0.006	0.148	0.108	4.58	1.50	0.013	1.42
7/9/02	0.575	5.11	170		61.0	1.73	16.2	0.007	0.165	0.115	4.98	1.76	0.014	1.60
7/21/02	0.557	4.61	148		57.7	1.68	15.3	0.007	0.161	0.138	4.71	1.70	0.013	1.57
8/1/02		4.70	149	79.7	62.8	1.78	16.9	0.008	0.166	0.133	5.00	1.80	0.016	1.70
9/21/02					69.0	1.92	18.5	0.006	0.145	0.131	5.57	1.56	0.017	1.50
Maximum				79.7		2.25	19.0	0.010	0.274	0.138	5.90	2.10	0.017	2.36

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$.*

TABLE A13. Peru Creek upstream of the confluence with the Snake River (PAS) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.258	5.52	104	75.5	60.0	1.60	16.9	0.005	0.074	0.006	4.36	1.02	0.008	1.29
12/8/01	0.240	5.90	86.3	81.9	64.9	2.41	18.2	0.006	0.082	0.050	4.72	1.10	0.009	1.46
1/19/02		5.61	109	81.6	65.1	1.13	18.3	0.005	0.071	0.049	4.69	0.982	0.008	1.45
3/14/02	0.611	5.66	147	79.6	81.8	0.572	22.8	0.006	0.068	0.079	5.56	1.01	0.010	1.59
4/25/02	0.720	5.78	138	63.0	53.0	0.414	15.2	0.004	0.049	0.121	3.63	0.825	0.007	0.966
5/10/02	0.716	6.57	105	43.4	42.1	0.018	12.3	0.002	0.015	0.039	2.77	0.494	0.005	0.562
5/16/02	1.52	6.06	109	41.1	38.4	0.080	11.2	0.002	0.013	0.028	2.55	0.430	0.005	0.483
5/28/02	0.719	6.58	109	44.1	40.0	0.016	11.6	0.002	0.016	0.023	2.68	0.511	0.004	0.554
6/2/02	0.620	6.78	99.9	35.9	36.5	0.062	10.5	0.002	0.011	0.021	2.53	0.452	0.005	0.473
6/10/02	0.498	5.43	83.0	43.7	38.1	0.018	10.9	0.002	0.013	0.016	2.61	0.540	0.005	0.569
6/17/02	0.398	6.03	95.3	52.6	51.5	0.068	14.6	0.004	0.039	0.079	3.62	0.811	0.007	0.913
6/24/02	0.376		101	55.0	49.8	0.106	14.3	0.003	0.041	0.079	3.44	0.752	0.007	0.816
7/1/02	0.367	5.22	136	55.4	52.6	0.293	15.0	0.004	0.054	0.114	3.66	0.820	0.007	0.914
7/9/02	0.398	5.50	140	59.1	56.7	0.791	16.1	0.004	0.058	0.093	3.98	0.916	0.008	1.00
7/21/02	0.531	4.82	128		58.1	0.865	16.5	0.005	0.060	0.094	4.07	0.960	0.008	1.08
8/1/02		4.95	124	69.9	59.6	0.842	17.3	0.005	0.057	0.081	4.01	0.944	0.008	1.07
9/21/02					63.6	0.885	18.1	0.004	0.049	0.093	4.45	0.805	0.007	1.04
Maximum				81.9		2.41	22.8	0.006	0.082	0.121	5.56	1.10	0.010	1.59

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$. BDL indicates Below Detection Limit for that analyte.*

TABLE A14. Snake River downstream of the confluence with Peru Creek (SBP) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.425	6.17	98.0	65.0	69.5	0.022	20.6	0.002	0.004	BDL	4.40	0.508	0.006	0.676
12/8/01	0.592	7.03	92.2	66.4	72.3	0.020	21.7	0.002	0.008	0.024	4.37	0.476	0.006	0.657
1/19/02		7.28	124	69.8	77.0	0.028	23.5	0.002	0.007	BDL	4.45	0.452	0.006	0.623
3/14/02	0.479	6.69	145	68.9	80.0	0.019	23.0	0.003	0.010	0.042	5.47	0.606	0.008	0.933
4/25/02	0.928	6.86	128	54.9	52.1	0.025	14.9	0.002	0.008	0.050	3.61	0.535	0.007	0.601
5/10/02	0.993	6.76	103	41.4	42.4	0.021	12.3	0.001	0.005	0.004	2.85	0.372	0.005	0.395
5/16/02	1.35	6.54	110	37.2	39.1	0.020	11.3	0.001	0.004	0.004	2.63	0.313	0.004	0.343
5/28/02	1.08	7.22	105	38.5	40.5	0.023	11.6	0.001	0.005	0.007	2.78	0.346	0.004	0.348
6/2/02	0.926	7.07	90.8	30.7	35.3	0.078	10.2	0.001	0.005	0.021	2.42	0.295	0.003	0.284
6/10/02	0.715	7.16	84.3	36.7	38.3	0.032	11.0	0.001	0.004	BDL	2.60	0.372	0.004	0.366
6/17/02	0.509	7.10	98.4	43.4	44.7	0.028	12.8	0.002	0.006	BDL	3.07	0.455	0.005	0.483
6/24/02	0.458		98.8	45.3	47.2	0.020	13.6	0.002	0.006	BDL	3.24	0.466	0.005	0.479
7/1/02	0.598	6.82	126	47.5	50.3	0.037	14.7	0.002	0.006	0.004	3.53	0.496	0.006	0.510
7/9/02	0.562	6.90	126	47.0	53.4	0.025	15.3	0.002	0.006	0.005	3.71	0.506	0.006	0.558
7/21/02	0.660	6.62			56.3	0.029	16.2	0.002	0.008	0.008	3.84	0.543	0.006	0.593
8/1/02		6.75	120	60.8	66.8	0.022	19.2	0.003	0.009	BDL	4.60	0.602	0.006	0.744
9/21/02					72.3	0.018	20.5	0.003	0.013	0.010	5.16	0.660	0.008	0.835
Maximum				69.8		0.078	23.5	0.003	0.013	0.050	5.47	0.660	0.008	0.933

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$. BDL indicates Below Detection Limit for that analyte.*

TABLE A15. Snake River upstream of the confluence with the North Fork of the Snake River (SANF) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.477	7.34	97.5	52.7	63.6	0.027	19.2	0.001	0.003	BDL	3.79	0.334	0.004	0.456
12/8/01	0.332	7.25	88.5	56.2	68.7	0.029	20.7	0.001	0.006	0.022	4.14	0.331	0.004	0.496
1/19/02		6.32	112	58.7	74.4	0.027	22.6	0.001	0.005	BDL	4.35	0.318	0.004	0.488
3/14/02	0.487	7.11	168	53.8	62.6	0.018	18.4	0.002	0.003	BDL	4.04	0.312	0.004	0.505
4/25/02	0.826	6.98	130	48.7	54.2	0.015	16.0	0.001	0.005	0.009	3.48	0.314	0.004	0.449
5/10/02	0.881	7.01	108	40.3	44.3	0.028	13.1	0.001	0.004	0.006	2.84	0.318	0.004	0.356
5/16/02	1.56	6.70	111	36.5	41.4	0.094	12.2	0.001	0.005	0.034	2.68	0.250	0.004	0.305
5/28/02	1.18	7.25	107	36.6	40.7	0.029	11.8	0.001	0.003	0.007	2.70	0.271	0.004	0.278
6/2/02	0.808	7.13	92.4	30.5	37.2	0.042	10.8	0.001	0.003	0.006	2.46	0.239	0.003	0.250
6/10/02	1.07	7.20	87.2	38.4	50.9	0.031	14.8	0.001	0.005	0.014	3.42	0.255	0.003	0.294
6/17/02	0.532	7.26	99.2	40.3	47.5	0.044	14.4	0.002	0.004	BDL	3.28	0.378	0.005	0.413
6/24/02	0.482		101	40.7	45.6	0.026	13.3	0.001	0.003	BDL	2.99	0.327	0.004	0.356
7/1/02	0.842	6.94	126	42.7	48.4	0.056	14.1	0.001	0.004	0.007	3.19	0.331	0.004	0.348
7/9/02	0.658	7.19	121	41.5	51.8	0.135	15.2	0.001	0.005	0.031	3.37	0.316	0.005	0.402
7/21/02	0.721	7.03	118		51.0	0.026	15.0	0.001	0.004	0.003	3.31	0.299	0.004	0.348
8/1/02		7.00	113	50.7	58.5	0.027	17.2	0.002	0.003	BDL	3.78	0.316	0.003	0.438
9/21/02					65.9	0.018	19.0	0.002	0.004	BDL	4.46	0.432	0.005	0.588
Maximum				58.7		0.135	22.6	0.002	0.006	0.034	4.46	0.432	0.005	0.588

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$. BDL indicates Below Detection Limit for that analyte.*

TABLE A16. North Fork of the Snake River upstream of the confluence with the Snake River (NFS) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.683	7.77	59.8	6.90	42.0	0.005	12.7	BDL	BDL	BDL	2.37	BDL	BDL	BDL
12/8/01	0.908	7.54	62.5	6.81	41.5	0.004	12.7	BDL	BDL	0.012	2.36	BDL	BDL	BDL
1/19/02		7.35	83.0	7.05	40.5	0.004	12.4	BDL	BDL	0.009	2.33	BDL	BDL	BDL
3/14/02	0.787	7.71	140	7.41	48.2	0.006	14.7	BDL	BDL	0.009	2.77	0.003	BDL	BDL
4/25/02	4.091	7.46	107	5.94	38.3	0.008	11.6	BDL	0.002	0.050	2.25	0.002	BDL	0.003
5/10/02	2.09	7.71	85.9	4.45	32.4	0.012	9.90	BDL	0.001	0.045	1.87	0.003	BDL	0.006
5/16/02	2.95	7.12	88.0	4.28	29.1	0.013	8.86	BDL	0.002	0.050	1.69	0.002	BDL	BDL
5/28/02	2.67	8.09	80.1	4.49	28.4	0.017	8.68	BDL	BDL	0.048	1.63	0.003	BDL	BDL
6/2/02	2.06	7.69	73.7	4.63	25.7	0.012	7.89	BDL	BDL	0.036	1.46	0.003	BDL	0.003
6/10/02	1.67	7.85	61.1	5.56	30.8	0.010	9.43	BDL	BDL	0.034	1.76	0.003	BDL	BDL
6/17/02	1.10	7.69	68.0	5.96	34.8	0.008	10.7	BDL	BDL	0.030	1.95	BDL	BDL	BDL
6/24/02	0.971		68.6	6.15	33.8	0.006	10.4	BDL	BDL	0.023	1.91	0.002	0.001	0.002
7/1/02	0.950	7.53	87.5	6.05	34.6	0.008	10.7	BDL	BDL	0.021	1.92	0.001	BDL	0.002
7/9/02	0.997	7.54	93.1	6.26	38.4	0.012	11.8	BDL	BDL	0.023	2.16	0.002	BDL	0.008
7/21/02	3.52	7.26	86.6		38.4	0.006	11.8	BDL	BDL	0.018	2.14	0.001	BDL	0.002
8/1/02		7.54	82.6	7.09	36.4	0.007	12.5	BDL	BDL	0.018	2.26	BDL	BDL	BDL
9/21/02					43.3	0.007	13.3	BDL	BDL	0.018	2.47	BDL	BDL	BDL
Maximum				7.41		0.017	14.7	BDL	0.002	0.050	2.77	0.003	0.001	0.008

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$. BDL indicates Below Detection Limit for that analyte.*

TABLE A17. Snake River downstream of confluence with the North Fork of the Snake River (SBNF) water quality data (mg/L)

Date	DOC*	pH*	Cond.*	SO_4	Hardness*	Al	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Zn
11/4/01	0.822	7.81	85.2	36.3	53.6	0.022	16.3	0.001	0.001	BDL	3.15	0.201	0.002	0.223
12/8/01	0.214	7.20	82.2	40.9	62.3	0.008	18.8	0.001	0.003	0.031	3.72	0.260	0.002	0.309
1/19/02		6.65	103	41.3	64.4	0.017	19.5	BDL	0.003	0.029	3.81	0.242	0.002	0.271
3/14/02	0.613	7.11	141	37.1	61.3	0.017	18.3	0.001	0.003	0.025	3.79	0.226	0.001	0.277
4/25/02	1.39	7.23	118	33.9	47.5	0.027	14.2	0.001	0.005	0.025	2.97	0.228	0.002	0.279
5/10/02	1.25	7.42	104	29.0	42.1	0.032	12.5	0.001	0.005	0.021	2.64	0.202	0.002	0.223
5/16/02	2.02	6.88	105	26.0	36.8	0.035	10.9	0.001	0.005	0.047	2.33	0.163	0.002	0.185
5/28/02	1.73	7.69	98.4	23.3	36.5	0.017	8.7	0.000	0.001	0.047	1.64	0.003	0.001	0.002
6/2/02	1.08	7.45	88.8	22.2	32.8	0.051	9.7	0.001	0.003	0.013	2.07	0.151	0.002	0.144
6/10/02	1.18	7.43	80.8	28.3	41.2	0.062	12.0	0.001	0.003	0.012	2.71	0.224	0.002	0.220
6/17/02	0.692	7.46	92.7	30.7	45.5	0.055	13.4	0.001	0.004	0.009	2.91	0.249	0.003	0.258
6/24/02	0.711		93.6	31.5	43.6	0.047	12.9	0.000	0.004	0.008	2.76	0.237	0.004	0.241
7/1/02	0.630	7.07	117	34.1	44.1	0.056	13.1	0.001	0.004	0.010	2.78	0.231	0.003	0.226
7/9/02	0.745	7.41	108	31.7	47.5	0.037	14.0	0.001	0.003	0.016	3.03	0.225	0.005	0.322
7/21/02	0.928	7.12	110		47.7	0.030	14.2	0.001	0.002	0.009	2.99	0.210	0.004	0.229
8/1/02		7.40	106	38.7	48.3	0.020	14.4	0.001	0.002	0.009	2.99	0.194	0.002	0.262
9/21/02					59.4	0.031	17.3	0.002	0.003	0.009	3.95	0.318	0.005	0.397
Maximum				41.3		0.062	19.5	0.002	0.005	0.047	3.95	0.318	0.005	0.397

**DOC is reported in mg C/L. pH is dimensionless. Conductivity is reported in µS. Hardness is reported as mg/L of $CaCO_3$. BDL indicates Below Detection Limit for that analyte.*

TABLE A18. Aluminum maximum hazard quotients calculated using year round and limited Snake River Watershed datasets, and both Criteria Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) (EPA, 2002). EPA aluminum water quality criteria values were as follows: CMC = 750 µg/L and CCC = 87 µg/L (at pH 6.5 – 9.0).

	LIMITED DATA					YEAR ROUND				
		CMC		CCC			CMC		CCC	
Site ID	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result
SAD	6060	8.1	**FAIL**	70	**FAIL**	6190	8.3	**FAIL**	71	**FAIL**
DAS	26.7	0.0		0.30		51.3	0.1		0.60	
SBD	2060	2.7	**FAIL**	24	**FAIL**	3380	4.5	**FAIL**	39	**FAIL**
MONT	709	0.90		8.1	**FAIL**	793	1.1	**FAIL**	9.1	**FAIL**
SAP	127	0.20		1.5	**FAIL**	127	0.2		1.5	**FAIL**
APENN	28.1	0.0		0.30						
BPENN	428	0.60		4.9	**FAIL**					
BCINN	1920	2.6	**FAIL**	22	**FAIL**					
PAS	885	1.2	**FAIL**	10	**FAIL**	2410	3.2	**FAIL**	28	**FAIL**
SBP	78.2	0.10		0.90		78.2	0.1		0.90	
SANF	135	0.20		1.5	**FAIL**	135	0.2		1.5	**FAIL**
NFS	55.0	0.10		0.60		55.0	0.1		0.60	
SBNF	61.6	0.10		0.70		61.6	0.1		0.70	

TABLE A19. Cadmium maximum hazard quotients calculated using year round and limited Snake River Watershed datasets, and both Criteria Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) (EPA, 2002). EPA cadmium water quality criteria values were as follows: CMC = 2.0 μg/L and CCC = 0.25 μg/L.

	LIMITED DATA					YEAR ROUND				
		CMC		CCC			CMC		CCC	
Site ID	Maximum Measured (μg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result	Maximum Measured (μg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result
SAD	4.4	2.2	**FAIL**	18	**FAIL**	4.6	2.3	**FAIL**	19	**FAIL**
DAS	0.0	0.0		0.0		0.0	0.0		0.0	
SBD	2.1	1.1	**FAIL**	8.4	**FAIL**	3.4	1.7	**FAIL**	14	**FAIL**
MONT	1.8	0.90		7.4	**FAIL**	1.9	1.0		7.8	**FAIL**
SAP	1.1	0.60		4.4	**FAIL**	1.5	0.70		5.9	**FAIL**
APENN	0.9	0.50		3.6	**FAIL**					
BPENN	4.9	2.4	**FAIL**	19	**FAIL**					
BCINN	7.8	3.9	**FAIL**	31	**FAIL**					
PAS	4.6	2.3	**FAIL**	19	**FAIL**	6.1	3.0	**FAIL**	24	**FAIL**
SBP	3.0	1.5	**FAIL**	12	**FAIL**	3.2	1.6	**FAIL**	13	**FAIL**
SANF	2.1	1.1	**FAIL**	8.4	**FAIL**	2.1	1.1	**FAIL**	8.4	**FAIL**
NFS	0.8	0.40		3.1	**FAIL**	0.8	0.40		3.1	**FAIL**
SBNF	1.6	0.80		6.2	**FAIL**	1.6	0.80		6.2	**FAIL**

TABLE A20. Copper maximum hazard quotients calculated using year round and limited Snake River Watershed datasets, and both Criteria Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) (EPA, 2002). EPA copper water quality criteria values were as follows: CMC = 13.0 µg/L and CCC = 9.0 µg/L.

	LIMITED DATA					YEAR ROUND				
		CMC		CCC			CMC		CCC	
Site ID	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result
SAD	21.7	1.7	**FAIL**	2.4	**FAIL**	22.1	1.7	**FAIL**	2.5	**FAIL**
DAS	1.9	0.10		0.20		2.7	0.20		0.30	
SBD	11.8	0.90		1.3	**FAIL**	14.1	1.1	**FAIL**	1.6	**FAIL**
MONT	6.3	0.50		0.70		8.9	0.70		1.0	
SAP	2.3	0.20		0.30		2.3	0.20		0.30	
APENN	2.5	0.20		0.30		0.0				
BPENN	95.3	7.3	**FAIL**	11	**FAIL**	0.0				
BCINN	166.0	12.8	**FAIL**	18	**FAIL**	0.0				
PAS	59.6	4.6	**FAIL**	6.6	**FAIL**	82.0	6.3	**FAIL**	9.1	**FAIL**
SBP	12.6	1.0		1.4	**FAIL**	12.6	1.0		1.4	**FAIL**
SANF	5.2	0.40		0.60		5.6	0.40		0.60	
NFS	3.3	0.30		0.40		3.3	0.30		0.40	
SBNF	4.6	0.40		0.50		4.8	0.40		0.50	

TABLE A21. Manganese maximum hazard quotients calculated using year round and limited Snake River Watershed datasets, and both acute and chronic thresholds found in the literature (Fey et al., 2001). Manganese water quality criteria values from this source were as follows: CMC = 3320 µg/L and CCC = 790 µg/L.

	LIMITED DATA					YEAR ROUND				
		CMC		CCC			CMC		CCC	
Site ID	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result
SAD	1440	0.40		1.8	**FAIL**	1590	0.50		2.0	**FAIL**
DAS	7.0	0.0		0.0		8.50	0.0		0.0	
SBD	741	0.20		0.90		1180	0.40		1.5	**FAIL**
MONT	516	0.20		0.70		618	0.20		0.80	
SAP	426	0.10		0.50		465	0.10		0.60	
APENN	292	0.10		0.40						
BPENN	865	0.30		1.1	**FAIL**					
BCINN	1800	0.50		2.3	**FAIL**					
PAS	960	0.30		1.2	**FAIL**	1100	0.30		1.4	**FAIL**
SBP	660	0.20		0.80		660	0.20		0.80	
SANF	432	0.10		0.50		432	0.10		0.50	
NFS	155	0.0		0.20		155	0.0		0.20	
SBNF	318	0.10		0.40		318	0.10		0.40	

TABLE A22. Nickel maximum hazard quotients calculated using year round and limited Snake River Watershed datasets, and both Criteria Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) (EPA, 2002). EPA nickel water quality criteria values were as follows: CMC = 470 µg/L and CCC = 52 µg/L.

	LIMITED DATA					YEAR-ROUND				
		CMC		CCC			CMC		CCC	
Site ID	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result
SAD	29.4	0.10		0.60		29.4	0.10		0.60	
DAS	1.3	0.0		0.0		1.3	0.0		0.0	
SBD	15.4	0.0		0.30		20.8	0.0		0.40	
MONT	11.9	0.0		0.20		14.0	0.0		0.30	
SAP	7.8	0.0		0.10		9.1	0.0		0.20	
APENN	3.4	0.0		0.10						
BPENN	8.7	0.0		0.20						
BCINN	16.7	0.0		0.30						
PAS	8.1	0.0		0.20		10.2	0.0		0.20	
SBP	7.6	0.0		0.10		8.4	0.0		0.20	
SANF	5.1	0.0		0.10		5.1	0.0		0.10	
NFS	2.7	0.0		0.10		2.7	0.0		0.10	
SBNF	4.7	0.0		0.10		4.7	0.0		0.10	

TABLE A23. Zinc maximum hazard quotients calculated using year round and limited Snake River Watershed datasets, and both Criteria Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) (EPA, 2002). EPA zinc water quality criteria values were as follows: CMC = 120 µg/L and CCC = 120 µg/L.

	LIMITED DATA					YEAR ROUND				
		CMC		CCC			CMC		CCC	
Site ID	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result	Maximum Measured (µg/L)	Max. Hazard Quotient (HQ)	Result	Max. Hazard Quotient (HQ)	Result
SAD	872	7.3	**FAIL**	7.3	**FAIL**	1010	8.4	**FAIL**	8.4	**FAIL**
DAS	6.4	0.10		0.10		6.4	0.10		0.10	
SBD	452	3.8	**FAIL**	3.8	**FAIL**	737	6.1	**FAIL**	6.1	**FAIL**
MONT	403	3.4	**FAIL**	3.4	**FAIL**	518	4.3	**FAIL**	4.3	**FAIL**
SAP	381	3.2	**FAIL**	3.2	**FAIL**	613	5.1	**FAIL**	5.1	**FAIL**
APENN	262	2.2	**FAIL**	2.2	**FAIL**					
BPENN	1080	9.0	**FAIL**	9.0	**FAIL**					
BCINN	1700	14	**FAIL**	14	**FAIL**					
PAS	1080	9.0	**FAIL**	9.0	**FAIL**	1620	14	**FAIL**	14	**FAIL**
SBP	835	7.0	**FAIL**	7.0	**FAIL**	933	7.8	**FAIL**	7.8	**FAIL**
SANF	588	4.9	**FAIL**	4.9	**FAIL**	588	4.9	**FAIL**	4.9	**FAIL**
NFS	7.8	0.10		0.10		7.8	0.10		0.10	
SBNF	397	3.3	**FAIL**	3.3	**FAIL**	397	3.3	**FAIL**	3.3	**FAIL**